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The design and welfare implications of mandatory pension plans

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Abstract: In a rich, calibrated life-cycle model, we show that welldesigned mandatory pension plans significantly improve the welfare of individuals procrastinating on savings, and even improve most rational individuals' welfare through a return tax advantage and fair annuitization. For a group of heterogeneous savers, in terms of preferences and sophistication, the best plan has contributions of 10% of income from age 30, a glidepath investment strategy, payouts following a variable lifelong annuity, and options to choose a different investment strategy and to modify the annuitization feature. This plan generates an average welfare gain of \$175,000 per individual.

Keywords: Retirement saving, life cycle, consumption, investment, annuitization, welfare, procrastination.

JEL subject codes: D14, D15, G11, G41, G51.

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1 Introduction

Large population groups build up insufficient savings for retirement. Close to half of adult Americans do not have access to a workplace retirement saving plan, and more than half worry that they will not have enough money for retirement.¹ Gomes, Hoyem, Hu, and Ravina (2020) estimate that, in a sample of U.S. workers in a pension plan, 75% save too little. Retirement saving is further challenged by the predicted rise in longevity, possible cuts in Social Security, soaring health care costs, and the increase in self-employed and gig workers.

Evidently, mandatory pension plans can reduce the under-saving problem. Mandatory defined contribution (DC) saving plans exist for the majority of workers in many countries (e.g. the U.K., the Netherlands, Australia, and Denmark), but with considerable variation in the plan design. In the U.S., several states are introducing or expanding such programs. While some economists and politicians push for a universal mandatory retirement saving program, e.g., the plan by Ghilarducci and James (2018), opponents point out, among other things, that mandatory programs harm individuals capable of accumulating sufficient savings on their own. These observations give rise to important questions that we address in this paper: How do various pension plan designs affect the individual participants? What is the best mandatory plan design for a heterogeneous group of participants? In particular, which fraction of their income should workers contribute to the pension plan?

We embed a mandatory DC pension plan in a rich life-cycle model of individual consumption and investment decisions with Epstein-Zin preferences, uncertain labor income, mortality risk, Social Security benefits, and possible out-or-pocket medical costs. The model features both an illiquid pension saving account and a liquid private account, and both private and pension savings can be invested in stocks and

¹See 2018 Bureau of Labor Statistics at https://www.bls.gov/ncs/ebs/benefits/2018/ benefits_retirement.htm and a 2019 Gallup survey at https://news.gallup.com/poll/ 249164/americans-feel-generally-positive-own-finances.aspx.

bonds. Calibrating the model to U.S. data, we show that a mandatory plan greatly improves the welfare of individuals procrastinating on savings by generating a more balanced life-cycle consumption-saving profile closer to the rational ideal. Rational individuals can to a large extent undo the undesired consequences of a mandatory plan by adjusting private saving and investment decisions. In fact, a well-designed mandatory plan can even improve the welfare of rational individuals through a more lenient taxation on returns on pension savings than private savings and through access to annuitization at better terms than in the current annuity market.²

Our analysis points to designing the plan as follows. Each member contributes 10% of income from age 30 until retirement to an individual pension account. The default choice is that the balance of the account is invested in a glidepath strategy with 90% stocks until 25 years before retirement sliding to 30% 10 years after retirement and staying there—similar to target date funds available in the industry. The pension savings are paid out as a life annuity with constant expected payouts until death. The default option is a 100% solidarity factor so that, upon death, the entire balance of the member's account is distributed to surviving members' accounts.

What are the welfare implications of this plan relative to the case with only private savings and the option to annuitize retirement savings at a realistic 20% cost? Consider a 25-year old individual with initial wealth and life-cycle income profile similar to the median U.S. worker. The individual has a relative risk aversion (RRA) of 4, an elasticity of intertemporal substitution (EIS) of 1/4, and modest bequest motive. The mandatory pension plan outlined above leads to a welfare gain of 30.3% or roughly \$262,000 in present value terms for an individual procrastinating on savings to an extent that she expects to build up only around 1/3 of the retirement savings that a fully rational individual does (about \$165,000 instead of \$463,000).

²Positive welfare effects could also come from the pension fund generating a better pre-tax risk-return tradeoff by having access to better diversification, additional asset classes (commercial real estate, infrastructure, foreign investments), and maybe superior asset selection skills, but the empirical evidence indicates that pension fund managers have a hard time beating low-cost ETFs.

An otherwise identical rational individual experiences a welfare gain of 2.0% or about \$18,000 in present value terms with most of the gain stemming from the automatic and fairly priced annuitization. The welfare gain is generally increasing with the risk aversion of the individual.

Rational individuals with low risk aversion, low EIS, and a small bequest motive prefer accumulating little wealth and may thus experience a modest welfare loss when forced into the pension plan. To accommodate such individuals, we suggest allowing each member at enrollment to choose a different, riskier investment strategy and a lower solidarity factor so that a share of the deceased member's balance is distributed to designated beneficiaries. We also show that an option to pay out up to a certain fraction of pension savings some years before retirement is particularly valuable to these risk-tolerant rational individuals. Such options reduce the welfare loss of risk-tolerant rational participants considerably, and sometimes turn a loss into a small gain. At the same time, these options do not allow procrastinators to avoid building up considerable retirement savings.

When designing a mandatory pension plan for a heterogeneous group of individuals, the share of procrastinators is important. A large psychology literature has documented that many individuals procrastinate when faced with various decisions (Steel, 2007; Klingsieck, 2013). Many individuals seem to postpone or refuse to set money aside for retirement (Bernheim, Skinner, and Weinberg, 2001; Benartzi and Thaler, 2007; Choi, Laibson, and Madrian, 2011; Heimer, Myrseth, and Schoenle, 2019), but a precise estimate of the fraction of people procrastinating on retirement saving is unavailable. Among employees in a major U.S. company, Choi, Laibson, Madrian, and Metrick (2002) found that 68% recognize they save too little, 24% plan to increase savings within the next two months, but only 3% do so. For our model to match the wealth-income ratio seen in U.S. data, around 2/3 of the population must procrastinate on savings, which implies that our suggested plan generates an average welfare gain of around \$175,000 per individual in a group with heterogeneous preferences and sophistication. While the estimate of the procrastinator frequency depends on the assumed preference parameters, the optimal pension plan design is relatively insensitive to the exact share of procrastinators.³

Our main analysis assumes Social Security retirement benefits at the current level. However, according to the April 2020 report of the Social Security and Medicare Boards of Trustees, the Social Security system lacks funding and benefits have to be cut by 24% to make the system sustainable.⁴ We find that with a 24% reduction of Social Security, the optimal contribution rate increases from 10% to 11%, and the average gain goes up by about \$18,000 per individual.

A significant driver of the welfare gains generated by the mandatory pension plan is the built-in annuitization of retirement savings. Annuitization implies that individuals share lifetime risks to avoid ending up consuming too little if living long—or bequeathing too much if dying early—and is backed by economic research (Yaari, 1965; Davidoff, Brown, and Diamond, 2005; Koijen, Nijman, and Werker, 2011; Yogo, 2016). However, surveys estimate that only 4.3% of U.S. households (Lockwood, 2012) and 5.9% of English households (Inkmann, Lopes, and Michaelides, 2011) participate in the annuity market. This annuitization puzzle can be partly explained by the costs of private market annuities: Mitchell, Poterba, Warshawsky, and Brown (1999) report that for a 65-year old annuitant the money's worth ratio of U.S. life annuities is 75-85% depending on the annuitant's gender and the discount rate used, and assuming population mortality rates. Households may perceive costs to be higher due to adverse selection issues, product opacity, and limited financial literacy. With few people annuitizing, the issuers cannot rely on diversification of lifetime risk across customers, which can explain high direct costs. A broad mandatory plan can implement annuitization at much lower costs.

³Brown and Previtero (2020) also discuss the role of procrastination for various pension-related decisions of individuals enrolled in a retirement saving scheme, and they identify procrastinators as individuals postponing a certain health care decision to the last possible day.

⁴Source: https://www.ssa.gov/OACT/TR/2020/index.html, accessed on August 7, 2020.

Our paper builds upon life-cycle models (e.g. Viceira, 2001; Cocco, Gomes, and Maenhout, 2005; Gomes and Michaelides, 2005) that, among other things, conclude that most individuals should invest all their savings in stocks early in life and then gradually replace stocks by bonds.⁵ Our model adds a mandatory illiquid pension scheme, which complicates the solution as the optimal private decisions depend on the accumulated pension savings in addition to the level of labor income and private savings.

Only few papers explicitly model an illiquid pension account. Campbell, Cocco, Gomes, and Maenhout (2001) assume a predetermined, constant contribution rate and fund asset allocation, and derive the individual's optimal consumption and private investments over the life cycle. They compare welfare and optimal decisions for two fund allocation strategies, namely (i) 100% in the riskfree asset vs. (ii) 50% in stocks, 50% riskfree. We extend the analysis by deriving the optimal combination of contribution rate and fund allocation strategy, and we discuss various option features. As we do, Blake, Wright, and Zhang (2014) investigate the optimal contribution rate and stock-bond allocation of the pension plan. However, they disregard bequest and taxes as well as free savings outside the plan, which fixes consumption at a fraction of current income and thus prevents consumption smoothing.⁶

The most closely related paper is Dahlquist, Setty, and Vestman (2018) who set up a model of the Swedish pension system and calibrate it to register data. They fix the contribution rate at the current Swedish level and search for the optimal

⁵The canonical life-cycle model has been extended to labor supply flexibility (Bodie, Merton, and Samuelson, 1992), housing (Cocco, 2005), time-varying investment opportunities (Koijen, Nijman, and Werker, 2010), unemployment risk (Branger, Larsen, and Munk, 2019), income-stock market co-integration (Benzoni, Collin-Dufresne, and Goldstein, 2007), habit formation in preferences (Gomes and Michaelides, 2003), and stock market entry/participation costs (Fagereng, Gottlieb, and Guiso, 2017).

⁶Other papers focus on how rational investors for a given contribution rate can exploit the differential taxation of pension returns and private returns, cf., e.g., Dammon, Spatt, and Zhang (2004), Gomes, Michaelides, and Polkovnichenko (2009), and Fischer and Gallmeyer (2017). These papers do not discuss the optimal contribution rate or, more generally, how the pension system should be designed.

default investment strategy of the pension fund, allowing each investor to switch at a certain cost and only at age 25—to an alternative strategy.⁷ The investor's private stock market participation is also an active decision with an entry cost. While our model disregards switching and stock market entry costs, we incorporate taxes, procrastination, and quantify the welfare implications of mandatory schemes, and we search for both the optimal contribution rate and fund investment policy.

The behavioral household finance literature has documented that the financial decisions of many individuals deviate systematically from what standard theoretical models prescribe, cf. the surveys by Campbell (2006; 2016), Guiso and Sodini (2013), and Beshears, Choi, Laibson, and Madrian (2018). Behavioral biases translate into welfare losses of a moderate or large magnitude depending on the specific setting (Calvet, Campbell, and Sodini, 2007; Bhamra and Uppal, 2019). We show that biases against retirement savings and annuitization induce substantial welfare losses, but also that a well-designed mandatory pension plan can reduce these welfare losses considerably by generating consumption at a higher level and with a balanced lifecycle profile. In fact, a mandatory pension plan with a significant, stable stock market investment can also improve the welfare of households who invest too little in risky assets, are under-diversified, or trade too frequently (Barber and Odean, 2000; Calvet et al., 2007), but we focus on procrastination in this paper.

The rest of the paper is organized as follows. Section 2 sets up the model and fixes the baseline parameter values. Section 3 presents the optimal decisions of a rational individual without a mandatory scheme, which serves as a benchmark in our welfare analysis. Section 4 identifies pension plan designs that improve the welfare for a range of individuals with both different preference parameters and different degrees of financial sophistication. Section 5 discusses limitations and possible extensions of our setting. Finally, Section 6 concludes.

⁷In an extension, Schlafmann, Setty, and Vestman (2020) consider the implications of letting the contribution rate depend on the income level and the stock market participation of the saver.

2 The modeling framework

This section describes our model and introduces our baseline parameter values that are summarized in Table 1. Figure 1 illustrates the sequence of events in a typical year in our model. Each variable is described in detail below.

[Table 1 about here.]

[Figure 1 about here.]

2.1 Mortality and income

We use a model with annual time steps for the decision problem of an individual who has just turned $t_1 = 25$ years old, retires when she turns $t_R = 67$ years old (the Social Security full-benefit retirement age when born 1960 or later), and may live on until the end of her year $t_M = 100$. Being alive at age t, the probability of being alive at age t + 1 is p_t with $p_{t_M} = 0$, and $P_{t,s} = p_t \times p_{t+1} \times \cdots \times p_{s-1}$ is the probability of being alive at age s conditional on being alive at age t, with $P_{t,t} = 1$. We use mortality rates from the 2017 life table for the U.S. population (Arias and Xu, 2019).

As illustrated in Figure 1, the individual receives income Y_t at the beginning of year t from labor, a state pension, or other sources. The income dynamics are

$$Y_{t+1} = Y_t R_{Yt},\tag{1}$$

where

$$R_{Yt} = \begin{cases} \exp\{\mu_{Yt} - \frac{1}{2}\sigma_Y^2 + \sigma_Y \varepsilon_{Yt}\} & \text{for } t = t_1, \dots, t_R - 2, \\ \zeta & \text{for } t = t_R - 1, \\ 1 - \phi_t h - \Phi_t H & \text{for } t = t_R, \dots, t_M - 1. \end{cases}$$
(2)

The shocks are $\varepsilon_{Yt} \sim N(0,1)$ and independent over time. We take an income volatility of $\sigma_Y = 10\%$ and a zero income-stock correlation, consistent with typical

estimates in the literature (e.g. Davis and Willen, 2000; Cocco et al., 2005; Fagereng et al., 2017). The initial annual pre-tax labor income is \$40,000 and, following Cocco et al. (2005) and others, the expected labor income growth $\mu_{Yt} = \ln(E_t[Y_{t+1}/Y_t])$ is described by a third-order polynomial; we determine the coefficients of the polynomial so that expected labor income peaks at age 55 at a value 50% above initial income and subsequently drops by 10% until retirement. The income numbers are broadly consistent with the median earnings of full-time workers in different age groups reported by the Bureau of Labor Statistics in 2020Q1.⁸

The constant ζ is the ratio of the annual state pension to pre-retirement income. We let $\zeta = 0.45$, leading to an expected after-tax annual state pension of \$17,328. Social Security benefits depend non-proportionally on the average of the 35 careerhighest inflation-adjusted annual earnings, but our model requires proportionality for tractability. Due to the hump-shaped income over life, the average salary over the best 35 years is typically not far from the final salary. In our baseline case, this salary level is likely to be \$50-60,000, and the annual Social Security benefits in year 2020-dollars are then between 45.5% and 43.1% thereof, justifying our value of ζ .⁹

Out-of-pocket medical costs can reduce disposable retirement income and significantly impact saving and risk taking (e.g. De Nardi, French, and Jones, 2010). To match cost estimates at different ages reported by Koijen, van Nieuwerburgh, and Yogo (2016) and De Nardi, French, Jones, and McCauley (2016), together with the observed large dispersion across individuals, we set up a two-shock structure. We let $\phi_t, \Phi_t \in \{0, 1\}$ indicate whether a health shock with a small cost h = 3%(e.g. for prescription medicine), respectively large cost H = 85% (e.g. for nursing home spending), occurs at age t. The small-shock probability is the constant

⁸The median annual earnings are \$31,460 (20-24yrs), \$45,344 (25-34yrs), \$56,160 (35-44yrs), \$57,252 (45-54yrs), \$56,264 (55-64yrs), and \$48,776 (65+ yrs), respectively. Source: https://www.bls.gov/news.release/wkyeng.t03.htm, accessed April 28, 2020.

⁹Using 2020 as the year of eligibility, the monthly benefits are $0.9x + 0.32 \max\{0, \min\{x - 960, 4825\}\} + 0.15 \max\{0, x - 5785\}$, where x is the monthly salary. Source: https://www.ssa.gov/oact/cola/piaformula.html, accessed on April 28, 2020.

 $q = \operatorname{Prob}(\phi_t = 1) = 15\%$, whereas the large-shock probability $Q_t = \operatorname{Prob}(\Phi_t = 1) = \min\{0.03 \times \frac{t-t_R}{t_M-t_R} + \left(\frac{(t-t_R-15)^+}{t_M-t_R-15}\right)^2, 0.5\}$ grows linearly until 15 years into retirement where it accelerates until reaching 50%. Based on simulations of our model, medical costs are expected to be 2.9%, 10.4%, 26.6%, and 85.3% of Social Security pay at ages 72, 79, 86, and 93, in line with Koijen et al. (2016) and De Nardi et al. (2016).¹⁰

2.2 Pension savings and private wealth

The individual has a private, liquid wealth F_t and pension savings A_t at the beginning of year t. The initial pension savings are zero, $A_{t_1} = 0$, and the initial liquid wealth is $F_{t_1} =$ \$5,000 to broadly match the median 25-year old U.S. worker, cf. the family net worth statistics of the 2016 Survey of Consumer Finances (SCF) and the online Net Worth Percentile Calculator of Personal Finance Data.¹¹

The individual pays the fraction $\alpha_t \in [0, 1)$ of pre-tax income into the pension fund and withdraws a fraction $m_t \in [0, 1)$ of the balance of the fund. We restrict α_t and m_t to depend only on age and assume that

$$\alpha_{t_R} = \alpha_{t_R+1} = \dots = \alpha_{t_M} = 0, \quad m_{t_1} = m_{t_1+1} = \dots = m_{t_R-1} = 0,$$

so that contributions to the pension fund are made only before retirement and

¹⁰Koijen et al. (2016, Table III) report health expenses in 2005-dollars at selected ages from 51 to 93. Our model has medical costs in retirement, so we take their mean expenses at ages 72, 79, 86, and 93 in excess of expenses at age 65, and adjust for inflation by multiplying by the ratio 257.971/190.7 of CPI in January 2020 to January 2005 (see https://www.usinflationcalculator.com, accessed on May 20, 2020). The mean excess expenses constitute 2.3% of expected after-tax Social Security benefits at age 72, 10.9% at age 79, 28.9% at age 86, and 181.9% at age 93. A similar exercise based on De Nardi et al. (2016, Figure 3) leads to average expenses of 3.2%, 9.9%, 20.0%, and 41.7% at the same ages, i.e., much lower late-life expenses. Our expected expenses at each age level fall in between the estimates from the two papers. For parsimony, we assume that any health-related reduction in disposable income are permanent (transitory shocks have little impact anyway), and we do not model transitions between different health states as computation time would grow proportionally with the number of states.

¹¹See SCF Table 2 in Bricker et al. (2017) and https://personalfinancedata.com/networthpercentile-calculator/, accessed April 28, 2020.

withdrawals only in retirement. The income after pension contribution and any withdrawals from the pension fund are subject to a proportional tax given by the rate $\tau_Y = 30\%$, which is in the range of tax rates across U.S. states.

The disposable wealth (aka. cash-on-hand) at time t is therefore

$$\tilde{F}_t = F_t + (1 - \tau_Y) \left[(1 - \alpha_t) Y_t + m_t A_t \right].$$

Of disposable wealth, she decides to consume a fraction $c_t \in (0, 1)$ and to invest the remainder $(1 - c_t)\tilde{F}_t$ in financial assets with a share of $\pi_t \in [0, 1]$ in the stock market index and the rest in the riskfree asset. The private wealth dynamics are thus

$$F_{t+1} = (1 - c_t)\tilde{F}_t R_{Ft},$$
(3)

where R_{Ft} is the after-tax gross return over year t on the private investments.

We assume a constant annual log riskfree rate of r, that the log stock market return over any period dt is normally distributed with expectation $(r + \mu_S - \frac{1}{2}\sigma_S^2) dt$ and standard deviation $\sigma_S \sqrt{dt}$, and that returns are independent in the time dimension. The expected annual rate of return on the stock is thus $\exp\{r + \mu_S\} - 1$, i.e. μ_S captures the excess expected stock return. We assume the standard parameter values r = 1%, $\mu_S = 4\%$, and $\sigma_S = 15.7\%$.

By assuming that the private portfolio is continuously rebalanced through year t to maintain a constant stock weight of $\pi_t \in [0, 1]$, the log return on the portfolio over the year is normally distributed with expectation $r + \pi_t \mu_S - \frac{1}{2}\pi_t^2 \sigma_S^2$ and standard deviation $\pi_t \sigma_S$.¹² All returns on private investments—realized or not—are taxed at

$$W_{t+\Delta} = W_t \exp\left\{\left(r + \pi\mu_S - \frac{1}{2}\pi^2 \sigma_S^2\right)\Delta + \pi\sigma_S \left(z_{t+\Delta} - z_t\right)\right\}$$

where $z_{t+\Delta} - z_t \sim N(0, \Delta)$. Hence, the pre-tax rate of return over a one-year period can be written

¹²The continuous-time stock price dynamics are $dS_t = S_t[(r + \mu_S) dt + \sigma_S dz_t]$, where z is a standard Brownian motion. With a fraction π_t of wealth in the stock and the rest in the risk free asset, the wealth dynamics are $dW_t = W_t[(r + \pi_t \mu_S) dt + \pi_t \sigma_S dz_t]$, which with a constant $\pi_t = \pi$ implies

year-end at a proportional rate of $\tau_F = 20\%$, so that the after-tax gross return is

$$R_{Ft} = 1 + (1 - \tau_F) \left[\exp\left\{ r + \pi_t \mu_S - \frac{1}{2} \pi_t^2 \sigma_S^2 + \pi_t \sigma_S \varepsilon_{St} \right\} - 1 \right],$$

where $\varepsilon_{St} \sim N(0, 1)$ is uncorrelated with the income shock ε_{Yt} as mentioned above.

We explore different pension fund designs. One design aspect is what happens to the balance of the pension account upon death. We let $I \in [0, 1]$ denote the fraction of the balance which is distributed across accounts of surviving members of pension fund, with the remaining balance being paid out to the heirs of the deceased member. We refer to I as the *solidarity factor*. With I = 0, the fund member has a personal plan, isolated from the accounts of the other members. With I = 1, the plan is fully solidary. For a large group of members of age t with the same balance, the balance of each member surviving until age t + 1 will be added a fraction $d_t = I(1 - p_t)/p_t$ of the balance at the end of year t due to transfers from deceased members. The pension fund invests $(1 - m_t)A_t + \alpha_t Y_t$, i.e. the time t balance plus net contribution, over year t with a fixed share (continuously rebalanced) of w_t in the stock market index and the rest in the riskfree asset. The after-tax gross returns on pension investments in year t are thus

$$R_{At} = 1 + (1 - \tau_A) \left[\exp\left\{ r + w_t \mu_S - \frac{1}{2} w_t^2 \sigma_S^2 + w_t \sigma_S \varepsilon_{St} \right\} - 1 \right],$$
(4)

where τ_A is the tax rate on pension returns with $\tau_A = 0$ as the baseline value. If the individual survives year t, next year's opening balance of the pension account is

$$A_{t+1} = [(1 - m_t)A_t + \alpha_t Y_t] R_{At}(1 + d_t).$$
(5)

We fix $m_{t_M} = 1$ so when the individual turns t_M years old, the fund pays out as $\exp\{r + \pi\mu_S - \frac{1}{2}\pi^2\sigma_S^2 + \pi\sigma_S\varepsilon_S\} - 1$, where $\varepsilon_S \sim N(0, 1)$. the remaining balance A_{t_M} . We define the payout rates recursively by

$$m_t = \left(1 + \{m_{t+1} \mathcal{E}_t[R_{At}](1+d_t)\}^{-1}\right)^{-1}, \quad t = t_R, t_R + 1, \dots, t_M - 1, \tag{6}$$

which implies that the monetary payouts in year t and t + 1 are linked by

$$m_{t+1}A_{t+1} = m_t A_t \frac{R_{At}}{E_t[R_{At}]}, \quad t = t_R, t_R + 1..., t_M - 1,$$
 (7)

so that monetary payouts are constant in expectation through retirement.¹³ The expected annual payout increases in I through d_t .

With the mortality rates and parameter values assumed above, the expected annual payout from a \$100,000 investment at retirement in a fair-priced variable annuity with 50% stocks is \$4,622 for I = 0, \$6,130 for I = 1/2, and \$7,297 for I = 1. Figure 2 shows the mortality frequency at each age (dashed orange; maximum age of $t_M = 100$) and the probability of being alive at the end of each year conditional on being alive when turning 67 (solid orange).¹⁴ The grey lines show the value of the annuity portfolio for the three values of I. For I = 1, annual payouts are larger so the annuity value first declines steeply, but when the mortality rate picks up, more wealth is transferred from deceased portfolio holders causing the survivor's annuity value to decline less steeply. The downside of a higher I is the lower bequest upon death. With I = 1, the payout stream matches that of lifelong variable annuities (e.g., Charupat and Milevsky (2002) and Horneff, Maurer, Mitchell, and Stamos (2010)).

[Figure 2 about here.]

¹³The plan can also be designed to have expected payouts being either increasing or decreasing through retirement, but the welfare gains are only marginally different to the case with constant expected payouts. See the Internet Appendix for more information.

¹⁴Readers of the printed journal are referred to the online version for colors.

2.3 Decisions and preferences

The individual chooses c_t and π_t for $t = t_1, t_1 + 1, \ldots, t_M$ to maximize lifetime utility. We let J_t denote the indirect utility at time t, conditionally on being alive, and this includes the utility of consumption in year t and subsequent years, as well as any bequest utility. At the end of any year t, after receiving the returns on investments over the year, the individual dies with a probability of $1 - p_t$. The private wealth is then F_{t+1} which is passed on to the heirs. The pension wealth is $[(1-m_t)A_t + \alpha_t Y_t]R_{At}$ of which a fraction 1-I is passed on to the heirs—subtracting income tax as contributions were made out of pre-tax labor income—and the rest is distributed to surviving fund members. The total bequest is thus

$$B_{t+1} = F_{t+1} + (1 - \tau_Y)(1 - I)[(1 - m_t)A_t + \alpha_t Y_t]R_{At}$$

Should the individual reach the maximum age, the pension account has already been paid out, so the bequest is then $B_{t_M+1} = F_{t_M+1}$.

We assume Epstein-Zin utility with J_t satisfying the recursive relation

$$J_{t} = \max_{c_{t},\pi_{t}} \left\{ \left(c_{t} \tilde{F}_{t} \right)^{1 - \frac{1}{\psi}} + \beta \operatorname{CE}_{t}^{1 - \frac{1}{\psi}} \right\}^{\frac{1}{1 - \frac{1}{\psi}}},$$
(8)

where

$$CE_t = \left(p_t E_t \left[J_{t+1}^{1-\gamma} \right] + (1-p_t) E_t \left[\bar{U}_{t+1}^{1-\gamma} \right] \right)^{\frac{1}{1-\gamma}}$$
(9)

is the certainty equivalent of next period's utility which is J_{t+1} if surviving and the bequest utility \bar{U}_{t+1} if not. We assume $\bar{U}_t = \xi^{\frac{1}{\psi-1}} B_t$, where $\xi \ge 0$ measures the strength of the bequest motive: if death at the end of the year is certain, the individually chooses consumption in that year so that the bequest is roughly ξ times consumption (see the Internet Appendix). In addition to ξ , preferences are characterized by the relative risk aversion (RRA) $\gamma > 0$, the elasticity of intertemporal substitution (EIS) $\psi > 0$, and the subjective discount factor $\beta > 0$.¹⁵

The baseline values are RRA 4, EIS 1/4, and bequest weight 2, but we also consider other values. The subjective discount factor is $\beta = 0.96$. These parameter values are similar to those used in related papers and consistent with empirical estimates. Based on a Swedish administrative panel data set, Calvet, Campbell, Gomes, and Sodini (2021) estimate the cross-sectional distribution of preferences among middle-aged, stockowning households. The median estimates include an RRA of 5.30, an EIS of 0.42, and a discount factor of 0.9600 (they report $\ln \beta = -0.0408$). Using Italian data on household income and wealth, Chiappori and Paiella (2011) report a mean RRA of 2.5-4.2 depending on which households are included. Based on decisions of U.S. investors on a person-to-person lending platform, Paravisini, Rappoport, and Ravina (2017) find a mean RRA estimate of 2.81. Both papers find substantial cross-sectional variation in the RRA.¹⁶ In Merton's no-income setting, the optimal stock weight is 81.1%, 40.6%, and 27.0% with RRA equal to 2, 4, and 6, respectively, showing that the 2-6 RRA range we consider covers a wide range of risk attitudes. In our framework, without imposing a mandatory pension plan, an individual with RRA 2 (and EIS 1/4 and bequest weight 2) optimally invests 100% in stocks all life, which supports the view that RRA 2 represents a strong risk tolerance in the context of our model. While varying substantially across studies, most EIS estimates based on microdata are positive and below 1. For example, Vissing-Jørgensen (2002) report 0.3-0.4 and Bonaparte and Fabozzi (2017) 0.33-0.56, both using U.S. stockholder data. In settings related to our, Dahlquist et al. (2018) assume an EIS of 0.5, and Gomes and Michaelides (2005) consider 0.2 and 0.5.

¹⁵We assume $\gamma \neq 1$ and $\psi \neq 1$, but cases with $\gamma = 1$ or $\psi = 1$ or both can be studied separately with appropriate adjustments of (8) and (9).

¹⁶To obtain a match between life-cycle model predictions and observed savings and investment decisions of Scandinavian households, Fagereng et al. (2017) and Dahlquist et al. (2018) estimate γ in the range 11-15 (to produce low stock weights) and β in the range 0.75-0.93 (to produce low savings). However, these estimates may reflect behaviorial biases rather than genuine preferences, and such values fall outside the intervals generally considered reasonable based on introspection, experiments, and other empirical studies.

The combinations of RRA and EIS we consider involve cases with a preference for early resolution of uncertainty ($\psi > 1/\gamma$) or late resolution of uncertainty ($\psi < 1/\gamma$) or an indifference towards the timing ($\psi = 1/\gamma$; time-additive power utility).

As argued in the introduction, some individuals procrastinate on savings. For convenience, we model procrastination as follows. The utility the individual derives from any consumption plan is associated with the baseline discount factor $\beta = 0.96$. However, due to lack of self-control, the individual applies a lower value, $\beta = 0.85$, when making decisions, so she consumes too much early in life and builds up too little wealth as illustrated below.¹⁷ In Section 3.2 we argue that with $\beta = 0.85$ approximately 2/3 of the population procrastinate on retirement saving.

Given our set-up, the indirect utility is a function $J_t = J_t(F_t, Y_t, A_t)$ of private wealth, current income, and pension wealth. We show in the Internet Appendix that the dimension of the state space can be reduced by one by exploiting a homogeneity property; our assumptions on proportional taxation and that the state pension is proportional to pre-retirement income are needed here. More precisely,

$$J_t = (F_t + [1 - \tau_Y]A_t) G_t (y_t, a_t), \qquad (10)$$

where

$$y_t = \frac{[1 - \tau_Y]Y_t}{F_t + [1 - \tau_Y]A_t}, \qquad a_t = \frac{[1 - \tau_Y]A_t}{F_t + [1 - \tau_Y]A_t},$$
(11)

and we solve for G and optimal decisions by backwards dynamic programming on a grid of points (y_i, a_j) . We simulate 10,000 paths forward and report averages at each age to indicate an expected life-cycle pattern. The Internet Appendix has details on the numerical solution approach.

¹⁷To be clear, we assume that $c_t(a_t, y_t)$ and $\pi_t(a_t, y_t)$ are derived by the dynamic programming technique assuming $\beta = 0.85$ and then evaluated with $\beta = 0.96$. The evaluation of a given strategy (c_t, π_t) follows the same backwards iterative approach as when deriving the optimal strategy, except that no maximization is performed. Procrastination can also be modeled using (quasi-)hyperbolic discounting (Laibson, 1997), but this is computationally more demanding.

2.4 Welfare metric

In our setting, the pension fund design is characterized by a sequence of contribution rates $\alpha_{t_1}, \alpha_{t_1+1}, \ldots, \alpha_{t_R-1}$ and stock weights $w_{t_1}, w_{t_1+1}, \ldots, w_{t_M-1}$, as well as the solidarity factor *I*. For simplicity, we represent such a design by (α, w, I) .

A key element of our analysis is to compare the utility or welfare that an individual can generate with a certain mandatory pension plan to the utility without a pension plan, but under the same assumptions about income, initial wealth, etc. Let $J_{t_1}(F, Y, A; \alpha, w, I)$ denote the indirect utility with a pension plan (α, w, I) and $J_{t_1}(F, Y, A; 0)$ the indirect utility without a plan. We can quantify how much better off the individual is with (α, w, I) than without a plan by the fraction λ of additional life-time labor income and initial wealth that the individual without a plan would need to receive to obtain the same lifetime utility as with the plan (α, w, I) . With the additional income and wealth, the indirect utility without a plan is

$$J_{t_1}\left([1+\lambda]F, [1+\lambda]Y, [1+\lambda]A; 0\right) = (1+\lambda)J_{t_1}\left(F, Y, A; 0\right).$$
(12)

Equating this with $J_{t_1}(F, Y, A; \alpha, w, I)$, we find

$$\lambda = \frac{J_{t_1}(F, Y, A; \alpha, w, I)}{J_{t_1}(F, Y, A; 0)} - 1.$$
(13)

Of course, $\lambda < 0$ means that the pension plan leads to a welfare loss. To give a better sense of the size of the gain/loss, we transform it into a dollar amount by multiplying λ by the sum of the initial financial wealth and the present value of after-tax income (from labor and Social Security less medical expenses). Since the income is not spanned by traded assets, there is no unique way to fix the discount rate for future expected income. To be specific, we compare with the stock market where the risk premium is assumed to be 4% for a standard deviation of 15.7%. Scaling by the 10% standard deviation of income, we apply a risk premium of 2.55%, i.e. a discount rate of 3.55%, giving a present value of income equal to \$859,722 on top of the financial wealth of \$5,000. Hence, a welfare gain λ of 1% corresponds to \$8,647.¹⁸

2.5 Pension plan design features

To streamline the analysis, we focus on simple plan designs; simplicity is also important for transparency and thus public support of a broad or even universal mandatory retirement saving program. We assume a constant contribution rate α either applying immediately from age 25 or from a later age and always until retirement, and we consider only integer contribution percentages. We focus on the following fund investment policies each characterized by how the stock weight varies with age:

IP1: 50% stocks all life;

IP2: stock weight at age t is (120 - t)%;

IP3: 90% stocks until age $t_R - 25$, slopes to 30% at age $t_R + 10$ and stays there;

IP4: 100% stocks until age $t_R - 20$, slopes to 50% at age $t_R + 20$ and stays there;

IP5: 100% stocks all life.

IP1 and IP5 feature a constant stock weight, whereas the other policies have a glidepath element. IP2 is the '120-minus-age' strategy seemingly popular among some financial advisors. IP3 emulates Vanguard's target date funds.¹⁹ The more aggressive IP4 resembles the life-cycle pattern of the average optimal stock weight for rational individuals without a pension plan, cf. Panel D of Figure 3 below. We consider values of the solidarity factor I in multiples of 0.1 within the interval [0, 1].

¹⁸Using the riskfree rate as a discount rate, as Guiso and Sodini (2013) and others do, a 1% welfare gain corresponds to a present value gain of \$15,184. Using the unscaled equity premium and thus a discount rate of 5%, a 1% welfare gain corresponds to \$6,677.

¹⁹Source: https://institutional.vanguard.com/web/c1/investments/product-details/ fund/1691 accessed on March 12, 2021. Vanguard's description of the asset allocation glidepath involves U.S. stocks, international stocks, U.S. nominal bonds, international bonds, and short-term TIPS. Based on the 2060 fund, we add U.S. and international stocks to get the stock weight used in our model. Vanguard's downward-sloping stock weight is slightly non-linear, but we approximate it with a linear relation.

We assume that a broad plan covering heterogeneous individuals stipulates a default choice of (i) the contribution rate and starting age, (ii) the investment policy IPn for some $n \in \{1, ..., 5\}$, and (iii) the solidarity factor I. We discuss the implications of adding various options to deviate from the default choice. We stick to options that are computationally tractable so that the homogeneity property (10) is preserved. This includes options to change the investment policy and the solidarity factor from the initial date, without the possibility to revise the choice later. We also consider options that can be exercised at a later age, namely the option to end contributions or to pay out a fraction of the pension savings prematurely.

3 Benchmark: no mandatory pension plan

This section studies the case without a mandatory pension plan which serves as a benchmark for the subsequent analysis of the design and implications of such a plan. Compared to mainstream life-cycle models (Viceira, 2001; Cocco et al., 2005), our model includes taxes on income and returns, Social Security retirement benefits, out-of-pocket medical costs, and the possibility to annuitize retirement savings. We consider both rational individuals and individuals procrastinating on saving.

We derive decisions and utility both without and with access to annuities. In the latter case, the individual decides at retirement upon the fraction of wealth to spend on a variable life annuity with an equal mix of stocks and bonds. The Internet Appendix extends our model with the option to annuitize. An annuity is fairly priced if payments are based on the population mortality rate and the annuity issuer makes a zero expected profit. We consider both fair annuities and—as motivated in the Introduction—annuities with a 20% cost meaning that payouts are 20% lower.

3.1 Life-cycle patterns and annuitization

Figure 3 illustrates the life-cycle patterns generated by the model for the baseline preference parameters, and Table 2 lists selected results also for other combinations of preference parameters. For now, we assume the baseline parameters. The saving rate shown is defined as after-tax income less consumption, $(1 - \tau_Y)Y_t - c_t\tilde{F}_t$, relative to after-tax income, $(1 - \tau_Y)Y_t$.

- [Figure 3 about here.]
- [Table 2 about here.]

First, focus on the rational individuals without annuity access (solid, blue lines). Panel A of Figure 3 shows that expected consumption has the hump-shape typically produced by life-cycle models with consumption peaking near retirement. Panel B shows that the individual saves a relatively large fraction of income early in life to build a wealth buffer against bad times, and the expected saving rate exceeds 10%up to age 50 after which it gradually declines and turns negative around age 60, meaning that consumption exceeds after-tax income. To smooth consumption over time and states, the optimal saving rate depends on the individual's income and accumulated wealth and can deviate considerably from the expected value shown. Panel C documents that wealth is steadily built up until retirement, after which wealth decumulates—at first rather slowly due to the risk of significant medical expenses. Without annuities, expected wealth peaks at around \$527,000 at retirement, and at age 60 the accumulated wealth is 11.2 times annual after-tax income. With access to annuities at 20% costs, expected wealth is \$463,000 at retirement and the age 60 expected wealth-income ratio is 10.2.²⁰ Until around age 55, all financial wealth is held in stocks, but then bonds enter the portfolio and the stock weight declines steadily towards 50% late in life, cf. Panel D. Consistent with the existing

 $^{^{20}\}mathrm{With}$ a zero-cost annuity, the numbers are \$442,000 and 9.5, respectively.

life-cycle literature, this glidepath pattern emerges because of the gradual decline in the bond-like human capital relative to financial wealth.

Panels A and B of Table 2 show that with access to an annuity with 0% [20%] cost the rational individual chooses to annuitize 76.8% [75.0%] of wealth at retirement, which increases the individual's welfare by 3.61% [2.14%] or about \$31,000 [\$18,500] in present value terms. Annuitization allows significantly larger consumption late in life and also slightly larger consumption in the working years as less wealth has to be accumulated for retirement. The annuity has 50% invested in stocks, but the individual prefers a higher stock weight early in retirement and therefore tilts the private portfolio more towards stocks.

Next, turn to the procrastinator. Figure 3 shows that expected consumption is again hump-shaped but peaks already around age 50. Relative to the rational individual, the procrastinator consumes more and saves less early in life and ends up with very low consumption near and in retirement. Without annuitization, expected wealth peaks at 185,000-35% of the rational individual's maximum wealth—and the wealth-income ratio at age 60 is only 2.6. With access to annuities at 20%cost, the procrastinator's expected wealth peaks at \$165,000 and the age 60 wealthincome ratio is 2.5. The procrastinator's wealth is tilted towards the bond-like human capital throughout life which generates a higher portfolio share of stocks. Also the procrastinator appreciates annuity access and, with 20% costs, chooses to annuitize 44.6% of wealth with a welfare gain of 7.97\%, cf. Table 2. In dollarterms the annuity bought generates only a modest income, and late-life consumption remains low. With optimal annuitization at 20% costs, the procrastinator's welfare is 25.5% lower than for the corresponding rational individual or roughly \$220,000 in present value terms. A mandatory pension plan can reduce this welfare loss substantially by bringing the life-cycle patterns closer to that of the rational ideal.

3.2 Implications for pension plan design

The saving rate of 10-15% through most of working life shown in Panel B of Figure 3 does not translate directly into preferred contribution rates in a mandatory pension plan. The pension savings are illiquid, and the buffer saving motive can only be met by saving in a private account. This suggests that the contribution rate should be somewhat lower than the saving rate in the no-pension case. On the other hand, the tax benefits of pension returns can motivate larger savings. It is also important to note that the saving rate varies considerably with preference parameters. As an indication, Panel C of Table 2 shows the expected wealth-income ratio at age 60. With a RRA of $\gamma = 2$, this ratio is around 6 compared to 10 for $\gamma = 4$ and 12 for $\gamma = 6$. The saving rate is increasing in the bequest motive and varies somewhat with the EIS parameter ψ . A high contribution rate could significantly reduce the welfare of rational, risk-tolerant individuals.

Panel D of Figure 3 suggests that a mandatory pension fund should employ a fairly aggressive (i.e. stock-heavy) glidepath strategy.²¹ The optimal stock weight is generally decreasing in the RRA, but relatively insensitive to other preference parameters. With a moderate contribution rate, high-RRA individuals will likely maintain significant private savings which could be invested primarily in bonds to counter-balance a high stock weight of the pension fund. Low-RRA individuals prefer a high stock weight throughout life. At the same time, they save less, so they would dislike maintaining a large private stock position to balance off the lower stock weight applied by the fund. Therefore, while a fairly aggressive glidepath strategy seems like a good default choice for a mandatory pension fund, an option to choose an even more aggressive strategy is probably highly valued by low-RRA individuals.

Table 2 shows that annuitization is particularly valuable to individuals with a medium-to-high risk aversion and a modest bequest preference. In spite of the pres-

²¹Such a strategy would also benefit the many individuals holding no or only few stocks.

ence of annuity-style Social Security benefits, possibly large medical expenses, and a 20% cost rate, these individuals benefit substantially from annuitizing a large share of savings. A reduction in the costs from 20% to 0% improves welfare by 1-2 percentage points for many such rational individuals and by more for procrastinators. In contrast, low-RRA individuals worry less about outliving their wealth and thus annuitize a much lower fraction of their wealth which improves welfare only marginally. These results suggest that a broad mandatory pension plan should feature automatic annuitization of a significant default share of retirement savings, but also allow individuals to select a lower degree of annuitization.

The design of a broad mandatory pension plan should acknowledge the welfare of individual members who are heterogeneous in terms of preferences, rationality, wealth, and income. Clearly, the distribution of individuals along such dimensions is important. For our analysis, the share of procrastinators in the economy is a central factor, but difficult to assess. An individual might save very little as a deliberate, active choice based on the discount rate β , the RRA γ , and the bequest weight ξ being low. The observed saving behavior is only informative about the procrastinator share if we fix other preference parameters. However, within our modeling framework, the very low savings accumulated by many U.S. households can only be an optimal, rational choice for preference parameter values that are generally considered extreme in the economics literature.

In the age group 55-64 in the 2019 SCF, the median net worth is 212,500 and the median before-tax income is 63,600.²² Deducting 30% income tax, this leads to a wealth-income ratio of 4.8. Panel C of Table 2 shows that, for rational individuals, the optimal wealth-income ratio at age 60 in our model is larger for all preference parameter combinations considered; the ratio seems fairly insensitive to initial income and wealth. Our model can generate an average wealth-income ratio similar to that derived from the SCF if a significant share of individuals are

²²https://www.federalreserve.gov/econres/scfindex.htm, accessed on March 11, 2021.

procrastinators. As a back-of-the-envelope calculation, suppose that the share s of individuals are rational and the rest procrastinators. The rational individuals are split evenly among RRA 2, 4, and 6, and similarly for the procrastinators. All individuals have the baseline values for other parameters. Then s must be around 0.32 to generate an average wealth-income ratio at age 60 equal to the SCF-motivated value of 4.8. Roughly 2/3 of the population would then be procrastinators. The mirror image of the observed low saving rate is a front-loaded consumption profile. In fact, the data shows a hump-shaped consumption pattern peaking already at age 45 (Thurow, 1969; Gourinchas and Parker, 2002). Comparing with Panel A of Figure 3, this is also supportive of a large share of procrastinators in the economy.

4 Designing a mandatory pension plan

This section explores how mandatory pension plans affect procrastinators and rational individuals. For each pension design we calculate an individual's utility gain using (13) relative to the case without a mandatory pension plan but with optimal choice of annuitization at a 20% cost. Given that few individuals buy annuities, the calculated welfare gains are probably understating the true gains. For the nopension benchmark we assume all returns are taxed at $\tau_F = 20\%$. The gains thus reflect how a tax-reduced mandatory pension plan affects individual welfare compared to a case with no subsidies to retirement savings. We discuss the role of the tax differential later. A mandatory plan instituted by the government to help irrational individuals should preferably not harm a large number of rational individuals relative to a situation with no government interventions at all. The mandatory plan covers individuals with different preferences and sophistication and thus affects their welfare differently. To streamline the presentation and keep the numerical calculations tractable, we first focus on differences in the RRA across individuals since the optimal consumption, investment, and annuitization decisions vary substantially with RRA and less so with the EIS and the bequest weight, as Table 2 also shows. Subsequently, we discuss how the results vary with the other preference parameters.

4.1 Identifying a good plan

Table 3 illustrates the percentage welfare gains of plans with mandatory contributions from age 25, 30, or 35 and until retirement for a selection of contribution rates. We label the plan with 7% contributions from age 25 as '7%/25y', etc. We consider rational individuals in Panel A and procrastinators in Panel B. In each group we consider RRA of 2, 4, and 6, and use the baseline values of other preference parameters. To identify a good default design, we determine for each individual the best choice of investment policy (out of IP1, ..., IP5) and the best choice of the solidarity factor I (out of 0.0, 0.1, ..., 1.0). For example, with the 10%/30y plan the rational individual with RRA 4 prefers IP3 and I = 0.9, which gives a welfare gain of 2.06%. The procrastinator with RRA 4 also prefers IP3 but I = 1.0, leading to a welfare gain of 30.34%. Looking across the table, we see that individuals with RRA 4 or 6 prefer IP3 and I = 1.0 or I = 0.9. Individuals with RRA 2 prefer the more aggressive IP5 and a lower I. This is true for any combination of the contribution rate and enrollment age covered by the table. Given the (limited) literature on the cross section of preferences, an RRA around 2 (or lower) does not appear dominating, so we choose IP3 and I = 1.0 to be the default plan choice.

[Table 3 about here.]

We see that procrastinators benefit substantially from a mandatory plan, in particular procrastinators with RRA 4 or 6 for which the welfare gains are up to 47%, corresponding to about \$406,000 in present value terms. The procrastinators with RRA 4 or 6 are happy with the default plan. Procrastinators with RRA 2 also benefit from the default plan, but would increase their welfare gains notably by actively choosing IP5 and a low value of *I*. Rational individuals with RRA 4 or 6 benefit marginally from all the plans shown in Table 3, but would lose e.g. if the plan mandates contributions from age 25 above a certain level. In contrast, rational individuals with RRA 2 dislike most of the mandatory plans considered, but if they can choose IP and I themselves even these individuals benefit from plans with low-to-modest contributions not starting very early.

For each contribution rate and enrollment age, we calculate the average percentage welfare gain across the six participant types considered in the table, i.e. rational individuals and procrastinators with RRA 2, 4, and 6. Panel C reports both an equal-weighted average gain and an weighted average assuming that (i) 2/3are procrastinators and 1/3 rational as suggested by our previous discussion and (ii) 25% of individuals have RRA 2, 50% have RRA 4, and 25% have RRA 6. We assume either that all individuals stick to the default IP and I, that all individuals optimize over IP and I, or that only the rational individuals optimize. In any case, the largest average gain is obtained either by the 10%/30y or the 11%/30yplan, which indicates some robustness towards how different individual types are weighted, although extreme weights clearly lead to other plans having the highest average gain. Henceforth, we focus on the 10%/30y plan since this has a slightly higher average gain than the 11%/30y plan for most of the averages considered and because the 10%/30y plan is less harsh on the rational, RRA 2 individuals with a loss of 0.21% instead of 0.62% with optimal choice of IP and SF. The 0.21% loss corresponds to about \$1,800 in present value terms. Below we discuss the introduction of additional options that may eliminate the loss. Assuming that all individuals optimally self-select the investment strategy and the solidarity factor, the weighted average gain for the 10%/30 plan is 20.31% or about \$175,000 per participant.

Table 4 further illustrates how the investment policy and the solidarity factor affect the welfare implications of the 10%/30y plan. The investment policy is only marginally important for the rational individual with RRA 4 who can adjust the private investments accordingly, but the policies IP2-4 with a glidepath element

are preferred. The rational, RRA 2 individual prefers the full-stock policy IP5. Given the sizeable mandatory pension savings, this individual holds little private savings and thus cannot make up for a conservative fund strategy by investing all private savings in stocks. The solidarity factor has at least as large a welfare effect as the investment policy. Overall, the IP and I options reduce the welfare loss of the risk-tolerant, rational individual from 1.89% to 0.21%. Also, the risk-tolerant procrastinator benefits substantially from the options that increase the welfare gain from 7.13% to 12.32%. A pension plan with full solidarity resembles a variable life annuity so the finding that low RRA individuals dislike full solidarity is consistent with the results on optimal annuitization in Table 2. Of course, the optionality also opens up for welfare-reducing, sub-optimal decisions, and for the procrastinator with RRA 4 the welfare gain of 30.34% with the default choice drops to 15.16% with the worst choice of IP and I. Intuitively, individuals procrastinating on saving decisions might be more prone to stick to the default choices than rational individuals, and it is difficult to see why procrastinators should actively pick a non-default choice of investment policy and solidarity factor as these quantities have no effect on their consumption potential early in life.

[Table 4 about here.]

Table 5 provides the welfare implications of the 10%/30y plan for a broader set of preference parameters. The welfare gain is sizeable for all procrastinators considered and increases with the RRA and EIS and decreases with the bequest weight. The rational individuals with RRA 4 or 6 gain moderately from the plan with the gain increasing in the EIS. However, rational individuals with RRA 2 and a relatively low bequest weight and a relatively low EIS (and thus a preference for late resolution of uncertainty) incur a small loss. As seen in Table 2, these individuals are not interested in building up substantial savings and gain little from annuitization. Panel B of Table 5 confirms that investment policy IP3 and full solidarity (I = 1) is a good default choice but also that risk-tolerant individuals prefer a riskier investment strategy and less-than-full solidarity.

[Table 5 about here.]

4.2 Effects on life-cycle decisions

In order to better understand why and how the mandatory pension plan identified above improves welfare, Figure 4 investigates how the introduction of the plan changes the consumption and investment decisions of both the rational individual and the procrastinator with baseline preference parameters. The dashed curves are for the case with no mandatory savings but access to annuitization with a 20% cost, as in Figure 3. The solid curves are for the case with the mandatory plan.

[Figure 4 about here.]

Panel A shows that the expected consumption of the procrastinator moves close to that of the rational individual when imposing the plan. The mandatory savings reduce the procrastinator's excessive early-life consumption and boost retirement consumption. The consumption pattern is close to what the procrastinator prefers, but is unable to generate without the mandatory saving plan. The rational individual expects to consume slightly more at all ages with the mandatory plan, which is possible because of the lower return taxation and the better annuitization terms.

As shown in Panel B, the rational individual lowers the private savings to compensate for the mandatory savings, but still builds a liquid wealth buffer in the early years. The procrastinator accumulates some liquid wealth early on, but then saves, on average, virtually nothing from age 35 to 50, whether or not the plan is imposed. Without the plan, the procrastinator saves considerably in the years leading up to retirement, partly to make use of the annuitization option. With the plan, the procrastinator does not have to do that as the annuitization is built into the plan. The rational individual's total wealth pattern is roughly the same with the mandatory plan as without, cf. Panel C, so the mandatory pension savings are replacing voluntary, private savings. As indicated by the difference between the solid blue curve and the dotted grey curve, the rational individual maintains a size-able liquid wealth, which is desirable to have for buffering against shocks. The total wealth of the procrastinator is obviously much larger with the mandatory plan as the large mandatory savings by far outweigh the small reduction in private savings.

Panel D shows the optimal fraction of private wealth invested in stocks together with the stock weight of the pension savings. Note that the private portfolio is tilted more towards stocks than the pension portfolio. While this could indicate that individuals would like the pension fund to take more risk, even late in life, we find that IP3 is preferred to the more aggressive IP4-5 for individuals with RRA 4 or 6. By having the larger stock weight in the private, liquid portfolio, the individuals can quickly reduce their stock exposure if hit by large income or medical shocks or very poor returns, whereas the asset allocation mix of the pension savings is inflexible.

4.3 Sources and robustness of welfare gains

With the baseline parameter values, the welfare gain is 2.06% for a rational individual and 30.34% for a procrastinator when the 10%/30y pension plan with individual choice of investment policy and solidarity factor is imposed. Table 6 shows how these welfare gains are impacted by variations in some assumptions and plan features.

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[Table 6 about here.]
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First, we have measured welfare gains relative to the case with optimal individual annuitization assuming a 20% cost on annuities. Even when comparing to the case with fair annuities, the welfare gain is still large for the procrastinator (24.49%) and stays positive for the rational individual (0.61%). The gains generated by the mandatory plan are significantly larger (40.73% and 4.25%, respectively) when we

compare with the case without individual annuitization, which seems a relevant benchmark for most individuals given the low observed annuitization rates.

Secondly, the gains are partly due to pension fund returns being tax-exempt. However, if all returns are taxed at 20%, the welfare gain is only marginally reduced to 1.56% for the rational individual and 29.56% for the procrastinator. If all returns are untaxed, the gains are slightly smaller, 1.36% and 28.44%. With $\tau_A = 10\%$ and $\tau_F = 20\%$, the gains are 1.79% and 29.89%. Some tax advantage may be important, though, for the acceptance of a mandatory pension scheme by individuals with low RRA and EIS. A lower, but positive, tax rate on pension returns may, in fact, lead to similar or larger total return tax revenues due to the significantly larger investments—and thus more taxable returns—with a mandatory pension plan. For example, with $\tau_A = 10\%$, $\tau_F = 20\%$, and baseline preferences, the present value of life-time return taxes drops from about \$92,000 to \$68,000 for the rational individual, but increases from about \$30,000 to \$48,000 for the procrastinator.²³ With 2/3 of individuals being procrastinators, total revenues increase.

Thirdly, our baseline assumption is that both the private investor and the fund manager face a riskfree rate of 1% and a risky asset portfolio with an expected excess return of 4% and a volatility of 15.7%. Due to economies of scale, access to more asset classes, or simply better information and skills, pension fund managers may be better investors than private investors, even after accounting for management fees. Table 6 shows that if the fund manager can up the expected excess return to 4.5% for the same volatility, the welfare gains increase moderately to 2.87% and 31.32% for the two investor types. Conversely, if the fund manager can obtain the expected excess return of 4% with a volatility of only 14.7%, the gains are 2.47% and 30.84%.

Finally, our model includes the risk of substantial out-of-pocket medical expenses late in life—a key concern of U.S. households. Such costs affect life-time utility both with and without a pension scheme. Since medical costs cannot be paid out

 $^{^{23}}$ We discount expected return tax payments from simulations to age 25 using the riskfree rate.

of illiquid pension savings, a mandatory pension scheme is less appreciated when medical costs are large, but Table 6 shows that gains are relatively insensitive to the assumed costs.

4.4 Sweetening options

Rational individuals with low RRA (and low-to-modest EIS and bequest weight) dislike the plan with 10% contributions from age 30, even if they can choose the fullstock strategy IP5 and their favorite solidarity factor. While they would benefit from contributions at a lower rate or starting later, such a change would reduce the welfare gains for procrastinators and more risk-averse rational individuals. An alternative is to maintain the 10%/30y plan but add options that are valuable primarily to the low-RRA rational individuals and do not allow procrastinators to reduce their savings substantially in the early part of the accumulation phase. For computational tractability, the options have to respect the separation (10).

By choosing IP5 instead of the default IP3, the rational RRA 2 individuals obtain a 19% larger expected pension wealth at age 60 (using I = 1). Hence, we consider a "payout option" allowing individuals turning 60 to pay out up to 19% of their pension savings, taxed at the income tax rate but without any penalty for the premature payout. By adding this option, the welfare loss can be transformed into a gain for some risk-tolerant, rational individuals. For example, with RRA 2, EIS 1/4, and bequest weight 2, the loss of -0.21% turns into a gain of 0.38%. However, with RRA 2, EIS 1/6, and bequest weight 1/2, the option cannot generate a gain, but the loss is reduced from 1.35% to 0.61%; such an individual needs an option to pay out 35% at age 50, for example, to reach a gain. On average, rational individuals with RRA 2 choose to pay out 13-16 percent of their savings with the exact number depending on the EIS and bequest weight. The '19% at 60' payout option even leads to a slightly larger gains for procrastinators who would fully exploit the option in most states. However, a higher payout percentage or earlier payout age can reduce the gains for procrastinators. Overall, an option to pay out 19% at age 60 seems valuable to a broad range of individuals and particularly to the risk-tolerant rational individuals. The Internet Appendix provides additional numerical analysis of payout options.

An alternative is a "halt option" allowing members to end contributions at some specified age before retirement. As the payout option, individuals would exercise the halt option if their pension wealth is a large share of total wealth or if income is low relative to total wealth. However, ending contributions, say, at age 60 reduces the accumulated savings at retirement rather modestly which results in smaller welfare improvements than found for the payout option. For example, a rational individual with RRA 2, EIS 1/4, and bequest weight 2 chooses to halt contributions at age 60 in 31% of the states, which reduces the loss from 0.21% to 0.11%.

4.5 Reduction in Social Security benefits

The above analysis is calibrated to the current level of Social Security benefits paid to retirees. However, in a 2021 Gallup poll 73% of respondents worry a great deal or a fair amount about the Social Security system.²⁴ Such concerns seem justified. The Social Security and Medicare Boards of Trustees concludes in their April 2020 report that the system will show net cash outflows from 2021, and by 2035 benefits have to be cut by 24% to make the system sustainable.²⁵

We thus consider the implications of a 24% reduction in Social Security benefits from 45% to 34.2% of pre-retirement income. Since we have modeled the possible out-of-pocket medical expenses as fractions of Social Security benefits, we multiply these fraction by 1/(1-0.24) to keep expenses fixed in dollar terms. Repeating the

²⁴Source: https://news.gallup.com/poll/1693/social-security.aspx, accessed on April 23, 2021.

²⁵Source: https://www.ssa.gov/OACT/TR/2020/index.html, accessed on August 7, 2020.

analysis from Section 4.1 with the new parameter values, we find that individuals appreciate a given pension plan more when Social Security is cut. The optimal contribution rate increases. Based on the weighted average gains, the best plans still have contributions from age 30, but now contribution rates of 11% or 12% provide the largest average gain of about 22.4% (or \$193,000), whereas the largest average gain of around 20.3% (\$175,000) in the base case was obtained with a contribution rate of 10% and 11%. As in the base case, the lower of the two contribution rates (now 11%) has the benefit of causing only marginal losses for the most risk-tolerant rational individuals, losses that can be eliminated or reduced by adding a payout option as discussed above. Hence, with lower Social Security benefits, a well-designed mandatory pension scheme is even more appreciated, and the optimal contribution rate increases from 10% to 11%. Details can be found in the Internet Appendix.

5 Discussion

Our analysis supports the introduction of a broad, well-designed, mandatory pension scheme. The presumably large group of individuals procrastinating on savings make significant welfare gains from such a scheme. Many rational individuals also experience gains, although smaller in magnitude, but some rational individuals with low RRA, low EIS, and a small bequest motive suffer a small welfare loss. We have given an example of an optional feature that primarily benefits these individuals. Within our framework, further improvements can be made by incorporating other options, additional fund investment policies to choose from, a more flexible contribution scheme, or pension payouts that are not constant in expectation through retirement. A downside of such features is the increased complexity of the plan. We acknowledge that, most likely, any pension plan with significant mandatory saving reduces the welfare of individuals who rationally prefer little saving due to "extreme preferences" such as a very low discount factor β , but presumably only few, if any, individuals have such preferences.

In reality, individuals have different degrees of procrastination but it is unclear how this distribution can be estimated. Due to the concavity of the utility function, the gain from the more balanced consumption induced by a mandatory pension plan is an increasing convex function of the degree of procrastination. Our assumption of a single degree of procrastination (decision-beta 0.85 versus evaluation-beta 0.96) thus leads to a lower average welfare gain from the mandatory plan than if we allowed for a distribution with the same average degree of procrastination. To illustrate this, recall that with a decision-beta of 0.85 (and baseline parameters), the expected wealth-income ratio at age 60 is 2.5 in the absence of a mandatory plan and the welfare gain from our 'favorite' plan is around 30%. A stronger procrastinator with a decision-beta of 0.8 has an expected wealth-income ratio at 60 of 1.5 and has a 65% gain from the plan. A weaker procrastinator with decision-beta 0.878 has an expected wealth-income ratio of 3.5 and a welfare gain of 17% from the plan. With an equal mix of the two types, the average degree of procrastination as measured by the wealth-income ratio at 60 is the same as before, but the average gain of 41%exceeds the 30% gain with our single type.

While our life-cycle model is rich, a number of relevant extensions easily come to mind. First, as the few other pension design papers, we ignore housing. Adding housing consumption and investments would complicate the numerical optimization method considerably and make our thorough analysis practically impossible. As broad mandatory plans embrace both renters and owners, the model should ideally endogenize the renting/owning decision, and is likely to result in renters preferring a very different pension plan than owners, among other things due to the fact that homeowners often build substantial home equity that can partly replace retirement savings. Young, prospective homeowners favor private saving for a down payment to illiquid pension savings, which backs our recommendation not to require pension contributions from an early age. We leave the very challenging pension design problem with both owners and renters to future research. Second, we assume illiquid pension savings, but it would be interesting to allow hardship withdrawals, maybe at some penalty rate, in case labor income drops considerably or medical shocks occur. Other extensions would be to allow for more elaborate labor income dynamics (see, e.g., Guvenen, Karahan, Ozkan, and Song, 2021), for non-proportional taxes and Social Security benefits, and for time-varying investment opportunities. Note, however, that any of these extensions induces an additional state variable which further complicates and prolongs the numerical solution.

Our welfare analysis ignores some potential general equilibrium effects. As pensions savings crowd out some private savings, a zero tax on pension returns lowers the total taxes collected from financial returns. However, we have shown that a mandatory pension scheme can be welfare improving even with no or only a modest tax advantage to pension savings, and with the increase in total savings the government could then collect an even larger return tax revenue compared to the case without mandatory saving. Also, with the higher retirement income generated by a broad mandatory plan, fewer retirees need tax-financed welfare payments or other forms of support. Our welfare calculations assume that the level of the riskfree rate and the expected excess return and volatility of the stock market do not change upon the introduction of the mandatory scheme. Any such changes could also have ramifications for firms' cost of capital and thus overall production and labor market conditions. We leave a complete general equilibrium analysis to future research.

6 Conclusion

Our quantitative life-cycle analysis shows that a well-designed mandatory pension scheme substantially improves the welfare of individuals who procrastinate on retirement saving. At the same time, the scheme slightly improves the welfare of rational individuals, except those with a low risk aversion, a low elasticity of intertemporal substitution, and a low bequest motive. Calibrated to U.S. data, our model suggests a scheme with (i) mandatory contributions of 10% of income from age 30 until retirement, (ii) a glidepath investment policy resembling existing target-date funds, (iii) tax-exempt returns on pension savings, (iv) automatic life-long annuitization, and (v) an option to choose a different investment policy and a different annuity solidarity factor. Across individuals with different levels of risk aversion and sophistication, such a scheme delivers an average welfare gain corresponding to \$175,000 per person in present value terms. The welfare gains come from reducing the undersaving problem of procrastinators, from ensuring annuitization of retirement wealth at fair terms, and—to a smaller extent—from eliminating taxes on returns on pension savings. With the projected cut in Social Security benefits, the contribution rate should be raised to 11%, and the mandatory savings plan is then even more appreciated with the average gain increasing to \$193,000.

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Figure 1: The sequence of events in a typical year in our model. See the main text for a detailed description of the notation and the model.



Figure 2: Annuity values and survival probabilities through retirement. The individual's age is depicted along the horizontal axis. The grey lines show the value of an annuity in thousands of USD for different values of the solidarity factor I. The annuity starts at age 67 with a value of \$100,000 and is a variable annuity with 50% stocks. The orange lines are to be read off the right-hand axis and show the probability of being alive at the end of a given year conditional on being alive when turning 67 (solid line) and the probability of dying in year t conditional on being alive at the beginning of year t (dashed line). These lines are based on the 2017 life table for the U.S. population (Arias and Xu, 2019) with an imposed maximum age of 100. Please, see online version for correct colors.



Figure 3: Life without a pension plan. The horizontal axis shows the individual's age. Blue lines refer to a rational individual, orange lines to a procrastinator. Solid lines are for the case without annuitization, dashed lines for the case with access to variable life annuities (50% stocks) with 20% cost. All lines show means across 10,000 simulated paths. Panel A shows the annual consumption and, in grey, labor income and state pension after taxes and medical costs. Panel B depicts the saving rate. Panel C shows financial wealth, including the value of the annuity portfolio after cost. Panel D illustrates the fraction of (non-annuitized) wealth invested in the stock market. The baseline parameter values listed in Table 1 are used. *Please, see online version for correct colors.*



Figure 4: Life with a pension plan. The horizontal axis shows the individual's age. Blue lines refer to a rational individual, orange lines to a procrastinator. Solid lines are for the case with a mandatory pension plan featuring 10% contributions from age 30, where the individual can choose the solidarity factor I and the investment policy from the menu IP1-5. The rational individual chooses IP3 and I = 0.9, the procrastinator IP3 and I = 1. The dashed lines are for the case with access to variable life annuities (50%) stocks) with 20% cost. All lines show means across 10,000 simulated paths. Panel A shows the annual consumption. Panel B depicts the private saving rate, i.e., the fraction of income after taxes and mandatory contributions that the individual chooses to save on a private account. Panel C shows total wealth, which includes either the value of the annuity portfolio after cost or the after-tax pension wealth $(1 - \tau_Y)A_t$. The dotted grey curve shows the after-tax pension wealth with IP3 and I = 1. Panel D illustrates the fraction of private wealth invested in the stock market. Here the dotted grey curve depicts the fraction of pension wealth invested in stocks under the investment policy IP3. The baseline parameter values listed in Table 1 are used. Please, see online version for correct colors.

Parameter	Description	Value
	Financial assets	
r	Riskfree interest rate	0.01
μ_S	Expected excess stock return	0.04
σ_S	Stock volatility	0.157
	Horizon, preferences, and initial wealth	
t_1	Initial age in years	25
t_R	Retirement age in years	67
t_M	Maximum age in years	100
γ	Relative risk aversion	4
ψ	Elasticity of intertemporal substitution	0.25
β	Subjective discount factor	0.96
ξ	Bequest strength parameter	2
F_{t_1}	Initial financial wealth (thousand USD)	5
A_{t_1}	Initial pension wealth (thousand USD)	0
	Income	
Y_{t_1}	Initial annual income (thousand USD)	40
σ_Y	Income volatility	0.1
$ ho_{YS}$	Income-stock correlation	0
ζ	Social Security relative to final salary	0.45
	Tax rates	
$ au_Y$	Income tax rate	0.30
$ au_F$	Tax rate on private returns	0.20
$ au_A$	Tax rate on pension returns	0.00

Table 1: **Baseline parameter values.** See the main text for the motivation of the assumed parameter values.

		$\gamma = 2$			$\gamma = 4$			$\gamma = 6$	
	$\psi = \frac{1}{6}$	$\psi = \tfrac{1}{4}$	$\psi = \frac{1}{2}$	$\psi = \frac{1}{6}$	$\psi = \tfrac{1}{4}$	$\psi = \tfrac{1}{2}$	$\psi = \frac{1}{6}$	$\psi = \tfrac{1}{4}$	$\psi = \tfrac{1}{2}$
Panel A: Optima	al perce	entage	of weal	lth annui	tized a	t retire	ement		
$0\% \cos t$									
Rational $\xi = 0.5$	47.8	56.5	82.8	85.6	85.8	90.8	87.1	89.7	91.8
Rational $\xi = 2$	29.8	37.3	66.3	72.5	76.8	86.8	78.8	82.6	89.8
Rational $\xi = 5$	12.6	17.4	40.9	54.3	59.0	77.2	64.1	68.3	82.4
Procrast $\xi = 2$	6.7	3.1	1.4	54.0	50.0	46.8	65.8	64.1	61.9
$20\% \cos t$									
Rational $\xi = 0.5$	26.2	35.0	69.8	83.7	87.3	91.2	88.5	89.7	92.2
Rational $\xi = 2$	3.2	8.3	42.4	68.2	75.0	87.8	80.7	84.1	89.5
Rational $\xi = 5$	0.0	0.0	6.2	45.3	51.5	73.1	62.5	67.3	80.9
Procrast $\xi = 2$	0.0	0.0	0.0	48.1	44.6	40.0	65.4	62.8	57.1
Panel B: Percen	tage we	elfare g	gain fro	m annuit	ization	L			
$0\% \cos t$									
Rational $\xi = 0.5$	0.47	0.68	1.67	4.36	4.49	4.74	6.58	6.44	6.02
Rational $\xi = 2$	0.17	0.28	1.00	3.28	3.61	4.50	5.63	5.89	5.93
Rational $\xi = 5$	0.04	0.07	0.37	1.26	1.80	3.50	1.87	3.11	5.36
Procrast $\xi = 2$	0.42	0.25	0.15	11.38	13.03	10.68	15.29	19.81	18.89
$20\% \cos t$									
Rational $\xi = 0.5$	0.11	0.20	0.69	2.73	2.83	2.97	4.32	4.19	3.85
Rational $\xi = 2$	0.00	0.02	0.26	1.86	2.14	2.78	3.61	3.75	3.78
Rational $\xi = 5$	0.00	0.00	0.01	0.58	0.87	1.97	1.13	1.88	3.32
Procrast $\xi = 2$	0.00	0.00	0.00	6.82	7.97	6.72	10.29	13.31	13.24
Panel C: Wealth	-incom	e ratio	at age	60 (20%	cost)				
Rational $\xi = 0.5$	5.1	5.2	5.7	9.8	9.6	9.3	12.4	12.0	11.1
Rational $\xi = 2$	6.3	6.4	6.3	10.5	10.2	9.5	12.9	12.4	11.3
Rational $\xi = 5$	8.4	8.3	7.7	12.3	11.8	10.2	14.3	13.6	11.8
Procrast $\xi = 2$	2.4	1.7	0.7	3.9	2.5	0.7	5.5	3.4	0.9

Table 2: **Annuitization.** The individual is given the option to choose a fraction of wealth to annuitize at retirement through a variable life annuity with 50% in stocks and 50% in the riskfree asset. The annuity is either actuarially fair (0% cost) or has a 20% cost. Panel A shows the average fraction of wealth annuitized across 10,000 simulated paths. Panel B depicts the percentage welfare gain from the access to annuitization. Panel C shows the average value of the ratio of wealth to after-tax income at age 60 in the case with access to annuities with 20% costs. Results are shown for different combinations of the investor rationality, RRA γ , EIS ψ , and the bequest weight ξ . Numbers with a gray background are for the baseline preference parameter values.

		25-	66y			30-66y				35-66y		
	7%	8%	9%	10%	9%	10%	11%	12%	12%	13%	14%	15%
Panel A: Rational RRA 2												
Default	-2.39	-3.12	-3.91	-4.75	-1.43	-1.89	-2.39	-2.93	-1.06	-1.37	-1.71	-2.07
With IP/SF option	-0.15	-0.67	-1.26	-1.84	0.13	-0.21	-0.62	-1.08	0.32	0.07	-0.23	-0.55
Best IP/SF	5/0.1	5/0.2	5/0.2	5/0.0	5/0.3	5/0.3	5/0.2	5/0.2	5/0.4	5/0.4	5/0.4	5/0.3
RRA 4												
Default	1.40	1.13	0.94	0.13	2.08	2.03	1.85	1.58	2.18	2.18	2.11	1.97
With IP/SF option	1.44	1.27	0.69	0.47	2.08	2.06	1.97	1.78	2.18	2.18	2.19	2.12
Best IP/SF	3/0.9	3/0.9	3/0.9	3/0.9	3/1.0	3/0.9	3/0.9	3/0.9	3/1.0	3/0.9	3/0.9	3/0.9
RRA 6												
Default	1.98	2.21	2.25	2.09	2.15	2.50	2.73	2.84	2.08	2.39	2.63	2.80
With IP/SF option	1.98	2.21	2.25	2.09	2.15	2.50	2.73	2.84	2.08	2.39	2.63	2.80
Best IP/SF	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0
Panel B: Procrastin	ator											
RRA 2	0 74	0.15	F F 1	4 = 4	7 10	F 10	0.70	0.10	7 10	7.01	0.00	0.47
Default	0.74	0.17 10.77	5.51	4.74	7.49	7.13	0.70	0.19 11.co	7.49	7.21	0.80	0.47
With IP/SF option Bost IP/SF	12.98	12.((12.49	5/0.0	12.42 5/0.1	12.32 5/0.1	12.00 5/0.1	5/0.1	$\frac{11.72}{5/0.1}$	11.08 5/0.1	11.34 5/0.1	11.02 5/0.1
	5/0.0	5/0.1	5/0.0	5/0.0	5/0.1	5/0.1	5/0.1	5/0.1	5/0.1	5/0.1	5/0.1	5/0.1
RRA 4	00.00	00 ar	00.00	00 7 5	20.00	00.04	00.10	00.05	20 72	00 F F	00.00	00.00
Default	29.62	29.65	29.32	28.75	30.22	30.34	30.19	29.85	29.73	29.75	29.60	29.32
With IP/SF option	29.62	29.65	29.32	28.75	$\frac{30.22}{2/1.0}$	$\frac{30.34}{2/1.0}$	30.19	29.85	29.73	29.75 2/1.0	29.00	29.32
Dest IF/SF	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0
RRA 6									10.00			
Default	44.82	46.27	46.95	47.10	44.45	45.69	46.40	46.68	43.03	43.91	44.44	44.68
With IP/SF option	44.82	46.27	46.95	47.10	44.45	45.69	46.40	46.68	43.03	43.91	44.44	44.68
Best IP/SF	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0
Panel C: Average ga	ains											
Equal weights	12 70	12 70	12 51	12 01	1116	1/ 20	14 9F	14.04	19 01	14 01	12.00	12 06
All optimal ID/SE	15.70	15.72	15.00	13.01 14.75	14.10 15.94	14.30 15.45	14.20	14.04	13.91	14.01	15.99	13.80
Rational opt IP/SF	10.12	14 15	13.00	14.70	10.24	14 58	14 56	14 38	14.04	14.90	14.95	14.90
	14.00	14.10	10.31	10.00	14.44	14.00	14.00	14.00	14.14	14.20	14.20	14.14
Non-equal weights	10.05	10 -	10 5	10.00	10.1.	10.00	10.05	10.02	10 -	10.00	10.05	10.00
Default	18.67	18.74	18.54	18.02	19.14	19.30	19.25	19.02	18.78	18.88	18.85	18.69
All optimal IP/SF	19.90	20.06	19.88	19.52	20.09	20.31	20.31	20.12	19.60	19.73	19.73	19.60
national opt. IP/SF	19.90	18.90	18.72	18.32	19.27	19.45	19.42	19.21	18.89	18.00	19.88	18.84

Table 3: Welfare implications of selected pension plans. The plans have contribution rates and periods shown in the column headings, and the default is investment strategy IP3 and full solidarity (I = 1). Panel A considers rational individuals and Panel B procrastinators, in each case for RRA 2, 4, and 6. For each individual, we report the welfare gain from the default plan as well as the optimal IP and I and the corresponding gain. Panel C reports average gains across the six participant types, both an equally weighted average and a weighted average assuming 2/3 procrastinators and 1/3 rational and with 25% of each having RRA 2, 50% RRA 4, and 25% RRA 6. Each average is calculated assuming either that all take the default choice or that either all or only the rational optimally choose IP and I. Losses are in red. The maximum in each row is in blue. Except for the RRA, the baseline parameter values from Table 1 are used. *Please, see online version for correct colors.*

			RRA 2				RRA 4					
Ι	IP1	IP2	IP3	IP4	IP5	-	IP1	IP2	IP3	IP4	IP5	
Panel	A: Ra	tional										
0.0	-1.50	-1.22	-1.28	-0.67	-0.34		-2.32	-1.92	-1.86	-1.68	-1.86	
0.1	-1.34	-1.05	-1.11	-0.54	-0.26		-1.76	-1.31	-1.25	-1.12	-1.41	
0.2	-1.23	-0.93	-0.99	-0.46	-0.22		-1.23	-0.75	-0.68	-0.60	-1.00	
0.3	-1.16	-0.86	-0.91	-0.42	-0.21		-0.74	-0.23	-0.16	-0.13	-0.61	
0.4	-1.14	-0.84	-0.88	-0.42	-0.24		-0.29	0.24	0.31	0.30	-0.25	
0.5	-1.17	-0.87	-0.90	-0.46	-0.30		0.13	0.67	0.74	0.69	0.09	
0.6	-1.24	-0.94	-0.97	-0.55	-0.40		0.51	1.04	1.11	1.04	0.40	
0.7	-1.36	-1.06	-1.09	-0.69	-0.54		0.85	1.37	1.44	1.35	0.69	
0.8	-1.52	-1.24	-1.27	-0.88	-0.72		1.15	1.64	1.71	1.62	0.96	
0.9	-1.75	-1.50	-1.52	-1.15	-0.99		1.38	1.84	1.90	1.83	1.19	
1.0	-2.08	-1.87	-1.89	-1.56	-1.41		1.43	1.82	1.87	1.82	1.27	
Panel	B: Pro	ocrastir	nator									
0.0	10.65	11.03	10.87	11.83	12.31	1	18.31	19.66	19.58	19.38	15.16	
0.1	10.83	11.23	11.08	11.94	12.32	6 4	20.25	21.56	21.50	21.10	16.69	
0.2	10.89	11.30	11.17	11.94	12.24	د 4	21.87	23.13	23.09	22.54	18.04	
0.3	10.82	11.25	11.13	11.83	12.06	د 4	23.22	24.42	24.41	23.74	19.26	
0.4	10.59	11.04	10.94	11.59	11.77	6 4	24.32	25.48	25.48	24.75	20.40	
0.5	10.19	10.67	10.58	11.20	11.33	4 4	25.23	26.32	26.35	25.58	21.50	
0.6	9.54	10.07	9.99	10.60	10.72	4 4	25.97	27.00	27.05	26.31	22.60	
0.7	8.58	9.17	9.11	9.75	9.90	6 4	26.67	27.61	27.68	27.02	23.80	
0.8	7.51	8.10	8.06	8.74	8.95	6 4	27.56	28.38	28.44	27.92	25.23	
0.9	6.99	7.41	7.35	7.99	8.24	6 4	28.78	29.51	29.55	29.19	26.91	
1.0	6.84	7.20	7.13	7.69	7.91	6 4	29.60	30.28	30.34	30.07	28.19	

Table 4: The role of the investment policy and the solidarity factor. The table shows percentage welfare gains when individuals are enrolled in a mandatory pension plan with 10% contributions from age 30. The grey background indicates the default choice of IP3 and I = 1.0. The number in blue indicates the best combination of IP and I for the individual. *Please, see online version for correct colors.*

	RRA = 2			I	RRA =	4	RRA = 6		
	$\psi = \frac{1}{6}$	$\psi = \frac{1}{4}$	$\psi = \frac{1}{2}$	$\psi = \frac{1}{6}$	$\psi = \frac{1}{4}$	$\psi = \frac{1}{2}$	$\psi = \frac{1}{6}$	$\psi = \frac{1}{4}$	$\psi = \frac{1}{2}$
Panel A: Welfa									
Rational									
$\xi = 0.5$	-1.35	-0.72	1.28	1.93	2.10	2.46	2.28	2.38	2.59
$\xi = 2$	-0.53	-0.21	1.25	1.78	2.06	2.54	2.37	2.50	2.65
$\xi = 5$	0.25	0.37	0.95	0.65	1.09	2.32	0.83	1.52	2.67
Procrastinator									
$\xi = 0.5$	11.92	12.65	13.20	28.06	34.48	46.29	29.35	47.49	71.62
$\xi = 2$	11.57	12.32	11.10	24.07	30.34	28.73	31.46	45.69	43.14
$\xi = 5$	10.38	12.37	10.21	14.29	21.07	27.99	17.69	32.89	42.11
Panel B: Optin	nal IP/	I							
Rational									
$\xi = 0.5$	5/0.5	5/0.7	5/1.0	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0
$\xi = 2$	5/0.1	5/0.3	5/0.8	3/0.9	3/0.9	3/1.0	3/1.0	3/1.0	3/1.0
$\xi = 5$	5/0.0	5/0.0	5/0.4	3/0.6	4/0.8	3/1.0	3/1.0	3/1.0	3/1.0
Procrastinator									
$\xi = 0.5$	5/0.3	5/0.5	5/0.9	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0
$\xi = 2$	5/0.0	5/0.1	5/0.5	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0	3/1.0
$\xi = 5$	5/0.0	5/0.0	5/0.1	4/1.0	4/1.0	3/1.0	3/1.0	3/1.0	3/1.0

Table 5: Welfare implications of the 10%/30y plan. For a range of combinations of the preference parameters γ (RRA), ψ (EIS), and ξ (bequest weight), Panel A shows the percentage welfare gain of imposing the plan with 10% mandatory contributions from age 30 and the option to choose the investment policy and the solidarity factor. Panel B provides the optimal choice of the investment policy and the solidarity factor.

	Rational	Procrastinator
Baseline parameters and plan	2.06	30.34
Gain relative to fair-annuity case	0.61	24.49
Gain relative to no-annuity case	4.25	40.73
No tax advantage, $\tau_A = \tau_F = 20\%$	1.56	29.56
No tax advantage, $\tau_A = \tau_F = 0\%$	1.36	28.44
Smaller tax advantage, $\tau_A = 10\%, \tau_F = 20\%$	1.79	29.89
Larger exp. return in fund $(+0.5 \text{ pct pts})$	2.87	31.32
Lower volatility in fund (-1 pct pt)	2.47	30.84
Medical costs (h, H) reduced by $1/3$	2.46	31.00
No medical costs	3.27	32.24

Table 6: Robustness of welfare gains. The table lists percentage welfare gains from imposing a mandatory pension plan with 10% contributions from age 30 and a choice of the investment policy and the solidarity factor. The baseline parameter values listed in Table 1 are used. In particular, $\gamma = 4$, $\psi = 1/4$, and $\xi = 2$.