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Money-Back Guarantees in Individual Retirement Accounts: Are They Good Policy?
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ABSTRACT

Pension products embedding guarantees have been adopted worldwide, including in the Pan-European Personal Pension Products (PEPP) recently launched in the European Union. Using an economic life cycle model where investors have access to stocks, bonds, and tax-qualified retirement accounts, we show that abandoning the guarantee could enhance old-age consumption for over 75% of retirees without harming pre-retirement consumption. Life cycle funds offer an alternative for capital preservation, but they would produce lower average payouts. Investors averse to equity losses accumulate only moderately more in guaranteed accounts, as these offer only limited protection against market crashes.

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1 Introduction

In spite of historically high equity market premiums achievable at reasonable risks, many private investors are reluctant to expose their savings to stocks. While low stock market participation has been researched for more than 25 years (see Gomes et al. 2021), recent studies document that households exhibit strong demand for equity savings embedding minimum return guarantees. Calvet et al. (2023) showed that the volume of capital guarantee products in Sweden after their introduction quickly reached more than 1% of GDP, leading to an increase in expected portfolio returns, particularly for those initially having positive but low equity exposures. Milevsky and Salisbury (2022) reported that, over the last decade, the percentage of price quotes referring to money-back guaranteed variable annuities rose from 18.5% to almost 60% of the entire U.S. annuity market.

Due to the many challenges posed by insufficient private retirement savings, numerous countries have adopted tax-qualified individual retirement accounts (IRAs) as a means to fill the gap between retiree income needs and benefits payable under national social security systems.[1] To encourage participation, policymakers have sought to protect savers against capital losses, with one approach mandating that plan sponsors provide money-back guarantees for participant contributions. Thus, private financial institutions in Europe have offered principal guarantees at market prices (Maurer and Schlag 2003), and Japanese defined contribution plans are required by law to offer at least one guaranteed account (Allianz Global Investors nd).

From a policy perspective, mandating retirement account guarantees can be rationalized if they are conducive to achieving high-priority goals. For example, Célérier and Vallée (2017)

[1] For instance, individual retirement accounts and defined contribution 401(k) retirement saving plans in the U.S. are the primary tax-qualified mechanism helping private sector workers accumulate retirement assets, now totaling over $25 trillion (ICI 2024). Ernst & Young (2017) report that individual retirement accounts are available in most European Union countries, though the market is fragmented across member states. Total assets under management amount to €600 billion, of which most, €224 billion, is held by the German Riester IRAs.

showed that catering to household behavioral traits can foster private savings, thus reducing retirees' dependence on state pensions already stressed by population aging (Mercer 2020). There is also evidence that many workers are loss-averse, deterring them from saving and investing in the stock market (e.g., Haliassos and Bertaut 1995, Abdellaoui et al. 2007). Moreover, Calvet et al. (2023) reported that providing people access to equity-linked products with a capital guarantee could boost stock market exposures and portfolio returns, especially for loss-averse households. Additionally, since women live longer, yet tend to be more loss-averse, than men (Schmidt and Traub 2002), including money-back guarantees in their retirement plan menus could enhance their willingness to participate in pension accounts.

Such investment guarantees can protect financially illiterate workers against the shortfall risk of fluctuating equity markets, but policymakers must better understand the economic costs of such guarantees as well as their incidence. In the early 21st century, for instance, money-back guarantees would have cost around 5% of annual contributions for U.S. IRAs (Lachance and Mitchell 2003). During the prolonged period of low/near-zero interest rates in European capital markets during the second decade of the 21st century, these guarantee costs would have risen to over 20% of annual contributions. Though interest rates are currently high, the potential return of persistently low or even negative interest rates of the past decade suggest that it is timely to reevaluate pension guarantee products.

This paper illustrates when such guarantees can adversely impact consumer old-age security. In particular, we investigate quantitatively how these shape household economic behavior, and how adjustments to the guarantee design affect lifetime welfare. Our analytical framework is a realistically calibrated life cycle model with endogenous consumption, savings, investment decision in risk-free bonds and risky stocks held inside or outside tax-qualified individual retirement accounts. The economic framework allows for heterogeneous preferences for households with standard CRRA lifetime preferences over consumption, along with additional disutility for losses from risky investments. In this setting, we then compare results with and without the money-back guarantees as well as for two life cycle funds, in both a 'normal' and a 'low return' environment.

As noted by Gomes (2020), it is crucial to develop models capturing relevant institutional features of retirement savings, especially with respect to the tax structure, the national social security system, and labor income dynamics. To this end, we calibrate our model using the German IRAs adopted in 2002, known as Riester accounts.[2] This program permits tax-qualified individual retirement accounts as long as these include embedded mandatory money-back guarantees. Not only do product providers promise participants a money-back guarantee during the accumulation phase, but the government also subsidizes workers' contributions (up to a cap) in the form of deferred taxation and direct subsidies. In retirement, benefits must be paid as guaranteed lifetime income streams. Such accounts have been popular, with over 35% of eligible German employees holding contracts; in fact, they have been more prevalent than occupational pensions (Börsch-Supan et al. 2012, 2015). Assets under management account for about 7% of Germany's GDP.

Our analysis is also motivated by the recent adoption of a Pan-European Personal Pension Product (PEPP) in the European Union (European Commission 2017; European Parliament 2019). This is a standardized tax-qualified funded defined contribution (DC) plan offered by financial institutions such as asset managers, life insurers, and banks. These accounts – conceptually comparable to U.S. IRAs – are intended to encourage retirement savings and allow pension portability for the more than 200 million workers in the European Union. During the worker's accumulation phase, a provider must offer a default option (called the *Basic PEPP*) which governs the plan's investment strategy when the saver provides no instructions on how to invest the funds. Besides a yearly cap on fees and expenses of 1% of accumulated capital,

[2] Member states in the EU have a uniform capital market with similar interest rates, but the tax and social security systems still differ. Accordingly, we focus on a specific country to illustrate how our model works. Online Appendix I shows that our results can be portable to other developed nations.

this default option requires capital protection – inspired by the protection currently required in the German Riester accounts – either in the form of a money-back guarantee or another risk mitigation technique, ensuring that PEPP savers can recoup all funds contributed by the end of the accumulation phase.[3]

Five main findings emerge from our analysis. First, during what were 'historically normal' capital market periods, money-back guarantees had only a modest effect on consumption prior to retirement, but they did reduce consumption in retirement for about 75% of retirees, by an average of 1.45% per year. This means that eliminating these money-back guarantees would have boosted lifetime utility for three-quarters of people having standard preferences.

Second, in a low interest environment, the money-back guarantee has a more nuanced impact. On the one hand, many people benefit from the account guarantee: the shortfall probability of losing money at age 67 without the guarantee is 9.6%, compared to 2.0% in the 'normal' capital market environment. On the other hand, the costs of protection are so high that 84.3% of retirees would end up with markedly lower old-age consumption, by an average of 5.95% per year. Consumption during the worklife would also be lower with the guarantee.

Third, we analyze whether implementing an age-based life cycle investment approach would be a better risk mitigation technique than the money-back guarantee. In 'normal' capital markets, we show that life cycle funds provide less lifetime consumption than do guaranteed accounts. Yet in a low interest rate regime, a life cycle fund maintaining high equity exposure during most of the worklife generates 2.75% higher average old-age consumption than anticipated with the money-back guarantee.

[3] Berardi and Tebaldi (2024) also study the role of return guarantees in IRAs and reach conclusions that are (at least in part) similar to ours. However, they conduct extensive Monte Carlo simulations to generate return and downside risk profiles of final wealth from different savings plan strategies with fixed contributions. In contrast, we focus on the impact of guaranteed returns in IRAs on household consumption possibilities, where contributions to retirement accounts are endogenous, and we include all other sources of financing, such as earned income, social security, and assets outside tax-subsidized retirement accounts.

Fourth, while eliminating money-back protection may make many retirees better off in terms of lifetime utility, we confirm the finding of Calvet et al. (2023) that loss-averse households prefer to invest their retirement accounts in equity combined with a money-back guarantee. However, the money-back guarantee comes at the cost of significantly reduced old-age consumption, especially in a low interest rate environment, where this cost may be too high even for loss-averse investors.

Fifth, in adverse equity market scenarios, the protection provided by guaranteed IRAs is smaller than many would anticipate. For instance, and surprisingly, even if the stock market dropped by 35% in workers' final year of employment, most participants would be worse off, compared to not having a guarantee. The reason is that the cost of providing the guarantee erodes the account's asset base, relative to an unprotected scheme.

2 Riester Individual Retirement Accounts with Money-Back Guarantees

2.1 Eligibility, Incentives, and Institutional Framework

In 2024, 45 million German employees were entitled to contribute to tax-qualified Riester IRAs, and 15.5 million people held this type of contract (BMAS 2024). Workers have three incentives to save for retirement using such accounts (Börsch-Supan et al. 2008). First, the federal government pays a yearly subsidy into each worker's IRA of up to €175 plus €300 per child younger than age 25. To qualify for the full subsidy, the sum of employee contributions plus subsidies must equal 4% of pre-tax labor income (to a cap of €2,100). If the threshold of 4% is not met, subsidies are reduced proportionally. Second, employees earning higher incomes can benefit from deferred taxation. The tax authority checks whether the deductibility of contributions from taxable income is more favorable than the subsidy paid and settles corresponding differences through tax refunds.[4] Third, investment earnings on account assets are tax-exempt. In all cases, retirement withdrawals are subject to income tax.[5]

Approximately 65% of Riester contracts are held with life insurers, 20% with asset managers, and 15% with banks; here we focus on the accumulation/decumulation plans offered by asset managers. Providers of these contracts must abide by investment and income guarantee rules codified in the '*Certification of Retirement Pension Contracts Act*.' Specifically, during the decumulation phase: (i) payouts are allowed only from age 62 onwards; (ii) not more than 30% of accumulated assets may be withdrawn as a lump sum; (iii) the remaining assets must be distributed as lifelong non-decreasing guaranteed nominal benefits; and (iv) mandatory annuitization of the retiree's remaining capital is required by age 85 (at the latest). Usually, to fulfill the last requirement, IRA providers devote a share of savers' balances at age 67 to buy a deferred annuity paying benefits to the retiree from age 85 until death.[6] In addition, product providers must offer a money-back guarantee: that is, if at the end of the accumulation phase, the account value is lower than the sum of payments into the IRA, the provider must cover the shortfall using its equity capital.[7]

After strong initial growth in the German marketplace, the number of contracts has stagnated. A key reason is that the investment and income guarantees for Riester IRAs have become more expensive since the scheme was adopted in 2002, when the European Central Bank's quantitative easing strategy caused interest rates to plummet from a historical norm of about 3%, down to zero or even negative nominal rates. One result is that premiums for

[4] In the United States, deferred taxation and government subsidies for low-income workers, known as Saver's Tax Credit, are also available for contributions to IRAs (IRS nd). By contrast, employer matching of employee contributions to workplace 401(k) retirement accounts (ICI 2021), also common, differs because it is provided by employers in addition to, rather than as an alternative to, deferred taxation.

[5] If the participant dies, any remaining (non-annuitized) IRA assets can be transferred to the spouse's IRA tax-free. Alternatively, it can be paid out to the other heirs, who must, however, repay subsidies and/or tax deductions to the tax office received by the grantor in addition to inheritance taxes.

[6] This does not necessarily correspond to optimal timing of the deferred annuity purchases (Huang et al. 2016), but it relieves the product provider from holding equity capital to ensure non-decreasing payouts after age 85.

[7] During the payout phase, annuity claims under Solvency II regulation are protected by a collective guarantor of the insurance industry, comparable to the State Guaranty funds in the U.S.

mandatory annuitization became increasingly expensive. For example, the price of a deferred annuity purchased at age 67 paying lifelong benefits of €1 from age 85 onward rose from €1.59 (at an interest rate of 3%) to €2.92 (at a 0% interest rate). Another is that the low interest environment drove a substantial increase in the costs of providing the money-back guarantee.

2.2 Costs of Money-Back IRA Guarantees

From the perspective of the product provider, the money-back guarantee represents a financial risk, since in the event of a shortfall at retirement, the difference between the guaranteed amount and the value of the IRA must be covered from own funds. To control this risk, the product provider must implement hedging strategies, which in turn will result in hedging costs. There are various static or dynamic hedging strategies with or without the use of derivative financial instruments that product providers can use to hedge potential liability from investment guarantees. Here we use a simple put hedge approach, where a portion of the contribution paid by the participant is used to purchase an at-the-money put. We do not claim that this is the most efficient hedging strategy in practice, yet unlike most alternatives, it can be integrated into the life cycle model used later with reasonable numerical effort as it requires only one state variable. To illustrate the pricing (Lachance and Mitchell 2003), we consider a simplified IRA that omits optimal choice of annual contributions, as well as the plan's impact on consumption and the demand for liquid savings. We elaborate further on the model below.

We assume constant annual contributions A_t $(t = 1, \dots, T)$ by the plan participant until the end of the accumulation phase at time T, and the plan provider is obliged to compensate for any losses below the sum of contributions as of date T. The put hedging approach allows the provider to offer clients participation in the stock market, while partly transferring shortfall risks of not achieving the guaranteed amount to the capital markets. Formally, yearly contributions A_t are used to buy u_t units of an equity portfolio (represented by a diversified total return stock index) with price S_t, plus the same number of at-the-money European put options with price P_t and maturity at the end of the saving phase, i.e., $A_t = u_t S_t + u_t P_t$. Units of the equity portfolio are allocated to the plan participant's IRA. If the value of the equity portfolio is lower than the sum of contributions at the end of the accumulation phase, the provider must pay the difference, equal to $\max(\sum_{t=1}^{T} A_t - \sum_{t=1}^{T} u_t S_T, 0)$, into the participant's IRA. This produces an uncertain final IRA value at time T of $\max(\sum_{t=1}^{T} u_t S_T, \sum_{t=1}^{T} A_t)$. The put premiums charged by the provider from the participant's contributions are the cost of the money-back guarantee (Lachance and Mitchell 2003).

To quantify hedging costs for plan participants, we generate 100,000 Monte Carlo simulation paths, along with the resulting profit and loss (P&L) position of the plan provider. We posit that the stochastic dynamics of equities follow a geometric Brownian motion. Consistent with the life cycle model discussed below, we parameterize this process so that the annual (lognormally distributed) gross returns have a volatility of 15.96% and a risk premium (over the risk-free rate i_f) of 5.68% per year. Put option premiums are calculated using the Black and Scholes (1973) approach under both a 'normal' interest rate environment ($i_f = 3\%$), and the low interest rate scenario ($i_f = 0\%$). Table 1 summarizes the guarantee costs for plan participants, expected guarantee payouts, and the expected P&L for the plan provider.

Table 1 here

Panel A of Table 1 addresses the cost of the guarantee from the participant's perspective. At an interest rate of 3%, guarantee costs as a share of total contributions average 4.6–6.3%, depending on the plan's investment horizon. At lower interest rates, guarantee costs increase since the put options become more expensive. For instance, if the interest rate were 0% and the horizon 42 years (coincident with the Riester pension accumulation phase), 25.7% of annual contributions on average would need to be devoted to put options; over a 10-year horizon, the premiums would amount to 13.4% of annual contributions.

Panel B, Table 1, indicates that, in the 3% interest rate environment, expected guarantee payouts to the plan participant (as a percentage of total contributions) are lowest for long plan horizons since the portfolio value is less likely to fall short of the guarantee amount. For low interest rates, the larger share of contributions spent on put premiums effectively reduces the worker's asset base and increases guarantee payments from the provider to the client. In all scenarios, guarantee payments are lower than the put premiums charged to the participants. Hence in expectation, the provider might make a profit if the premiums were charged to the client but not used to buy put options. For instance, at the longest plan horizon of 42 years,[8] guarantee costs exceed payouts by 4.5% at a 3% interest rate, and by 20.8% in the 0% interest rate scenario. Of course, such a strategy would result in substantial downside risks to regulatory solvency capital requirements for the provider.

Even when the provider does buy options to hedge the risk of payment obligations from the money-back guarantee, gains and losses can still be incurred since the amount required to fulfill the liability to compensate shortfalls in a participant's account may deviate from the option payoffs.[9] The resulting expected profit/loss appears in Panel C (again expressed as a share of total contributions). At a 3% interest rate, the provider does not expect to suffer losses, and its P&L for intermediate to long investment horizons is sizeable, at 0.7–0.8% of contributions. Conversely, at a 0% interest rate, the P&L improves as the investment horizon lengthens, but in expectation no gains occur as initially high option premiums permit only relatively small investments in the equity index. Thus, strikingly, in the 0% interest scenario, even if the saving plan lasted for 42 years, losses of 1.2% of contributions would be expected.

It is not surprising that rising hedging costs in the low interest rate environment have prompted those offering Riester pensions to question their ability to continue supplying the market. Plan provider concerns about the viability of the guaranteed IRA market can thus

[8] Options of such long maturities cannot be bought in markets, yet asset managers could buy replication portfolios. Koijen and Yogo (2022) note that imperfect hedging adversely affects the regulatory capital and could result in the firm's inability to offer the product when interest rates are low; see also Milevsky and Salisbury (2022).

[9] Losses occur if put payoffs do not suffice to compensate for shortfalls in client accounts, e.g., in downward-trending markets. Gains result from volatile markets when puts bought at high stock index values in intermediate periods pay off, while no or little compensation payments are made to clients due to a positive account.

undermine the future of the funded private pension system as a complement to the statutory pay-as-you-go old-age scheme.

2.3 Evidence on Plan Participation and Risk Attitudes

The IRA we investigate offers access to several attractive features (i.e., subsidies, deferred taxation, and annuities) at a low entry barrier. IRAs can be divided into contracts investing primarily in equities (such as equity-oriented mutual funds), and those that invest primarily in interest-bearing securities (such as bank deposits or life insurance contracts). It is of interest to assess how financial risk attitudes and other household characteristics affect whether they participate in IRAs, their choice between the two product categories, and the conclusions that can be drawn about the role of the money-back guarantee. Using data on 5,300 German respondents to the Deutsche Bundesbank Panel on Household Finances, Table 2 reports the marginal effects at the means of all covariates from a multinomial logit regression of IRA participation on risk attitudes, income, financial wealth, and demographics. The mutually exclusive categories for the dependent variable are participation in an IRA that invests mainly in equity fund shares (Column 1), mainly in fixed income assets (Column 2), and non-participation (Column 3).

Table 2 here

Importantly, despite being protected by the money-back guarantee, risk-averse individuals are less likely (at the 5% significance level) to select equity-oriented IRAs. This may be due to the same factors that cause people to avoid the stock market, including financial illiteracy (van Rooij et al. 2011, Guiso and Jappelli 2005), peer effects (Brown et al. 2008, Hong et al. 2004), pecuniary and informational costs (e.g., Haliassos and Bertaut 1995, Vissing-Jorgensen 2004, Guiso et al. 2003, Kim et al. 2016), and household preferences such as ambiguity aversion (Dimmock et al. 2016). Those with above-average financial risk tolerance are indifferent between the available choices. We interpret this to mean that risk considerations play no major role in their retirement plan participation decisions, at least as long as savers cannot opt out of the money-back guarantee. Therefore risk-tolerant savers would likely favor higher expected payouts by avoiding guarantee costs. By contrast, the highly risk-intolerant are (insignificantly) more likely not to participate in or to select an IRA investing in fixed income assets.

Other results show that the government incentives to contribute to funded pensions are effective in enhancing IRA demand. Eligibility for the child subsidy significantly increases participation by 4.4%, and the participation boost is larger for IRAs investing mainly in fixed income compared to equity-oriented plans. Trust in others positively correlates with IRA participation (as for stock market participation; Guiso et al. 2008), and the effect applies to equity-oriented as well as fixed income accounts.

In the German dataset, we see that familiarity with equities (proxied by stocks held outside the IRA) significantly increases the probability of choosing equity-oriented IRAs by 3.6%, and it decreases the likelihood of non-participation by 4.8%.[10] Higher labor income, more financial wealth outside the pension system (including company pensions and whole-life insurance), and more education positively affect the likelihood of participating in government-sponsored IRAs.

Financial sophistication also appears to be linked to participation patterns as individuals with higher financial literacy are 2.1% more likely to participate in equity-oriented IRAs, and non-participation is 3.3% lower among this group (both effects are significant at the 5% level). Unemployment significantly decreases IRA participation (even though long-term unemployment still provides subsidies for only €60 of contributions).

In sum, more financially risk-tolerant individuals are willing to participate in equity-oriented IRAs, while risk-averse investors do not participate even with a guarantee, favoring instead non-participation or fixed income-oriented IRAs. In what follows, we use these results to calibrate our model (Section 3.5), focusing on the former group for our baseline case. A robustness analysis examines loss-averse investors.

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[10] Relatedly, Dahlquist et al. (2018) find that investors actively opting out of the default allocation in the Swedish pension system also have higher stock market participation outside of the pension account.

3 Money-Back IRA Guarantees in a Life Cycle Model

Evaluating how mandatory money-back guarantees in IRAs impact worker saving, investment, and consumption patterns requires building and calibrating a discrete-time life cycle model of consumption and portfolio choice. We do so by positing that the utility-maximizing worker decides how much to consume and invest in risky stocks, risk-free bonds, and tax-qualified IRAs. Our framework incorporates key aspects of the German tax structure, social security system, and labor income dynamics.

3.1 Preferences and Optimization

We consider an individual who lives from age 25 ($t = 1$) to age 100 ($t = T = 76$) and retires at the regular retirement age of 67 ($t = K = 43$). Utility is derived from annual consumption C_t, deflated by a consumer price index $\Pi_t = \Pi_{t-1}(1 + \pi)$. The price index is assumed to evolve at a constant and deterministic rate of inflation, π, and Π_0 is normalized to one. Inflation effectively devalues the IRA money-back guarantee because it is a nominal rather than an inflation-adjusted promise. Accordingly, the model cannot be solved entirely in real terms but instead requires explicit treatment of inflation, as in Koijen et al. (2011).[11]

Utility is measured by an Epstein-Zin utility function (Epstein and Zin 1989, Weil 1989). Using a certainty equivalent transformation, the value function J_t is given by:

$$J_t(X_t^R, IRA_t, G_t, D_t, s_t)$$

$$= \max_{C_t, S_t, B_t, A_t, W_{LS}} \left\{ \left(\frac{C_t}{\Pi_t}\right)^{1-\frac{1}{\psi}} + \beta \left[\left[\mathbb{E}_t\left[p_t J_{t+1}^{1-\gamma}\right]\right]^{\frac{1}{1-\gamma}} \right]^{1-\frac{1}{\psi}} \right\}^{\frac{1}{1-\frac{1}{\psi}}}. \quad (1)$$

In the base case, we set the elasticity of intertemporal substitution $\psi = \frac{1}{\gamma}$ such that the function collapses to CRRA utility. In sensitivity analysis, we also extend the utility function to include

[11] Our model is solved in a nominal world (i.e., all income figures, tax allowances, etc., grow at the rate of inflation) and the effect of inflation in the intertemporal tradeoff between consuming now and in the future is considered by optimizing real consumption. Results shown below are restated in real terms.

loss-averse preferences (Section 5.2), as in Barberis and Huang (2009). The subjective one-period discount factor is denoted β and the conditional survival probability from period t to period $t+1$ is p_t. Survival probabilities are taken from the population mortality table provided by the German Federal Statistical Office.

The value function J_t depends on current realizations of the state variables: these comprise cash on hand, X_t^R (in real terms); the value of the Riester account, IRA_t; the guaranteed amount (i.e., the sum of contributions and subsidies), G_t; the annual payout of the deferred annuity after age 85, D_t; and the labor/retirement income states, s_t. Expected lifetime utility is maximized by solving the recursive Bellman equation with respect to real consumption, C_t, stock investment, S_t, bond investment, B_t, the IRA contribution, A_t, and lump sum withdrawals W_{LS} from IRAs. Presuming the common short-sale and borrowing constraints implies non-negativity of all control variables, such that:

$$C_t, S_t, B_t, A_t, W_{LS} \geq 0\,. \tag{2}$$

With up to five state variables (excluding time t), this model is computationally expensive to solve. To mitigate the curse of dimensionality, we discretize the labor income process to n_s age-dependent levels, yielding a considerable reduction in execution time. Transitions between discretized income states are governed by a Markov chain, where $q_{s_t,s_{t+1}}$ denotes the probability of migrating from a current income state s_t to a subsequent period's state s_{t+1}. Consequently, the expectation of the value function $\mathbb{E}_t[J_{t+1}(\cdot)]$ is the probability-weighted average of future value functions given today's income state s_t and transition probabilities $q_{s_t,s_{t+1}}$:

$$\mathbb{E}_t[J_{t+1}(\cdot)] = \sum_s q_{s_t,s}\mathbb{E}_t[J_{t+1}(X_{t+1}^R, IRA_{t+1}, G_{t+1}, D_{t+1}, s_{t+1} = s)]\,. \tag{3}$$

3.2 Budget Constraints and Evolution of Cash on Hand

Prior to retirement (at $t = K = 43$), financial resources X_t are allocated to consumption, C_t, investment in stocks, S_t, investment in risk-free bonds, B_t, and IRA contributions, A_t. IRA contributions are unbounded, yet exceeding the amount allowed by the government does not further reduce tax liabilities or increase subsidies. After retirement, additional IRA contributions are not possible, so the budget constraint is:

$$X_t = \begin{cases} C_t + S_t + B_t + A_t & \text{for } t < K \\ C_t + S_t + B_t & \text{for } t \geq K\,. \end{cases} \tag{4}$$

Next period's cash on hand before, at, and in retirement (after $t = K$) evolves as follows:

$$X_{t+1} = \begin{cases} Y_t(1-h_t)(1-c_t^{SST}) + \mathrm{T}_t + S_t R_{t+1} + B_t R_f - CGT_{t+1} & \text{for } t < K \\ (Y_t(1-h_t) + W_{LS})(1-c_t^{SST}) + \mathrm{T}_t + S_t R_{t+1} + B_t R_f - CGT_{t+1} & \text{for } t = K \\ (Y_t(1-h_t) + W_t)(1-c_t^{SST}) + S_t R_{t+1} + B_t R_f - CGT_{t+1} & \text{for } K < t \leq K+17 \\ (Y_t(1-h_t) + D)(1-c_t^{SST}) + S_t R_{t+1} + B_t R_f - CGT_{t+1} & \text{for } t \geq K+18. \end{cases} \tag{5}$$

The first component of X_{t+1} is gross income Y_t, either from work or statutory pension benefits after retirement. Gross income is reduced by federal income taxes and required social security contributions (including unemployment insurance, health benefits, and state pensions), jointly levied as an average deduction rate c_t^{SST}. This formulation reflects the detailed rules and parameters of the German social security system as well as the progressive income tax code (see Online Appendix A for more detail). The average deduction rate is a function of gross income and whether someone is employed (equivalently, if time $t < K = 43$), or retired. We apply the rules and parameters as of 2019 to generate values for c_t^{SST} between 10% for retirees with relatively low pension benefits and 44% for workers with salaries above €150,000. Following Gomes and Michaelides (2005), the resulting net income is further reduced by age-dependent housing costs, h_t, which we estimate from the German Socio-Economic Panel (SOEP).[12] The tax refund T_t results if the deduction of IRA contributions from taxable income is more favorable than the subsidies paid directly into the account.

[12] Additional details are provided in Online Appendix B. Property is the largest component of German household wealth (Deutsche Bundesbank 2023), yet its purchase is generally accompanied by significant debt financing, violating our non-negativity assumption on asset holdings. For this reason, we do not integrate housing decisions in the model and implicitly treat everyone as tenants. Panel A of Online Appendix B reports our estimated rental costs as a percentage of net income.

The next component of cash on hand is the market value of last year's investments in stocks and bonds, including returns earned, $S_t R_{t+1} + B_t R_f$, less taxes on capital gains, CGT_{t+1}. R_{t+1} is the gross return on stocks which is assumed to be log-normally distributed, and R_f is the risk-free return on bonds. Investment income from stocks and bonds is tax-exempt up to an annual limit of €801; over this amount, a rate of 26.375% applies. After retirement, cash on hand includes lump sum withdrawals W_{LS} (at age 67), withdrawals W_t (from age 68 until 84) and constant nominal annuity payouts D from the IRA (from age 85 onward), reduced by income taxes and contributions to health and nursing care insurance.

In addition, each individual is posited to start the worklife with a given level of initial wealth, which we assume coincides with the worker's first simulated income level. Levels of starting wealth are estimated from PHF for individuals age 23–27.[13] In calibrating capital market parameters, we use post-German reunification data from June 1991 to December 2015; all calculations are carried out on a monthly basis and then annualized. All-item consumer prices are taken from Datastream and interest rate data refer to 1-year German government zerobonds taken from Deutsche Bundesbank. As a proxy for the equity market, we obtain euro-denominated MSCI World total return data from Datastream, reflecting the global investment focus of fund shares accumulated in Riester accounts.

For the 'base case' below, we use sample means for all variables reflecting what had traditionally been seen as a 'normal' capital market environment. Specifically, the annual inflation rate π is set to 1.75%, close to the European Central Bank's (2024) inflation target of '2% inflation over the medium term.'[14] Mean nominal returns on government bonds i_f are set at 3%. The equity risk premium of the stock index is 5.68% with a volatility of 15.96%. Both

[13] The values of starting wealth are {€0; €150; €620; €1,600; €2,560; €3,620; €7,160; €12,600; €19,500; €47,300}.
[14] Modeling stochastic inflation rates is computationally costly, which is why we choose a deterministic approach. Evidence supports this assumption: the volatility of German inflation rates from 1991–2020 was below 1% p.a.

estimates are consistent with international and German historical risk premiums, as documented by Jordà et al. (2019).

3.3 Labor Earnings and Retirement Income

To model labor income, most life cycle studies adapt the methodology of Carroll and Samwick (1997), where earnings are a function of a deterministic trend component as well as permanent and transitory shocks (e.g., Cocco et al. 2005, Fagereng et al. 2017). By contrast, Fehr and Habermann (2008) discretized the labor income process to six levels, with the transition path between the levels governed by a Markov transition matrix. In what follows, we combine both approaches, such that employees can migrate across $n_s = 10$ income levels $f_{t,s}$ ($s = 1, \ldots, 10$); we also add a transitory shock distributed as $\ln(U_{t,s}) \sim N(-0.5\sigma_{\mathrm{u,s}}^2, \sigma_{\mathrm{u,s}}^2)$. We assume labor income innovations are uncorrelated with stock returns. This approach retains the essence of Carroll and Samwick's (1997) method while being computationally less burdensome. Consequently, during the worklife ($t < K$), labor income Y_t is the product of the age and state-dependent income level $f_{t,s}$ and the transitory shock $U_{t,s}$ such that:

$$Y_{t,s} = f_{t,s} U_{t,s}. \qquad (6)$$

We calibrate the labor income process based on SOEP data.[15] After retirement at age 67, individuals in our model receive constant (real) lifelong benefits from the statutory pension system. These benefits are based on individual labor earnings (up to a ceiling) relative to the population average labor income each year during the worklife. Given 2019 values for the contribution ceiling (of €80,400) and mean income (of €39,301), an annual maximum of $\frac{80{,}400}{39{,}301} = 2.0457$ pension points can be earned. The sum of pension points earned is then multiplied by a 'pension value factor' (of €390.5) to determine annual pension income.[16]

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[15] For details on the estimation and results see Online Appendix C.

[16] We use the same number of n_s retirement income levels as for labor income, but once the pension state has been set, it remains indefinitely. Numerical values of each level's mean pension points and benefits (and boundaries between levels) are derived by simulating the income process prior to the optimization. The resulting (real) pension

3.4 Structure of the Riester IRA

During the worklife, the employee decides on how much to contribute each period to the IRA, A_t. In addition, the government contributes an amount b_t that includes the basic subsidy of up to €175, plus subsidies of up to €300 per child. We treat the number of children as deterministic and estimate the count of dependents using SOEP data.[17] Two requirements must be fulfilled to receive the maximum possible government contribution subsidy of $b^{max} = 175 + 300 \cdot n_{children}$. First, the worker must pay in at least €60 of own contributions to receive any IRA subsidy at all (i.e., $A_t \geq 60$). Second, the sum of the worker's own contribution A_t plus the government's subsidy b_t must equal the lesser of 4% of last year's annual gross income Y_{t-1} or €2,100 (formally, $A_t + b_t \geq \min(0.04 \cdot Y_{t-1}, 2100)$). Lower IRA contributions proportionally reduce the subsidies. Consequently, the fraction ($0 \leq \alpha_t \leq 1$) of the maximum attainable subsidy granted is given by ($A_t \geq 60$):

$$\alpha_t = \min\left(\frac{A_t}{\min(0.04 \cdot Y_{t-1}, 2100) - b^{max}}, 1\right) \tag{7}$$

and the resulting subsidy paid into the IRA is $b_t = \alpha_t \cdot b^{max}$.

During the worklife, we assume IRA assets are fully invested in stocks, and the product provider purchases at-the-money put options to hedge the money-back guarantee. Put premiums P_t, directly charged from contributions, are determined using the Black and Scholes (1973) formula. In addition, front-end loads may be paid out of contributions, but in our base case analysis, we set fees ζ to 0%. Consistent with Gomes et al. (2009), our model rules out the possibility of withdrawals from the IRA before retirement, due to high penalties which render this option unattractive.[18]

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benefits for the n_s levels are then {€9,427; €11,250; €12,574; €13,728; €14,819; €15,968; €17,202; €18,635; €20,419; €23,449}.

[17] Receipt of Riester child subsidies is contingent on entitlement to governmental child-care allowances, not reported in the SOEP. Instead, we use the number of children living with parents as a proxy. Panel B of Online Appendix B reports our estimated numbers of children by age.

[18] Early withdrawals of any amount trigger an immediate repayment of all granted subsidies and tax allowances. Given the average government grant of 38.2% per contribution (BMF 2019), we assume that early withdrawals are largely unattractive (as especially liquidity constrained low earners receive the highest grant rates).

IRA contributions cease at the age of 66 ($t = K - 1 = 42$). If the plan balance at retirement has fallen below the worker's lifetime sum of contributions and government subsidies, the product provider must top up the account by paying the difference $\Upsilon = \max(\sum_{t=1}^{K-1}(A_t + b_t) - IRA_K, 0)$. Subsequently, the saver may elect to withdraw up to 30% of the IRA value as a lump sum, W_{LS}. Moreover, an assumed share of 20% of the pre-withdrawal balance is spent to purchase a deferred annuity that provides lifelong, nominally-fixed benefits of D from age 85 onward. To price the deferred life annuity, we assume the discount rate corresponds to the assumed bond return; we also apply a population mortality table and add a markup of 12.5% to the respective annuity factor to reflect average loadings in the German private annuity market (Kaschützke and Maurer 2011).[19]

Annual withdrawals of IRA assets from age 68 to 84 are governed by the formula $W_t = \frac{IRA_t}{85 - age_t}$, which implies that an increasing fraction of the remaining balance is withdrawn, and the account is depleted at age 84. The government also requires that benefits during the payout phase may not decrease. Since the provider must make up for shortfalls with its equity capital, the portfolio allocation is shifted to a mix of 20% equities and 80% bonds during the payout phase. Therefore, the evolution of the IRA balance is given by:

$$IRA_t = \begin{cases} IRA_{t-1} \cdot R_t + (A_t + b_t)(1 - \zeta) - P_t & \text{for } t < K \\ (IRA_{t-1} \cdot R_t + \Upsilon) \cdot 0.8 - W_{LS} & \text{for } t = K \\ IRA_{t-1} \cdot (0.2 \cdot R_t + 0.8 \cdot R_f) - W_t & \text{for } K < t \leq K + 17 \\ 0 & \text{for } t > K + 17. \end{cases} \quad (8)$$

3.5 Calibration and Numerical Solution

We use dynamic stochastic programming to recursively solve the individual's optimization problem by backward induction. Derived policies govern how to behave optimally so as to maximize the present value of utility from current and future consumption. During retirement,

Technically, allowing for early withdrawals would require us to also track the sum of subsidies and tax allowances received, which would cost an additional state variable.

[19] The European Union Directive 2004/113/EC provides that men and women must be treated equally when calculating insurance premiums, so we compute annuity prices based on a unisex mortality table.

for all specifications, the model includes four state variables: cash on hand (X_t), the IRA balance (IRA_t), payouts from the deferred annuity (D), and the retirement income state (s). The state space is discretized using a 30(X)×20(IRA)×10(D)×10(s) grid size with equal spacing in the natural logarithm (measured in €1,000) for the three continuous state variables (X, IRA, and D). During the worklife and with the IRA investment guarantee, the state of the deferred annuity is replaced by an equal number of grid points tracking the sum of guaranteed contributions and subsidies (G_t), keeping the number of optimizations per time step at 60,000, the same as in the retirement period. In the absence of a guarantee, this state can be saved which decreases the problem size by a factor of 10. For each grid point, we calculate the optimal policies and value functions $\mathbb{E}_t[J_{t+1}(\cdot)]$ using Gauss-Hermite quadrature integration and cubic spline interpolation. In the subsequent simulation, $100{,}000$ independent life cycles are generated using optimal feedback controls. We select preference parameters such that the model generates average asset holdings consistent with empirical evidence derived from the Deutsche Bundesbank's PHF. Specifically, we assume the discount factor $\beta = 0.93$ and the coefficient of relative risk aversion is $\gamma = 7$, which is in line with evidence reported by Dohmen et al. (2011) using survey and SOEP data for German households.

4 Results for the Base Case

Next, we illustrate the implications of switching from the money-back guaranteed IRA to an otherwise identical retirement account without the guarantee, in two capital market environments. In particular, we show how eliminating the guarantee in the above model alters a utility-maximizing individual's optimal contributions to the IRA during the worklife, IRA payouts during retirement, liquid asset holdings, and consumption over the life cycle.

4.1 Normal Capital Market Environment

Our base case calibration assumes a nominal risk-free rate of 3% and an inflation rate of 1.75%, while the low return scenario posits a 0% interest and inflation rate. These alternatives highlight the protective role of the guarantee as well as its consequences for consumption.

Figure 1 shows how pre-tax earnings, liquid asset holdings (stock and bonds),[20] IRA contributions, balances, and payouts evolve in the base case, along with optimal non-housing consumption[21] for a money-back guarantee IRA (Panel A) versus an IRA without a guarantee (Panel B).[22] In both scenarios, consumption is hump-shaped. Rising consumption during the first decade of the worklife results from the well-known effect of constrained borrowing given rising labor income (Chai et al. 2011). Falling consumption during retirement is mainly driven by the interaction of a relatively low subjective discount factor and rising mortality probabilities that reduce the demand for consumption smoothing. Notably, consumption during the worklife is significantly below pre-tax labor income, mainly due to income taxes, social security contributions, housing costs, and to a lesser extent, savings. For example, at age 50 workers earn, on average, about €41,420. Out of that income, and with the IRA guarantee, they pay a total of €15,360 for social security contributions, income taxes, and capital gains taxes; €8,470 for housing; €16,930 for consumption. Only €660 is devoted to net savings, mostly using tax-qualified IRAs (€1,120), while already dissaving in liquid stocks (–€120) and bonds (–€340).

Figure 1 here

Panel A shows that at age 67 the IRA with a guarantee is reduced by about €36,400, to €69,900. This is because, first, the product provider expends 20% (€20,700) of the account balance to purchase an annuity with benefits being deferred until age 85. Second, the retiree withdraws about €15,700 (or 17.7%) of the IRA balance as a lump sum at that point. This is

[20] Detail on the breakdown of liquid savings is provided in Table F.2 of Online Appendix F.
[21] In the following, we use the terms '*non-housing consumption*' and '*consumption*' interchangeably.
[22] All values are expressed in €2019.

well below the allowed maximum of 30%, enabling the retiree to enjoy higher withdrawals later in life. Of this lump sum payout, about one-third (31%) goes to income taxes, and another 61.5% is used to support consumption. The remaining 7.5% is shifted into non-qualified liquid assets which offer greater flexibility in asset allocation and timing of cash flows than the IRA.

With the guarantee, at age 68, the saver's income consists of €15,800 from the social insurance system, €4,100 from the IRA withdrawal plan, and she sells €6,850 of stocks and bonds. After taxes and social security payments, €4,150 is spent on housing and €17,150 on non-housing consumption. Of these expenses, 45% are covered by public pension benefits, 16% from IRA payouts, and 39% from liquidating stock and bond holdings. In later periods, consumption smoothing allows the individual to reduce the sale of stocks and bonds when expected payouts from the IRA increase. At age 85, her IRA payouts consist only of constant nominal annuity payments. By then, the share of income from the social insurance program has risen to 58%, IRA annuity payouts to 33%, and stock and bond sales only amount to 9%. After age 85, consumption decreases because annuity payouts are devalued by inflation, and liquid assets have fallen to levels inadequate to maintain previous consumption levels (e.g., at age 85 stock and bond sales amount to only €1,500).

For the no guarantee case, we compare consumption, income, and asset holding patterns, depicted in Panel B. While most of the results are similar, the average IRA balance at retirement is about 7.6% higher without the guarantee (€113,300, versus €105,300 with the guarantee). Greater IRA saving results partly from lower liquid savings: by retirement, these are crowded out by about 5.3% (to only €47,100).[23] Additionally, without the guarantee, a higher share of consumption is financed by IRA distributions versus with it (12.1% vs. 11.6% at age 67, 35.5% vs. 33.6% at age 85).

[23] The first two columns of Table 6 summarize the data for the total population and IRAs with (without) money-back guarantee. A breakdown by income classes is provided in Table 3.

Differences in IRA balances can be attributed to paying hedging costs with a money-back guarantee, as well as to differences in contributions across the two scenarios. Figure 2 provides a more detailed picture of optimal IRA contribution patterns over the life cycle, again with and without the guarantee. Panel A shows the share of individuals contributing to the IRA, with results mostly comparable under the two scenarios. Starting from low participation rates around 20%, it gradually rises to about 50% by age 40 and further increases to approximately two-thirds by the early 60s. The lower participation rate by the young is driven by relatively low (but rising) labor incomes and households' need to build up precautionary liquid savings before engaging in illiquid retirement savings. Panel B depicts average IRA contribution rates (including subsidies) as a share of gross income, conditional on participation. Here contribution rates are hump-shaped, rising from 1.0–1.5% in the twenties to peaks of about 5% in the early 50s, falling to 1.2–3.6% after age 60. The model-determined falling contribution rates in later life are because the appeal of tax deferral declines as retirement approaches.[24]

Figure 2 here

Beyond age 60, Panel B shows that participation and contribution rates are systematically higher without the guarantee. Two factors drive this result. First, for the guaranteed IRA, the cost of purchasing put options becomes more relevant with less time to maturity, leading people to optimally reduce contributions as they near retirement. Second, IRA participants without the guarantee who experience unfavorable returns late in their worklives must optimally increase contributions to offset losses. Ultimately, higher guarantee costs change IRA contributions, withdrawals, portfolio allocations, and jointly translate into consumption differences.

For our base calibration, the fan chart in the top panel of Figure 3 depicts path-wise percentage consumption differences without versus with the guarantee, where the IRA with a guarantee is the reference. The turquoise line in the top panel depicts the mean consumption

[24] The hump-shaped contribution pattern generated by our model is largely in line with actual contribution patterns reported by Dolls et al. (2018), though they show contributions peaking around age 45.

difference, whereas the blue surface illustrates the 5th to 95th percentile, with shading being proportional to the distribution mass. The bottom panel reports the share of people having higher consumption in the absence of a guarantee (see Table 7 for comparisons with life cycle funds, discussed in Section 5.1). Overall, mean consumption differences are mostly positive, and the dispersion increases with age. Until age 60, consumption is virtually the same with or without the IRA money-back guarantee. In retirement, higher account balances in the no guarantee case result in larger plan withdrawals and annuity payouts that considerably improve old-age consumption. Importantly, consumption is enhanced most when it is at its lowest levels, and the marginal utility of consumption is highest. Put differently, eliminating the guarantee enhances consumption the most, just when unanticipated spending needs might not be met due to low levels of liquid assets and binding borrowing constraints.

Figure 3 here

The bottom panel of Figure 3 shows that most people would be advantaged if their retirement accounts had no guarantee. At retirement, for instance, two-thirds of all individuals would be better off without the IRA guarantee, and by the end of their lives, this percentage rises to 84.5%. This is because higher withdrawals improve consumption opportunities, and larger annuity payouts supplement social insurance program benefits after liquid assets are depleted. In the top panel, the distribution around the turquoise mean line is fairly symmetric, implying that even those who benefit from the guarantee experience relatively little advantage compared to those without the guarantee. For instance, some of the largest protection offered by the guarantee occurs at age 67, when consumption for the 5th percentile would be 2.6% higher for those with poor capital market experiences. At the same age, those with positive capital market experiences at the 95th percentile could boost their consumption by 3.3%, if the IRA had no guarantee. Until the terminal period, the level of protection provided tends to decrease, while excess consumption from abolishing the guarantee rises. For instance, at age 95, those in the 5th percentile receive 2.0% more consumption with the guarantee. Conversely, those at the 95th percentile expect 8.4% higher consumption if the IRA had no guarantee. Hence, without a guarantee, the upside exceeds the downside in terms of consumption.

Table 3 examines whether the implications of switching to a non-guaranteed IRA differ by income groups. In our base calibration, Panels A to D report consumption, liquid savings, IRA balances, and payouts (in €1,000) for the bottom, middle, and top 10% of lifetime income observations. Panel E quantifies the percent of retiree consumption and housing costs that can be financed by IRA payouts, while Panel F reports the frequency of simulated life cycles where the IRA balance at retirement falls short of the guaranteed amount. The columns labeled '*With*' show average amounts by age groups with a money-back guarantee; the columns labeled '*Without*' report results for the no-guarantee regime. Results are presented as a percentage of the respective guarantee counterfactual.

Table 3 here

A key lesson from Panel A is that average consumption is similar in the early years, but without a guarantee, consumption for all three income groups increases monotonically, rising to an annual 2–3% more for the no-guarantee case over the last 15 years of life. These improvements are largest in percentage terms for the middle income earners who can afford considerable IRA contributions, yet especially the 2% improvement for low income earners is important given the high marginal utility of consumption of low earners. We also find that IRAs without guarantees crowd out liquid savings (see Panel B). The reason is that higher average IRA payouts in retirement permit individuals to draw down liquid savings earlier, because the higher annuity payouts help reduce longevity risk. This reduction in liquid assets is most notable for middle earners, who reduce their liquid savings by 7% during early retirement (age 67 to 84) but increase their IRA balances by a substantial 9%, as displayed in Panel C. By contrast, workers earning the lowest and the highest incomes reduce their liquid assets by only 4% and 3%, respectively. Overall, low earners can still increase their retirement consumption by 1–2% as they boost their IRA balances the most, by 11% in early retirement. The increase in IRA balances is the lowest for high earners at 5%, a group that may be less sensitive to the IRA's guarantee costs due to their higher income and wealth.

Panel D summarizes IRA payouts mirroring results from prior Panels. For top (middle) earners, non-guaranteed IRA payouts are 4–5% (9%) higher than with guarantees; for low earners, IRA payouts rise by 10–11%. This large improvement for the lowest earners provides only a 1–2% total consumption increase, as their IRA balances and liquid assets are still low.[25] Panel E of Table 3 confirms that adverse capital market returns affect consumption more for higher paid workers. Conversely, lower earners benefit more from not being forced into a guarantee, compared to high earners.

Panel F quantifies the downside risk of switching from a guaranteed to a non-guaranteed IRA regime for each of the three income groups. By construction, for scenarios with money-back guarantees, there is no shortfall risk (defined as having an IRA balance at retirement below the sum of contributions and subsidies). Even without a guarantee, the shortfall probability for high and middle income earners is moderate, at 0.7% and 1.3%, respectively. Yet for low earners, the shortfall probability is much higher, at 5.4%. This difference can be attributed to the fact that low income earners tend to contribute considerably later, around age 56.7 on average, compared to around age 49.8 for high earners and 51.4 for middle earners. Forgoing early contributions implies that the low earners build only a small cushion against adverse capital market developments, and therefore they are more vulnerable to losses later in life. Panel G documents that for top earners switching to a non-guaranteed IRA would yield the same lifetime utility as the status quo even for a 0.4% reduction in cash on hand at age 25, but the benefit is less for middle (0.3%) and low earners (0.2%) due to their lower IRA balances.

Though low earners experience the least additional consumption and are exposed to the greatest increase in shortfall risk without guarantees, Table 4 reveals that the proportion of these

[25] Bonin (2009) and Börsch-Supan et al. (2008) note that low earners may find it unattractive to save in pensions due to high current consumption utility, and tax incentives tend to be weaker for them.

individuals better off without the guarantee is also among the largest. Early in retirement (age 67–84), 69% are better off, and 80% later in retirement (age 85–100). The proportions are even higher for middle earners, at 72% and 84%, respectively. Among the highest earners, 67% (71%) enjoy more consumption between age 67–84 (age 85–100).

Table 4 here

It is also of interest to compare IRA participation rates, which we do in Table 5. Here we see that, for all income and age groups, the share of workers contributing to an IRA is at least on par without a guarantee compared to with a guarantee. Nevertheless, high and middle earners follow a hump-shaped participation pattern over their life cycles, while participation for low earners is low during their early and middle years and rises as they near retirement.

Table 5 here

4.2 Low Return Capital Market Environment

Next, we consider the situation with a fundamentally different capital market scenario, each with an interest rate and inflation rate of zero percent. The results are shown in Table 6, where the first two columns provide (for comparison) the same information as Table 3, but now we present averages for the entire population instead of by income subgroups. Columns 5 through 8 show the corresponding results for the low interest rate environment. Results for life cycle funds (columns 3–4 and 7–8) are discussed below in the sensitivity analysis (Section 5.1).

Columns 5 and 6 of Table 6 show overall results for 0% interest and inflation rates. Here it is clear that the negative implications of the mandatory money-back guarantee are amplified due to the higher costs of providing the guarantee. Table 6 reveals that under the zero interest rate regime, IRA balances (Panel C) and payouts (Panel D) during retirement plummet by around 39–67% for IRAs with a guarantee and by 16–36% for IRAs without a guarantee. By contrast, liquid savings in early (late) retirement increase by 58% (117%) if IRAs have guarantees, and by 29% (47%) if they do not have guarantees (Panel B). Nevertheless, these higher liquid savings are insufficient to fully compensate for lower IRA payouts, hence old-age consumption (Panel A) declines in the low return scenario relative to the historically 'normal' environment: for the guaranteed IRA, consumption in early (late) retirement declines by 7% (19%), but without the guarantee, the decrease is less, at 6% (13%). Importantly, the relative advantage of abolishing the guarantee in terms of old-age consumption rises from 1–2% to 3–10% of retiree consumption, versus the normal capital market scenario, highlighting the negative impact of high IRA guarantee costs in a low interest rate environment.

Table 6 here

In the normal capital market environment, switching to a non-guaranteed IRA would be beneficial for participants, who would be willing to opt out of the guarantee in exchange for a reduction of 0.3% of cash on hand at age 25 (Panel G). In the low return scenario, the percentage is distinctly higher at 0.8% of cash on hand, corroborating the high benefit of eliminating the money-back guarantee in the current capital market environment, while still providing for the same lifetime utility.

Figure 4 provides insights into the heterogeneous changes in contributions and retiree consumption by average annual income, without versus with the guarantee. The horizontal axis shows the average yearly lifetime labor income, while the vertical axis displays the change in IRA contributions (including subsidies, expressed as percentage of lifetime labor income) if the IRA's investment guarantee were eliminated. Each of the 10,000 circles (corresponding to the first 10% of the simulated 100,000 optimal life cycles) indicates how much individuals would gain or lose from abolishing the money-back guarantee. Green (purple) circles depict increases (decreases) in average yearly retirement consumption, and darker color circles reflect larger changes (white circles indicate small or zero changes).

Figure 4 here

For the base case calibration with historical interest and inflation rates, Panel A indicates that most participants (about 69.3%) would boost their contributions without the guarantee. Moreover, the dispersion in contribution changes is wider for middle and high earners versus low earners. Consistent with the bottom Panel of Figure 3, green circles dominate, indicating that most retirees will enjoy greater consumption without the guarantee. Moreover, confirming the evidence in Table 3, those benefitting the most from abolishing the guarantee are mostly found among low and middle earners, who thus also tend to cut back on their contributions. The circle colors also indicate that those who neither gain nor lose from the IRA guarantee in terms of consumption still tend to decrease their contributions slightly if the IRA guarantee were abolished. Importantly, eliminating the guarantee permits these workers to increase liquid savings or consumption during their worklife.

Panel B of Figure 4 emphasizes that, in the low return environment, the impact of the IRA guarantee on consumption becomes more nuanced, with two offsetting impacts. On the one hand, retiree consumption rises the most without the guarantee – by an average of 5.9% – indicated by dark green circles which clearly outnumber the dark purple circles. On the other hand, the number of participants enjoying significant protection from a guarantee also rises when a low return environment prevails.

Several important differences should be noted in the low return environment. In particular, those who benefit greatly from abolishing the guarantee (dark green circles) tend to cut their lifetime contributions since they achieve desired IRA balances with lower contributions. Among low income earners, consumption improvements are either small or significantly positive, with cases of inferior consumption being rare. At the top of the income distribution, there is notably more heterogeneity in consumption changes, and we observe distinctly more cases of significantly lower consumption without the guarantee. As shown in Table 3, the relative importance of IRA savings to fund old-age consumption for wealthier individuals exceeds that of the less wealthy. Consequently, without the IRA money-back guarantee, the wealthy become more vulnerable to negative capital market experiences late in the worklife, compared to their less wealthy counterparts. The cluster of high earners having large consumption losses and making higher contributions (top right of Panel B) are those who experienced large IRA losses in the decade prior to retirement. To regain IRA wealth sufficient to support old-age consumption, their contributions in the last working period rise sharply.

Overall, this section has shown that eliminating the IRA guarantee enhances average consumption opportunities for savers, because the guarantee costs outweigh the benefits of downside protection. Moreover, people save more in their non-guaranteed IRAs compared to the guaranteed case. This conclusion is sharpened in a low return/inflation scenario, though more people will suffer losses when not covered by the IRA guarantee. Since significant losses can occur for savers without a guarantee, this raises the question as to whether a life cycle investment strategy such as a target date fund might provide an attractive alternative.

5 Robustness Checks

Having investigated the economic implications of a money-back IRA guarantee on household behavior, we next provide robustness tests. We start by showing that a life cycle or target date strategy with insufficient equity exposure could be even less attractive than a money-back IRA guarantee. Then we relax the assumption that participants of equity-oriented IRAs have standard preferences, and instead allow them to exhibit loss aversion. In the normal capital market scenario, shunning equities in absence of a guaranteed IRA adversely affects capital accumulation, leading to lower old-age consumption than with a guarantee. Importantly, in an environment with low interest rates, the trade-off between costly guarantees and higher returns without a guarantee still leads to superior wealth accumulation and higher mean consumption in absence of a guarantee, despite participant loss aversion. Finally, even for a scenario when an equity market crash happens during the last working period, plans without a guarantee perform surprisingly well.[26]

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[26] In the Online Appendix we provide further robustness tests. Online Appendix D shows results to Epstein-Zin-Weil preferences (for $\psi \neq 1/\gamma$), and to the inclusion of front-end loads on contributions. Online Appendix F extends the analyses on loss aversion for life cycle funds. Online Appendix G presents an alternative mechanism to hedge the risks associated with the money-back guarantee as well as the implications for plan participants. Online Appendix H changes the assumption on equity market parameters. Online Appendix I shows that the conclusions are not a result of uniquely German circumstances.

5.1 Life Cycle Target Date Funds

Some might argue that life cycle or target date funds could constitute a viable alternative to money-back guarantees as a risk mitigation technique. This type of investment approach follows an age-based allocation rule, starting with higher equity shares early in life, and gradually rebalancing along a glide path to less risky securities (such as bonds) near and through retirement (Vanguard 2017). In the U.S., much of the assets invested in 401(k) defined contribution retirement plans is automatically defaulted into target date investment strategies.[27] The regulatory environment for the European Union's *Basic PEPP* also permits providers to use a life cycle strategy instead of requiring a money-back guarantee, under the presumption that it is 'consistent with the objective of allowing the PEPP saver to recoup the capital' (see EU 2019/1238 (54) and Art. 46).

While there are many variants of life cycle strategies in the market, two general approaches are common.[28] One starts investors at a relatively high equity exposure and reduces this share annually using a moderate adjustment factor. For example, Malkiel (1996) postulates that the percentage of IRA assets invested in equities should follow a '*100 minus age*' rule. A second, more risk-tolerant approach retains a high equity exposure during much of the accumulation period but imposes a stronger de-risking pattern near retirement. This is largely consistent with the common practice in U.S. target date funds, where equity shares remain flat until about age 40 and then decrease almost linearly to about 30–40% before retirement (van Bilsen et al. 2020). Berardi et al. (2018) investigate a glide path, reducing a 100% equity exposure from age 55 onwards by 5% per year until retirement (hereafter referred to as the '*100-until-54, –5*' rule).

Using a simulation approach, Berardi et al. (2018) study a range of different glide path approaches, finding that the value of contributions can be preserved with over 99% probability

[27] The U.S. legislative framework has encouraged this practice, with the 2006 Pension Protection Act permitting plan sponsors to include target date funds as 'qualified default investment alternatives.'

[28] For an overview, see Poterba et al. (2009), Berardi and Tebaldi (2024), and Berardi et al. (2018).

given an intermediate investment horizon of 40 years; with a 95% probability, the final account balance is likely to be worth at least 1.8 times the sum of contributions. While these results suggest that derisking along pre-defined glide paths is appealing from a shortfall perspective, it has not yet been demonstrated whether such an approach would be preferable to a money-back guarantee in terms of consumption. Accordingly, we extend our analyses by introducing the two life cycle approaches sketched above, giving workers access to IRAs with more moderate risk exposures than those analyzed in Section 4. The remainder of the assets is invested in bonds. To maintain consistency with the previous setup, we assume the IRA switches to a 20% equity exposure after retirement. Results are presented in Tables 6 and 7.

Table 7 here

For the 3% nominal interest case, Panel A of Table 6 depicts old-age consumption when the IRA invests in a '*100 minus age*' life cycle fund, which generates 6% less consumption in early retirement and 15% less in later retirement, compared to the guarantee case. Panel A of Table 7 indicates that, during retirement, at least 80% of plan participants can consume more if they have a guaranteed IRA, versus the more conservative life cycle fund. This is because people accumulate about 40–50% less in their IRAs with the conservative life cycle fund, compared to the guarantee case (Panel C, Table 6).[29] As a result, the share of consumption financed by IRA payouts is also 8.5–12.5 percentage points lower than that resulting from a 100% equity exposure with a money-back guarantee. Panel G shows that switching to the life cycle fund causes a substantial utility loss, offset only if the individual were to receive in return 2.8% more cash on hand at age 25.

This highlights the fact that the conservative life cycle glide path reduces the equity share too quickly during the accumulation phase, so asset accumulation is hampered – even with

[29] Interestingly, the lower IRA balances are not driven by lower contributions: in fact, the sum of contributions is the highest for the '*100 minus age*' life cycle fund case, averaging €28,750, followed by the no guarantee case (€27,250), and the guarantee case last (€26,250).

higher contributions – and less capital can be withdrawn during the payout phase (Panel D, Table 6). This disadvantage can be partly mitigated by the more risk-tolerant life cycle rule (‘*100-until-54, –5*’), but it is not fully eliminated. Early in life, consumption is on par with the guarantee case, while retirement consumption falls by 2–4%. On net, lifetime utility can be preserved when switching to the risk-tolerant life cycle fund, while at the same time increasing cash on hand at age 25 by 0.3%.[30]

Next we explore how results differ in a less propitious capital market environment. As noted above, costs for money-back guarantees become more expensive due to lower interest rates. Moreover, the larger share of bonds in the life cycle strategy produces lower returns. Compared to the IRA guarantee case, expected old-age consumption in Table 6 with the conservative ‘*100 minus age*’ target date fund falls short by only 1–3% (Panel A), and 2.3% more cash on hand at age 25 would be required to achieve the same lifetime utility as with the guarantee (Panel G). The share of consumption (including housing) financed by IRA payouts is only about 2–3 percentage points lower with the life cycle fund (Panel E, Table 6). Panel B of Table 7 shows that only 26–28% of retirees anticipate consuming more in retirement with the life cycle fund, yet the shortfall probability (Panel F, Table 6) increases to 13.8%.

By contrast, in the zero interest rate scenario, the ‘*100-until-54, –5*’ fund holding 100% equity until age 54, can partly overcome the burden of the subsequent de-risking along the glide path. Compared to the money-back IRA, this more aggressive life cycle approach provides up to 4% more old-age consumption (Panel A, Table 6), and participants would require a smaller addition of 0.2% of cash on hand at age 25 to achieve the same lifetime utility with the life cycle fund as with the guaranteed IRA (Panel G, Table 6). Moreover, 63–71% of retirees can

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[30] Panel F of Table 6 confirms Berardi et al.’s (2018) finding that, in a normal capital market scenario, shortfalls are rare when the IRA is invested in a life cycle fund, occurring in only 0.2% (0.5%) of the cases for the ‘*100 minus age*’ rule (‘*100-until-54, –5*’ rule), versus the 2.0% shortfall probability without a guarantee. Yet Berardi et al. (2018) have a money-weighted timing of contributions in the middle of the accumulation phase, while in our case it is 5.5 years later (after 26.5 years); ours provides less time for compounding. Moreover, around half of their bond investments consist of credit-risky bonds, enabling their portfolios to benefit from a risk premium.

expect to consume more (Panel B, Table 7), and the share of expenditures in old-age financed by IRA payouts increases by 3.0–4.5 percentage points (Panel E, Table 6). Nevertheless, the shortfall probability is high, at 8.3%, a value inconsistent with the EU regulatory objective of 'recouping the capital' of the PEPP saver.

5.2 Loss Aversion

In Section 2.3, we documented that financially risk-intolerant workers dislike equity-oriented IRAs even when the accounts embed guarantees; instead, they prefer fixed income-oriented IRAs or non-participation. Conversely, risk-tolerant consumers' choices are unrelated to the choice of IRA type. Accordingly, we concluded that people self-selecting into equity-oriented plans can be modeled using standard CRRA preferences. This section now extends the model to allow savers to exhibit financial loss aversion additional above and beyond the usual aversion to consumption fluctuations.

In the life cycle literature, financial loss aversion is commonly modeled using a period-by-period time horizon (Barberis et al. 2001, Barberis and Huang 2009). In the present case, however, this conflicts with the essence of the IRA money-back guarantee that compensates consumers for financial losses realized only at the end of the accumulation phase. In the context of our model, for the money-back guarantee IRA, potential losses on equities are considered during the accumulation phase only if the IRA balance exceeds the guarantee amount. Without the guarantee and for life cycle funds, the entire loss is penalized. Losses in liquid stocks are generally subject to penalties, and in retirement, when no other guarantees exist, IRA losses are penalized for all plan designs. Formally, and following Barberis et al. (2001), Barberis and Huang (2009), and Ebner et al. (2022), we describe the period-by-period amount of gains and losses resulting from stock investments held in- and outside the IRA with the variable Γ_{t+1}, which affects utility through $v(\Gamma_{t+1})$ only if returns are negative:[31]

[31] Online Appendix E presents the calculation of Γ_{t+1} for all plan designs in detail.

$$v(\Gamma_{t+1}) = \begin{cases} 0 & \text{if } R_{t+1} \geq 1 \\ \Gamma_{t+1} & \text{if } \mathrm{R}_{t+1} < 1\,. \end{cases} \tag{9}$$

The expectation of $v(\Gamma_{t+1})$ enters the value function from Eq. (1), such that:

$$J_t(X_t^R, IRA_t, G_t, D_t, s_t)$$

$$= \max_{C_t, S_t, B_t, A_t, W_{LS}} \left\{ \left(\frac{C_t}{\Pi_t}\right)^{1-\frac{1}{\psi}} + \beta \left[\left[\mathbb{E}_t\left[p_t J_{t+1}^{1-\gamma}\right] \right]^{\frac{1}{1-\gamma}} + p_t \Lambda \mathbb{E}_t[v(\Gamma_{t+1})] \right]^{1-\frac{1}{\psi}} \right\}^{\frac{1}{1-\frac{1}{\psi}}}. \tag{10}$$

Compared to Eq. (1), the added term represents the extra disutility from expected losses in the stock market, with the parameter $\Lambda > 0$ indicating the strength of this component of the utility function relative to that from consumption.[32] For comparability with the previous results, we choose the same parameters for relative risk aversion $\gamma = \frac{1}{\psi} = 7$ and the time discount factor $\beta = 0.93$. The loss framing parameter is set to $\Lambda = 0.006$, which aligns with empirical studies on loss aversion (see Abdellaoui et al. 2007 and Dimmock and Kouwenberg 2010). Next, using these preferences and our other initial parameterizations we solve the life cycle model. Table 8 reports the life cycle patterns for financially loss-averse participants.

Table 8 here

Compared to standard preferences in a normal interest rate and inflation scenario (Table 6), loss-averse individuals increase their IRA holdings (by 1% in the second part of the worklife and by 5% in early retirement) because they value the protection offered by the money-back guarantee. At the same time, they adjust liquid asset holdings (by +2% in late worklife and by –10% in early retirement), reflecting a reduction in the equity allocation to mitigate the impact of losses on utility. Overall, the more cautious investment behavior of the loss-averse results in

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[32] This differs from Barberis and Huang (2009) who consider both, expected gains and losses in the utility function $\mathbb{E}_t[v(\Gamma_{t+1})] = b_0 \mathbb{E}_t[\max(\Gamma_{t+1}, 0) + \lambda \min(\Gamma_{t+1}, 0)]$; hence they use two parameters, a narrow framing b_0 and a loss aversion coefficient λ, to capture loss-averse preferences. Here we follow Ebner et al. (2022) who include only expected losses $\mathbb{E}_t[v(\Gamma_{t+1})] = \Lambda \mathbb{E}_t[\min(\Gamma_{t+1}, 0)]$ and derive for lognormally distributed returns an analytical formula how the loss framing parameter Λ is directly related to the Barberis and Huang (2009) two-parameter (b_0, λ)-approach. For our parameters on stock returns $\Lambda = 0.006$ corresponds to $\lambda = 4.21$ and $b_0 = 0.7$.

moderately lower old-age consumption (by at most 0.5%) than for those with standard preferences. In a low interest rate scenario, the shifts from liquid assets (-10% in worklife and -15% in early retirement) to IRAs (around +28%) by loss-averse households relative to CRRA savers are even more pronounced, but the impact on old-age consumption remains small ($\pm$1%).

Eliminating the money-back guarantee in the normal interest rate scenario significantly reduces IRA holdings for the financially loss-averse (by 25% in late worklife and 18% in early retirement), increases their holdings of liquid assets (by 23% in late worklife and 7% in early retirement), further reduces their already low liquid stock share (by about 15–20%, see Online Appendix F.2), and produces 3–8% lower consumption in old age. Yet the utility impact is moderate: the loss-averse would demand 0.2% more cash on hand at age 25 to give up the guarantee, whereas those with standard preferences would even be willing to give up 0.3% of their cash to abandon the guarantee. In summary, in the normal interest rate scenario, for financially loss-averse savers the attractiveness of the money-back guarantee in IRAs increases – as opposed to CRRA savers.

This changes in the low interest rate scenario. Removing the guarantee for the loss-averse increases IRA holdings relative to the guarantee case by about two-thirds, highlighting that high guarantee costs reduce the benefits of downside protection. As with CRRA savers, eliminating the guarantee enhances lifetime utility for loss-averse households. Consumption in retirement is higher than with the guarantee (by 2–5%), and loss-averse investors would be willing to give up 0.1% of their age-25 cash-on-hand to opt out of the guarantee.[33]

In summary, the guarantee is conceptually appealing to financially loss-averse workers because it provides downside protection for risky stock investments, yet its costs offset this advantage. Because the money-back guarantee only protects against losses below the guarantee

[33] In an extension reported in Online Appendix F, we also compare outcomes for loss-averse individuals under the IRA guarantee with those for the same life cycle funds examined above. We show that, in a normal return world, the financially loss-averse prefer the IRA guarantee over both life cycle funds. Specifically, IRA balances fall, payouts from IRAs decrease, and lifetime utility can only be maintained if the cash endowment at age 25 is raised by 1.8% for the conservative life cycle fund and by 0.2% for the risk-tolerant life cycle fund.

amount and leaves balances above that amount unprotected, its costs may be too high to make the money-back guarantee worthwhile, even to loss-averse savers.

5.3 Resilience to Capital Market Crashes

Policymakers intended that IRA guarantees would provide savers with downside protection against adverse capital market developments. However, as we have shown, this comes at the cost of lower average payouts. Indeed, our results show that guarantees erode consumption, and downside protection appears surprisingly small. Nevertheless, since savers choosing guaranteed IRAs seem to value the promised protection, we next quantify how well such IRAs might perform if a severe shock were to hit the equity market at the end of the accumulation phase. Specifically, we examine a scenario where the equity market unexpectedly plummets by 35% immediately before retirement. This roughly corresponds to the drop in the German stock market index after the outbreak of the Coronavirus in early 2020, the first European market crash during zero/negative nominal interest rates. This also corresponds to the 3.9th percentile of the distribution of 12-month rolling returns from 06/1990 until 06/2024.

The histograms in Figure 5 display the *distance to guarantee payoff* for the money-back IRA, compared to alternative risk mitigation techniques. This metric quantifies how big the equity return in the last working period would need to be, such that at retirement, the IRA balance exactly matched the sum of contributions and subsidies (the *guarantee amount*).

Figure 5 here

For the low interest rate scenario, in the left Panel, the light (dark) bars show the frequency distribution of the distance to the guaranteed payoff, for an IRA with (without) a money-back guarantee. This is measured one year from retirement, in all cases. The vertical line splits the data into accounts in surplus above the guaranteed amount (left of the line), and those in deficit (right of the line). With the guarantee, 32.1% of the IRA balances fall short one year before retirement, whereas without the guarantee, only 12.4% of the accounts are in shortfall. Meanwhile, in the no-guarantee scenario, the probability mass is much more concentrated in the left tail, where accounts deep in surplus are found. These have accumulated large cushions over the guarantee amount, allowing them to withstand even unusually large equity market crashes before balances fall below the guarantee. Significantly smaller cushions are evident for the money-back guaranteed IRA, attributed to the costs of providing the guarantee (see Panel A of Table 1). These expenses constitute a drag on investable capital, making it much more likely that a guarantee will eventually pay off.

The fan charts in Figure 5 illustrate path-wise consumption differences between the guaranteed IRA versus alternative risk mitigation strategies, when the equity market unexpectedly drops by 35% the year before retirement.[34] The right side of Panel A compares consumption and welfare under the no-guarantee IRA versus with the guarantee. Even after such a severe equity market crash, average retiree consumption without the guarantee would be about 1–8% higher, and 53–85% of the savers could consume more. Naturally, this comes at the cost of tolerating inferior downside measures for part of the return distribution. Yet even the least fortunate 5% quantile of the distribution would not experience disastrous consumption losses (though losing 3–6% of retiree consumption is still considerable). Still, it may be surprising that a guarantee does not strictly dominate, even in this rare market crash scenario,

Panels B and C evaluate life cycle funds as an alternative risk mitigation technique to money-back guarantees. Panel B implements the '*100 minus age*' rule, while Panel C implements the more risk-tolerant '*100-until-54, –5*' rule. One year before retirement, de-risking along the glide paths leaves the life cycle IRAs with equity exposures of only 34% and 40%, respectively. As a consequence, 12% of conservative and 46% of risk-tolerant life cycle strategies could withstand almost 100% equity market losses without their balances falling below the sum of contributions and subsidies, with the risk-tolerant strategies further benefiting

[34] Here, we focus only on losses during the last work period, because there is no chance that the balance can recover before the money-back guarantee is tested. Losses occurring at other times during the accumulation phase are less of a concern as the test is applied only at age 67.

from superior IRA balances. It is worth noting, however, that the distributions are more evenly arrayed along the horizontal axis than in Panel A. Accordingly, a year before retirement, the share of accounts with balances below the guarantee amount is larger for the life cycle funds (35.2% in Panel B and 15.6% in Panel C) than for the no-guarantee IRA, with the early shift to bonds leading to even more such cases than for the guaranteed IRA.

There are several reasons why life cycle funds can fall below the threshold. First, the accounts experience both surpluses and deficits along the glide path. Second, bond investments do not help build a cushion above the guarantee amount when the nominal interest rate is 0%. In line with this, in an extremely negative capital market scenario, the fan charts reveal that the no-guarantee IRA yields superior average consumption compared to the life cycle funds, while the downside is not distinctly worse. Importantly, between the two life cycle funds, the more risk-tolerant allocation (Panel C) performs better on consumption and downside risk, as it allows the individual to retain a higher participation in the equity market.

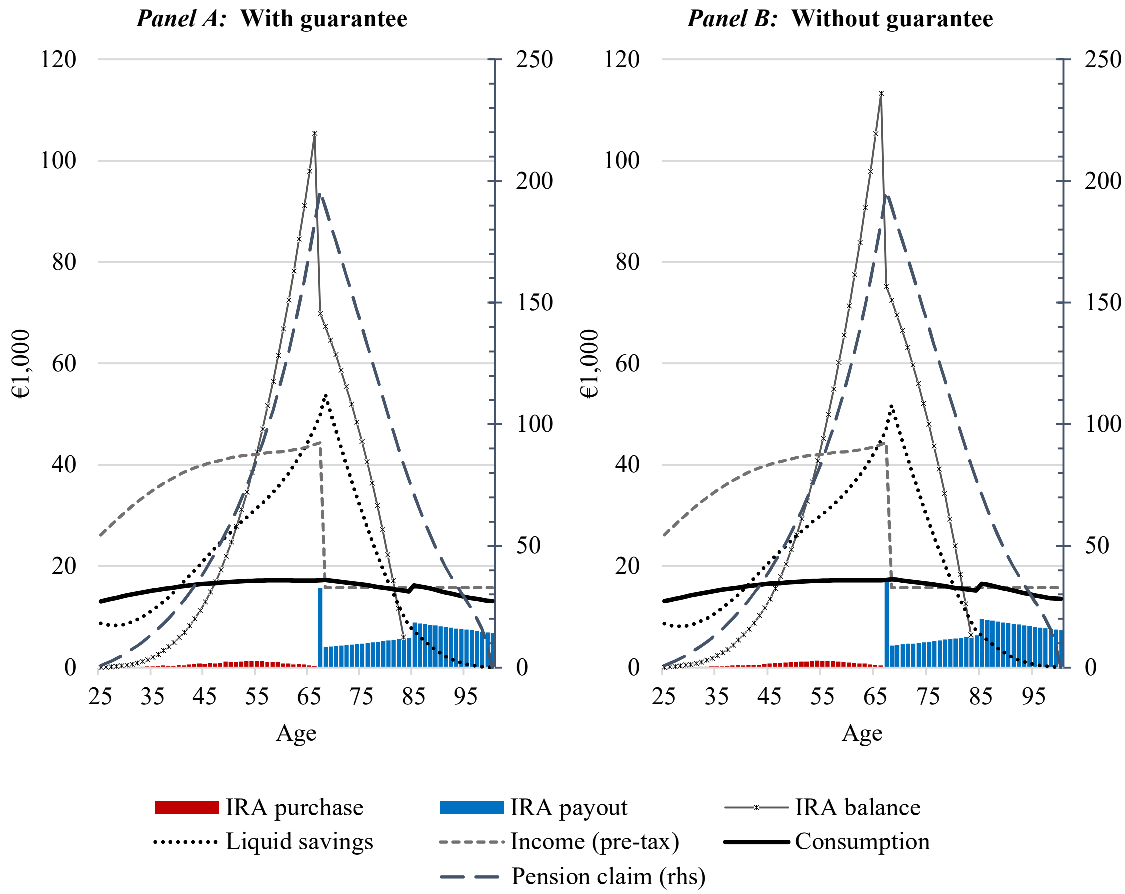
6 Conclusions

This study illustrates how money-back guarantees in individual retirement accounts alter lifetime consumption opportunities and portfolio decisions, when individuals who maximize their utility over lifetime consumption have access to stocks, bonds, and IRAs. In addition, we consider how loss-averse investors evaluate mandated guarantees similar to those embedded in the German Riester plans. We show that eliminating money-back protection can enhance old-age consumption for many retirees, because removing the guarantee saves the cost of providing it, allowing that money to be invested for the benefit of the saver. In a 'normal' capital market environment, such a guarantee could reasonably have been seen as an effective way to protect workers from investment losses in their IRAs. Yet if interest rates again become zero as they were over the past decade, these guarantee costs can cause unintended harm by eroding old-age consumption below what it would be otherwise. Moreover, even if the stock market were to crash right before retirement, most people would be better off without the guarantee.

Life cycle funds with sufficient equity exposure can be considered an alternative risk mitigation strategy; for instance, the Pan-European Personal Pension Product includes such a strategy as a suggested investment default. Our results show that in a normal capital market environment, both life cycle funds we examine yield distinctly lower consumption in retirement than with a money-back guarantee. In a low interest rate environment, the life cycle funds do better: consumption remains lower for the '*100 minus age*' fund but it is superior for the more risk-tolerant '*100-until-54, –5*' fund.

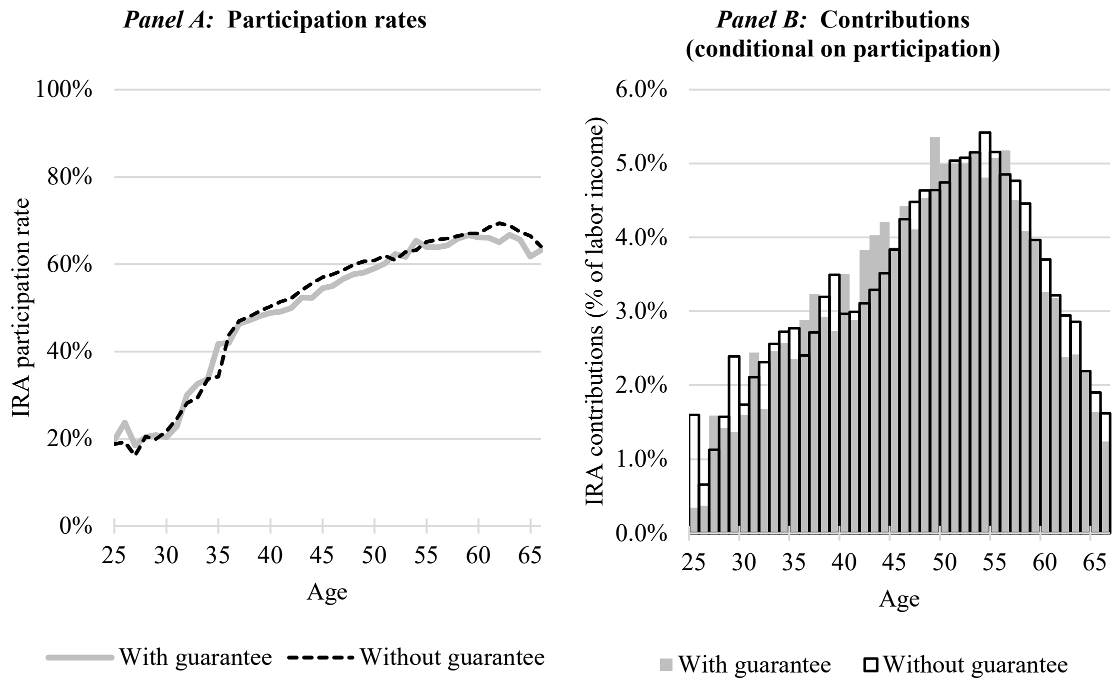
Our findings are relevant to policymakers, regulators, and plan sponsors globally, insofar as many countries are responding to the challenges of population aging by implementing funded individual retirement accounts. These include the U.S. 401(k) approach, the European PEPP, and defined contribution plans in Australia, Hong Kong, and Chile, along with many other countries. Of key importance in such funded pension systems is the appropriate design of default investment options which, on the one hand, protect savers from downside risks, while on the other hand, preserve the opportunity for savers to access equity markets. In particular, regulators will benefit from a clearer understanding of the costs and benefits associated with money-back guarantees, as well as other risk mitigation techniques, such as life cycle funds.

Figure 1: Life Cycle Profiles With and Without IRA Guarantee: Base Case



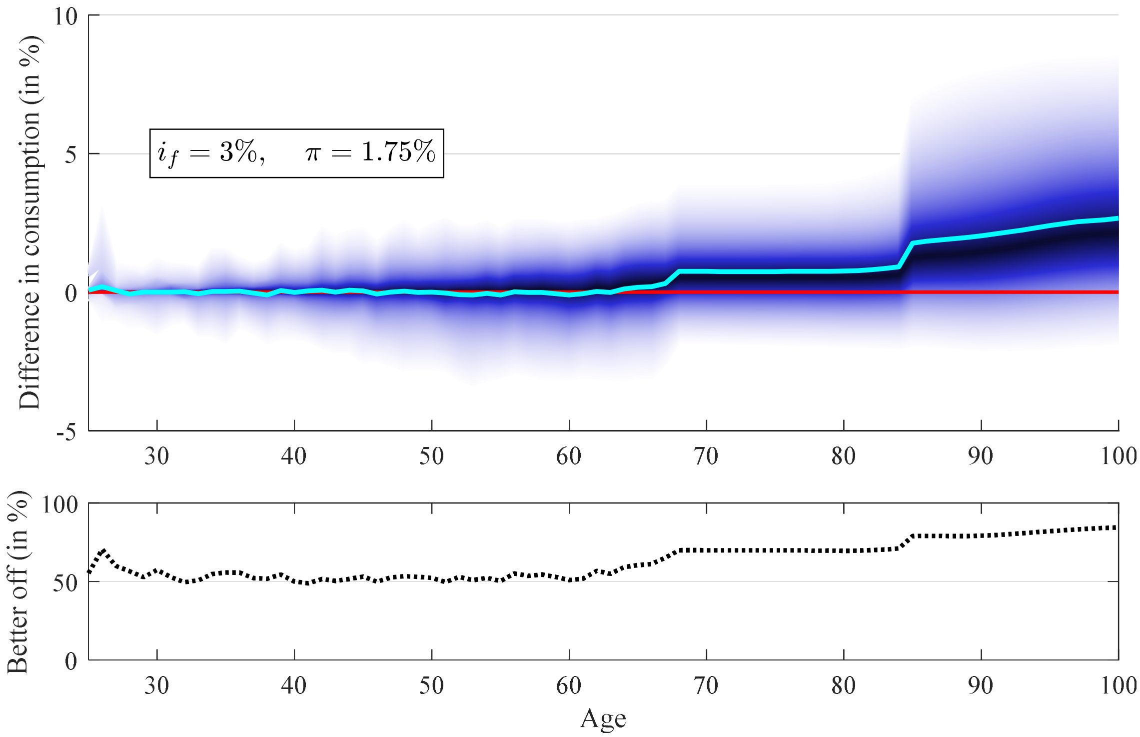
Note: The figure shows mean values of labor and pension income, non-housing consumption, financial assets (bonds, stocks, and IRA balances), and retirement plan payouts (in €2019, left axis). The right axis reports the present value of claims on the government pension system. Panel A refers to the base case, where the nominal risk-free rate is 3% and inflation is 1.75%. Stock investments earn a risk premium of 5.68% with volatility of 15.96%. Preference parameters include a discount factor of $\beta = 0.93$ and relative risk aversion of $\gamma = 7$. Panel B is otherwise identical but without a money-back guarantee in the IRA. Mean values are calculated based on 100,000 simulated life cycles which rely on optimal policies derived for all possible combinations of current income, cash on hand, IRA balances, guarantee amounts, and annuity payouts. Prior to retirement at age 67, the IRA is fully invested in equities, from age 67 to 84 the asset allocation consists of 20% stocks and 80% bonds. From age 85 onward, the plan pays out a lifetime annuity. See Section 3 for details.

Figure 2: IRA Participation Rates and Plan Contributions as a Percent of Gross Labor Income by Age: Base Case



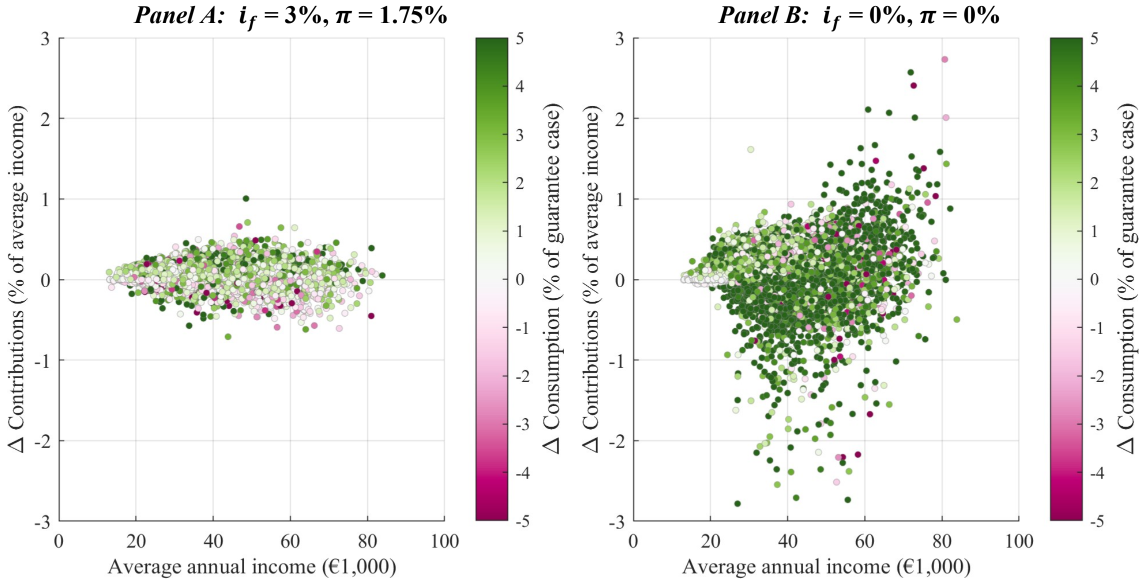
Note: Panel A shows the fraction of individuals making contributions to an IRA by age under the two alternative scenarios. For additional notes on base case parameters, see Figure 1. Panel B illustrates the pattern of average contributions (including subsidies) to IRAs (conditional on participation) as a percent of gross labor income by age, with and without a money-back guarantee. Results are from 100,000 simulated optimal life cycles.

Figure 3: Consumption Differences and Percent Better off by Age Without versus With the IRA Guarantee: Base Case



Note: The fan chart on the top illustrates path-wise differences in non-housing consumption drawn from 100,000 simulated optimal life cycles for IRAs *without* versus *with* a money-back guarantee. The cyan line represents the mean consumption difference, while darker areas indicate a higher probability density (between the 5 and 95% quantiles). Differences are expressed as a percent of optimal consumption with the money-back guarantee. The bottom panel shows the percentage of individuals having greater optimal consumption *without* versus *with* the money-back guarantee. For further notes on base case parameters see Figure 1.

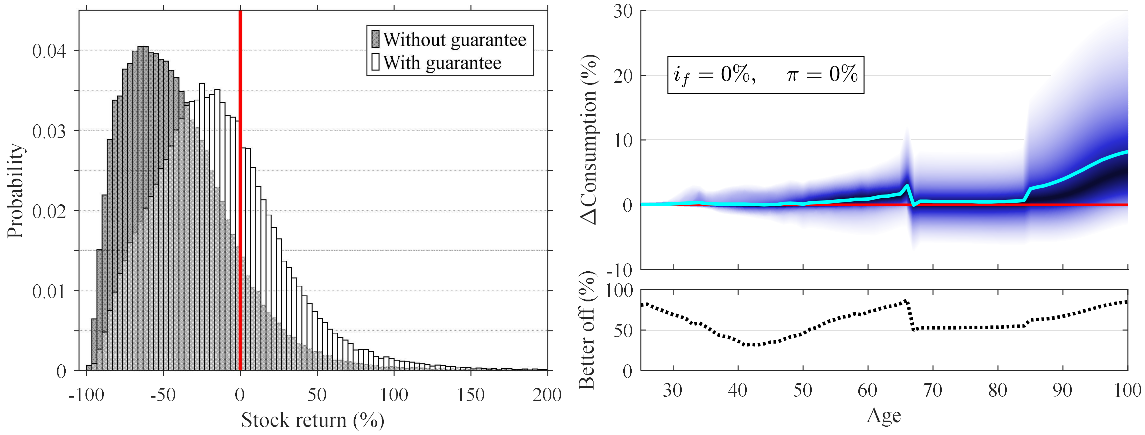
Figure 4: Heterogeneity of Impacts of Abolishing the IRA Guarantee by Lifetime Income: Contributions and Old-Age Consumption



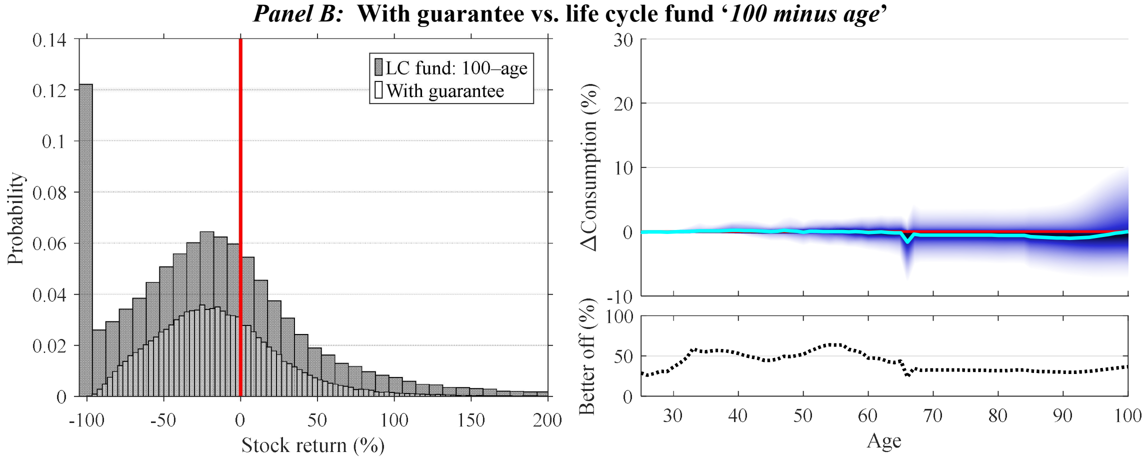
Note: This figure illustrates the effect of abolishing the money-back guarantee on total contributions (including subsidies; in percent of average labor income), and average non-housing consumption during retirement, by average lifetime earnings for a normal (Panel A) and a low (Panel B) interest rate and inflation scenario. Changes in consumption are in percent of the guarantee case. Consumption increases (decreases) are indicated by green (purple) circles, and color intensity is stronger for larger changes (white circles indicate tiny changes). Results are shown for the first 10,000 out of 100,000 simulated optimal life cycles. For additional information see Figure 1.

Figure 5: Impact of an Equity Market Crash on Consumption in the Low Interest Rate Scenario

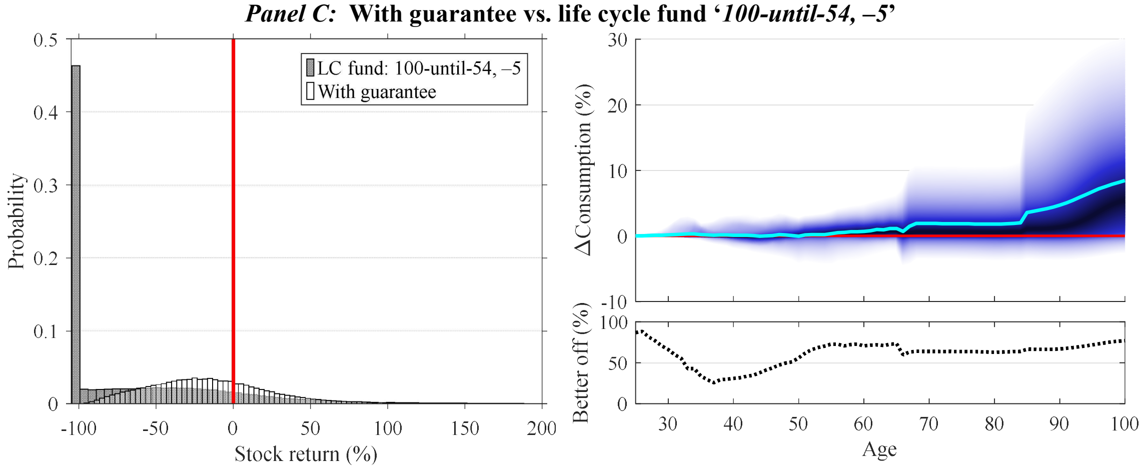
Panel A: **With guarantee vs. without guarantee**



Panel B: **With guarantee vs. life cycle fund '*100 minus age*'**



Panel C: **With guarantee vs. life cycle fund '*100-until-54, –5*'**



Note: The figure shows the performance of various risk mitigation techniques in the low interest scenario. We consider schemes *with* a money-back guarantee and alternatives *without* a guarantee (Panel A), and life cycle funds, which govern the equity share according to a '*100 minus age*' rule (Panel B), and a '*100-until-54, –5*' rule (Panel C). The histograms illustrate the frequency of the *distance to guarantee payoff*, which is the last work period's return that would equate the IRA balance at retirement to the guarantee amount. The fan charts show path-wise differences in consumption given that an unanticipated equity market crash of –35% happens in the period before retirement for IRAs *with* guarantees versus IRAs with alternative risk mitigation techniques. All remaining explanations are analogous to those of Figure 3.

Table 1: Costs and Benefits of IRA Money-back Guarantees for Participants and Providers (as a % of total contributions)

Investment horizon (years)	42	30	20	10
***Panel A:* Guarantee Costs Charged to Participant**				
$i_f = 3\%$	4.6	5.3	5.9	6.3
$i_f = 0\%$	25.7	22.0	18.3	13.4
***Panel B:* Mean Guarantee Payouts to Participant**				
$i_f = 3\%$	0.1	0.3	0.7	1.8
$i_f = 0\%$	4.9	6.0	6.9	7.6
***Panel C:* Mean Profits for Provider (Put Hedge Approach)**				
$i_f = 3\%$	0.7	0.8	0.8	0.3
$i_f = 0\%$	–1.2	–1.7	–2.2	–2.6

Note: Table 1 reports, as a % of total contributions, the costs (Panel A), mean payouts to the IRA participant (Panel B), and mean profits of the product provider resulting from using fairly-priced put options to hedge the money-back guarantee on contributions (Panel C). The example assumes constant annual contributions, and the guarantee is provided at the end of the investment horizon. The product provider buys at-the-money put options maturing at retirement to hedge downside risk for each contribution made. Option pricing follows Black and Scholes (1973) with an assumed equity volatility of 15.96% p.a. and interest rates of 3% and 0%. The simulation relies on 100,000 Monte Carlo paths using the same volatility and an equity risk premium of 5.68%.

Table 2: IRA Participation and Risk Attitudes: Multinomial Logit Regression (Marginal Effects at Means): Evidence from Deutsche Bundesbank PHF

IRA participation	(1) Equity-oriented	(2) Fixed income-oriented	(3) Non-participation
Financial risk tolerance: none	–0.023**	0.016	0.006
	(–2.552)	(1.311)	(0.426)
Financial risk tolerance: above average or considerable	–0.006	–0.027	0.033
	(–0.339)	(–1.098)	(1.091)
Child subsidy eligibility	0.016*	0.028**	–0.044***
	(1.859)	(2.088)	(–2.846)
Trust	0.004**	0.006**	–0.009***
	(1.965)	(1.966)	(–2.843)
Financially literate	0.021**	0.012	–0.033**
	(2.294)	(0.882)	(–2.097)
Stockholder	0.036***	0.012	–0.048***
	(3.334)	(0.823)	(–2.738)
Occupational pension	0.004	0.023*	–0.027*
	(0.504)	(1.830)	(–1.856)
Whole-life insurance	0.016*	0.039***	–0.055***
	(1.806)	(2.863)	(–3.492)
Employed	0.055***	0.087***	–0.142***
	(5.137)	(5.601)	(–7.958)
Net income (ln)	0.012	0.015	–0.027*
	(1.495)	(1.178)	(–1.838)
Financial wealth (ln)	0.002	0.013***	–0.015***
	(0.783)	(3.006)	(–3.033)
High school education	0.047***	0.004	–0.051
	(3.127)	(0.138)	(–1.615)
College education	0.043***	–0.006	–0.037
	(2.651)	(–0.205)	(–1.092)
Other control variables	Yes	Yes	Yes
Number of obs.		5,298	
Wald χ^2		712.00	
Prob > χ^2		0.0	
Pseudo R-squared		0.1133	

Note: The multinomial regression's dependent variable is categorical and codes participation in IRAs that focus on equities (Column 1), that mainly invest in fixed-income assets (Column 2), and IRA non-participation (Column 3). The coefficients of self-reported financial risk tolerance for the categories 'none' and 'above average or considerable' are relative to the base category of average risk tolerance. 'Child subsidy eligibility' = 1 if the individual could receive the IRA child subsidy. 'Trust' reports to what extent the individual trusts other people, with 0 = 'I do not trust others at all' and 10 = 'I trust others completely'. 'Financially literate' = 1 if the respondent answered three financial literacy questions correctly. 'Stockholder' = 1 if stocks are held (directly or through mutual funds). 'Occupational pension' = 1 if entitled to a firm pension. 'Whole-life insurance' = 1 if owning whole-life insurance. 'Employed' = 1 if employed. 'Net income (ln)' = the log of annual net income (in €1,000). 'Financial wealth (ln)' = the log of financial wealth (in €1,000; if a partner is present converted to a per spouse-measure) and includes saving accounts, direct or indirect stock or bond ownership, and all other liquid savings (excluding pension accounts). 'High school education' and 'College education' measure the impact of the educational attainment, relative to the base category of less than high school education. 'Other control variables' include the respondent's age and age², 'Married', 'Female' and 'Financially constrained' (if a respondent at least sometimes struggles to meet the expenses). We use data of persons older than 25, born after the year 1947 (presuming that individuals aged 55+ at the IRA introduction in 2002 were already too close to retirement to consider participation). Self-employed persons are excluded since they cannot benefit from subsidies and deferred taxation. t-values are given in parentheses (using robust standard errors). ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level.

Table 3: Heterogeneity Analysis for High, Middle, and Low Income Workers: Base Case

Lifetime income	Top 10%		Middle 10%		Bottom 10%	
Guarantee	With	Without	With	Without	With	Without
***Panel A:* Consumption** (in €1,000 or percent of guarantee case)						
Age 25–45	18.88	100%	15.27	100%	10.65	100%
Age 46–66	27.22	100%	16.29	100%	10.07	100%
Age 67–84	29.53	101%	15.18	101%	7.33	101%
Age 85–100	25.23	102%	13.98	103%	6.53	102%
***Panel B:* Liquid Savings** (in €1,000 or percent of guarantee case)						
Age 25–45	26.32	97%	11.93	97%	3.28	98%
Age 46–66	102.49	98%	22.99	94%	4.80	97%
Age 67–84	80.97	97%	23.26	93%	8.01	96%
Age 85–100	7.78	91%	1.65	85%	0.71	89%
***Panel C:* IRA Balance** (in €1,000 or percent of guarantee case)						
Age 25–45	7.98	108%	3.57	109%	0.36	114%
Age 46–66	116.63	105%	47.22	108%	7.08	108%
Age 67–84	94.29	105%	38.36	109%	5.90	111%
***Panel D:* IRA Payouts** (in €1,000 or percent of guarantee case)						
Age 67: lump sum	31.65	104%	14.86	109%	4.31	110%
Age 68–84: drawdown	10.98	105%	4.47	109%	0.69	110%
Age 85–100: annuity	17.18	105%	7.18	109%	1.29	111%
***Panel E:* Share of Consumption and Housing Costs Financed by IRA Payouts** (%)						
Age 68–84: drawdown	22.6	23.6	18.6	20.0	6.1	6.8
Age 85–100: annuity	39.2	40.6	30.8	32.8	12.1	13.2
***Panel F:* IRA Shortfall Probability** (%)						
Age 67	0.0	0.7	0.0	1.3	0.0	5.4
***Panel G:* Change in Cash on Hand Providing the Same Utility as the Guarantee Case** (%)						
Age 25	–	–0.4	–	–0.3	–	–0.2

Note: Panels A–D of Table 3 in columns labeled ‘*With*’ show mean values (in €1,000) of annual non-housing consumption, liquid assets, IRA balances, and payouts, by age ranges, for the top 10%, middle 10%, and bottom 10% of lifetime income earners. Columns labeled ‘*Without*’ indicate the percent of the respective guarantee values. Panel E quantifies the share (in %) of both consumption and housing costs financed by after-tax payouts from the IRA. Panel F reports the share of simulations where the IRA value at retirement falls short of the sum of contributions and subsidies. Panel G presents the percentage change in cash on hand at age 25 for which a switch to the alternative plan design yields the same lifetime utility as the guarantee. IRA assets are held entirely in stocks until retirement (protected with the hedges described above), while after retirement only 20% is allocated to stocks and 80% to bonds. Subgroups are generated using 1,000,000 simulation optimal life cycle paths and summing up individual lifetime labor incomes (all in real terms). For further notes on base case parameters see Figure 1.

Table 4: Percent of Individuals by Age and Lifetime Income Decile Having Higher Consumption Without versus With the IRA Guarantee: Base Case

Age	25–45	46–66	67–84	85–100
Top 10%	57	61	67	71
Middle 10%	56	54	72	84
Bottom 10%	45	46	69	80

Note: Table 4 reports the percent of individuals having higher non-housing consumption without the money-back guarantee, by age and lifetime income decile. Subgroups are generated using 1,000,000 simulation paths for optimal life cycles, adding up individual lifetime labor incomes (in real terms). The baseline case calibration uses a nominal risk-free rate of 3% and an inflation rate of 1.75%.

Table 5: Percent of Individuals by Age and Lifetime Income Decile Having Positive IRA Contributions, Without versus With the IRA Guarantee: Base Case

Age	25–45		46–66	
Guarantee	With	Without	With	Without
Top 10%	61	62	79	85
Middle 10%	39	39	65	65
Bottom 10%	9	9	35	36

Note: Table 5 presents the percent of individuals with positive contribution rates with and without the money-back guarantee, by age and lifetime income decile. Subgroups are generated using 1,000,000 simulation paths, adding up individual lifetime labor incomes (in real terms). For further notes on base case parameters see Figure 1.

Table 6: Impacts of Different Guarantees: No Guarantee and Life Cycle Risk Mitigation Techniques versus IRA Money-Back Guarantee

Plan design	With guarantee	Without guarantee	Life cycle funds		With guarantee	Without guarantee	Life cycle funds	
			'100–age'	*'100-until-54, –5'*			*'100–age'*	*'100-until-54, –5'*
i_f	3%				0%			
π	1.75%				0%			
***Panel A:* Consumption** (in €1,000 or percent of guarantee case)								
Age 25–45	15.05	100%	100%	100%	14.89	100%	100%	100%
Age 46–66	17.06	100%	98%	100%	16.50	101%	100%	101%
Age 67–84	16.26	101%	94%	98%	15.04	103%	99%	101%
Age 85–100	14.56	102%	85%	96%	11.78	110%	97%	104%
***Panel B:* Liquid Savings** (in €1,000 or percent of guarantee case)								
Age 25–45	12.74	97%	109%	97%	14.45	92%	102%	90%
Age 46–66	33.39	96%	125%	101%	47.90	78%	106%	87%
Age 67–84	30.20	94%	133%	107%	47.82	76%	98%	87%
Age 85–100	2.36	87%	168%	113%	5.12	59%	94%	75%
***Panel C:* IRA Balance** (in €1,000 or percent of guarantee case)								
Age 25–45	3.68	109%	61%	119%	1.20	258%	84%	291%
Age 46–66	51.70	107%	56%	100%	21.69	200%	80%	170%
Age 67–84	42.11	108%	52%	87%	16.27	185%	86%	139%
***Panel D:* IRA Payouts** (in €1,000 or percent of guarantee case)								
Age 67: lump sum	15.74	107%	60%	90%	9.57	148%	89%	122%
Age 68–84: drawdown	4.90	108%	52%	87%	1.86	185%	86%	139%
Age 85–100: annuity	7.83	108%	53%	87%	3.06	176%	87%	135%
***Panel E:* Share of Consumption and Housing Costs Financed by IRA Payouts** (%)								
Age 68–84: drawdown	19.0	20.3	10.5	16.8	7.7	13.9	6.7	10.7
Age 85–100: annuity	32.0	33.7	19.6	29.0	14.9	24.2	13.2	19.4
***Panel F:* IRA Shortfall Probability** (%)								
Age 67	0.0	2.0	0.2	0.5	0.0	9.6	13.8	8.3
***Panel G:* Change in Cash on Hand Providing the Same Utility as the Guarantee Case** (%)								
Age 25	–	–0.3	+2.8	+0.3	–	–0.8	+2.3	+0.2

Note: Panels A–D show mean values by age for four plan designs and two capital market environments as a percent of the guarantee values. Panel E quantifies the share of consumption and housing costs financed by IRA payouts; Panel F reports the share of cases where the retirement IRA value falls short of the sum of contributions and subsidies. Panel G presents the percentage change in cash on hand at age 25 for which a switch to the alternative plan design yields the same lifetime utility as the guarantee. For the guarantee case, IRA contributions (minus put premiums) are invested entirely in stocks until retirement. Without the guarantee, the IRA is fully exposed to equities during the worklife. For the life cycle funds, the fraction of assets invested in risky stocks versus bonds is specified according to a '*100–age'* rule (or '*100-until-54, –5'* rule, respectively), with no money-back guarantee. After retirement, 20% is allocated to stocks and 80% to bonds in all plan designs. For further notes on base case parameters, see Table 3.

Table 7: Percent of Individuals having Higher Consumption without a Guarantee, and with a Life Cycle Fund versus a Money-Back Guarantee IRA

Age	25–45	46–66	67–84	85–100
***Panel A:* 'Normal' Capital Markets (i_f = 3%, π = 1.75%)**				
Without guarantee	54	54	70	81
'*100–age*' rule	45	36	20	11
'*100-until-54, –5*' rule	46	43	39	35
***Panel B:* 'Low Return' Capital Markets (i_f = 0%, π = 0%)**				
Without guarantee	54	62	81	88
'*100–age*' rule	45	52	26	28
'*100-until-54, –5*' rule	49	66	63	71

Note: Table 7 shows the fraction (in %) of individuals having higher non-housing consumption in the no-guarantee case and two life cycle risk mitigation strategies, relative to a money-back guarantee and 100% equity allocation throughout the accumulation phase. To determine the percentage equity allocation, the first life cycle fund applies a relatively conservative '*100–age*' rule, and the second is fully invested in equities until age 54 and then reduces its equity allocation by 5 percentage points per year (termed '*100-until-54, –5*' rule). To maintain consistency, after retirement, only 20% is allocated to stocks and 80% to bonds in all plan designs. Panel A considers the 'normal' capital market scenario (nominal risk-free rate of 3% and inflation rate of 1.75%) and Panel B addresses the low return environment (nominal risk-free rate and inflation rate of 0%).

Table 8: Model Results under Loss Aversion

Guarantee	With	Without	With	Without
i_f	3%		0%	
π	1.75%		0%	
***Panel A:* Consumption** (in €1,000 or percent of guarantee case)				
Age 25–45	15.00	100%	14.88	100%
Age 46–66	16.90	100%	16.35	101%
Age 67–84	16.18	98%	14.92	102%
Age 85–100	14.56	94%	11.95	105%
***Panel B:* Liquid Savings** (in €1,000 or percent of guarantee case)				
Age 25–45	12.98	110%	13.79	99%
Age 46–66	33.97	116%	43.17	97%
Age 67–84	27.28	112%	40.74	90%
Age 85–100	1.62	110%	3.46	76%
***Panel C:* IRA Balance** (in €1,000 or percent of guarantee case)				
Age 25–45	3.74	52%	1.81	145%
Age 46–66	52.43	79%	27.92	130%
Age 67–84	44.37	83%	20.58	130%
***Panel D:* IRA Payouts** (in €1,000 or percent of guarantee case)				
Age 67: lump sum	14.95	82%	10.58	118%
Age 68–84: drawdown	5.17	83%	2.36	130%
Age 85–100: annuity	8.10	83%	3.74	128%
***Panel E:* Share of Consumption and Housing Costs Financed by IRA Payouts** (%)				
Age 68–84: drawdown	20.1	17.1	9.9	12.6
Age 85–100: annuity	33.0	28.9	18.0	22.2
***Panel F:* IRA Shortfall Probability** (%)				
Age 67	0.0	2.6	0.0	9.8
***Panel G:* Change in Cash on Hand Providing the Same Utility as the Guarantee Case** (%)				
Age 25	–	+0.2	–	–0.1

Note: Table 8 shows the model outcomes for both IRA guarantee types and economic environments if employees are loss-averse and optimize utility according to Eq. (10). We assume $\Lambda = 0.006$. Because the money-back guarantee is only tested once at retirement, approximations for intra-period loss penalties are required during the accumulation phase. For the IRA with the guarantee, we assume that losses are only subject to penalties as long as the IRA balance exceeds the guarantee amount. After retirement, when participants are no longer protected by guarantees, regular penalties apply. Losses in liquid equity investments and in IRAs without guarantees are always fully penalized. Other explanations are identical to those in Tables 3 and 6.

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Money-Back Guarantees in Individual Retirement Accounts: Are They Good Policy?

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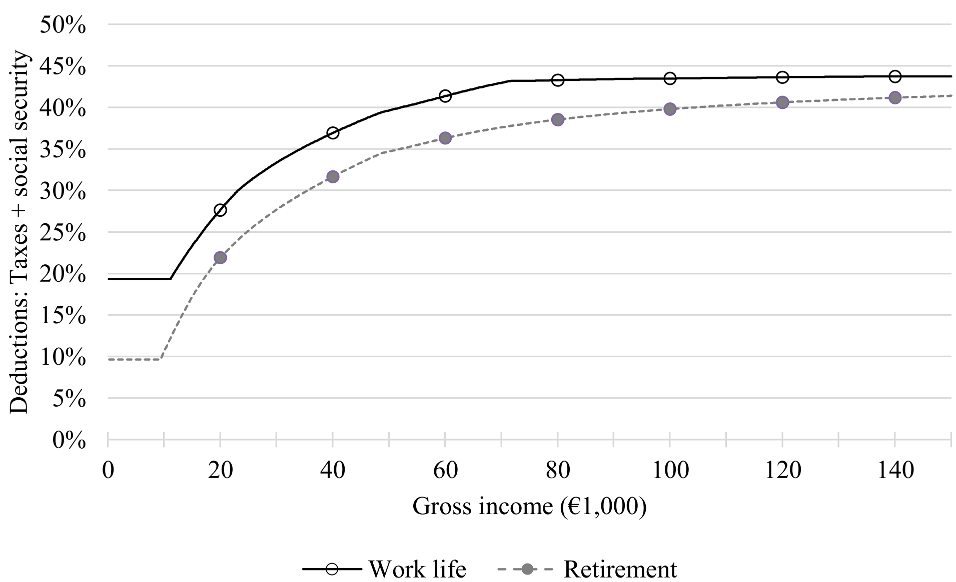
Online Appendix

Online Appendix A: Income Taxation and Social Security Contributions

Our model embeds the German social security and tax regulations as realistically as possible, though below, we show how these institutional details can be generalized to other nations (see Online Appendix I). The state-organized social insurance system includes contributions to pension, unemployment, health care, and nursing care insurance. During the worklife, employees and employers each contribute 9.30% of gross labor income to the statutory pension system and 1.25% to unemployment insurance (to an assessment ceiling of €80,400 p.a.). Health insurance costs 7.3% of labor income and nursing care insurance amounts to 1.525% for employees (to an assessment ceiling of €54,450 p.a.). Retirees do not pay pension and unemployment insurance contributions, but they pay 7.3% from pension income for health and 3.05% for nursing care insurance.

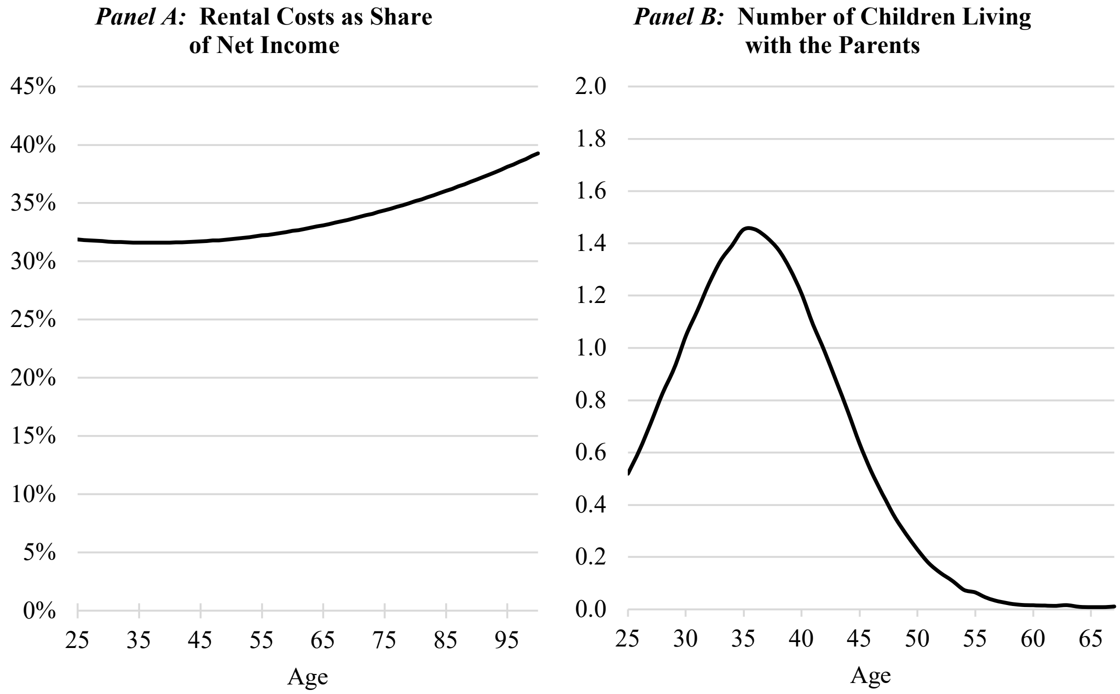
Federal income taxes are charged based on taxable income, which is gross income less (in part) contributions to the state-organized social insurance system, contributions and subsidies paid into tax-qualified IRAs, and several tax-exempt amounts. In 2019, 88% of both the employee's and employer's contribution to the statutory pension system could be deducted. This tax deductible contribution increases in 2% increments, such that in 2025, the full amount can be deducted. In addition, an individual's payments to nursing care insurance and 96% of the contribution to health insurance are tax deductible. The latter two may be increased by unemployment insurance contributions as long as the sum of the three is below €1,900. Furthermore, taxable income is reduced by income-related standard deductions of €1,000 for employees and €102 for retirees. In the context of our model, contributions and subsidies paid to Riester IRAs are tax deductible up to an annual limit of €2,100.

The progressive German income tax system grants tax exemption on the first €9,168 of taxable income. Between €9,168 and €55,960, marginal tax rates increase from 14% up to 42% of taxable income. For income above €265,326, the marginal tax rate is 45%. Taxes determined by these regulations are additionally increased by a solidarity supplement tax of 5.5%. The following figure illustrates the share of total deductions as a percentage of gross income (c_t^{SST}), i.e., social security and tax payments, for both employees and retirees.



Note: This figure represents the share of deductions (in %) from gross labor income resulting from income taxes and contributions to the German social insurance system. The figure assumes a worker (retiree) with no children and no contributions to (income from) tax-qualified IRAs.

Online Appendix B: Rental Costs and Number of Children



Note: Panel A of this figure illustrates tenants' rental costs as a fraction of net income (h_t), derived from all waves of SOEP from 1990 to 2020. The definition of housing costs for tenants is broad; besides rental payments, we include costs for hot and cold water, heating, garbage disposal, and cleaning services. Housing costs in SOEP are provided solely at the household level, so costs are divided by the aggregate of head's and – if present – spouse's net income. The population refers to all households in the panel, irrespective of the potential presence of spouses. The subsamples of females and males do indicate singles' housing costs, but in the model we use population values to avoid the need to make assumptions about relationship status. Panel B illustrates the average number of children living in a household with parents over the life cycle, from all waves of the Socio-Economic Panel (SOEP) from 1984–2020.

Online Appendix C: Labor Income Process

Estimation of the discretized Markovian income process relies on non-zero labor income observations of employed persons aged 25–67 from all waves of SOEP until year 2020. All income figures are converted to year 2019 prices (measured in €1,000), and in all specifications and for every age we drop the top and bottom 1% of observations to diminish effects of outliers. Next, each remaining observation is assigned to one of n_s equally-sized income levels. The lowest (highest) $1/n_s$ of observations are assigned to income level 1 (level n_s), etc.[35] We adapt the methodology of Cocco et al. (2005) to estimate deterministic annual income. First, for each income level s, we regress the natural logarithm of labor income, $\ln Y_{t,s}$, on personal characteristics to determine age dummy coefficients. We then regress the age dummies on first-, second- and third-order polynomials in age. Estimated coefficients are then used to determine predicted age-dependent log income figures, converted to level values, and interpreted to (roughly) indicate the level's middle income.

The second component of the labor income process is the variation of observed log income, $\ln Y_{t,s}$, around the regression-based predicted values, $\ln \hat{Y}_{t,s}$. Using the standard deviation of the difference, $\sigma_{u,s}$, as a measure of dispersion, a purely transitory shock is added to the level's deterministic trend. The natural logarithm of the shock is assumed to be normally distributed as $\ln U_{t,s} \sim N(-0.5\sigma_{u,s}^2, \sigma_{u,s}^2)$ and is intended to reflect additional variation in income beyond transitions between income states.

Finally, we estimate a Markov transition matrix which quantifies the probabilities of migrating from the current income state s_t to all other income states in the next period. To derive migration probabilities, we only consider cases where consecutive observations from one age to the next are available with no change in education. Both the transitory shock component within a level and transition probabilities across levels are assumed to be age-invariant.

Panels A and B of Table C.1 show the results of the state-dependent labor earnings regressions. Panel C reports the standard deviations $\sigma_{u,s}$ between observed (ln) income $Y_{t,s}$ from predicted (ln) income $\hat{Y}_{t,s}$ for all levels. The variation is U-shaped in income, meaning that heterogeneity in labor earnings is higher at more extreme income levels. In addition, the top and bottom level variations are more than twice as high as of the adjacent levels. Panel D quantifies the transition probabilities $q_{s_t,s_{t+1}}$ from current income level s_t to level s_{t+1} in the next period. Shading in the table is darker, the higher the probability. The likelihood of remaining in the same income level is especially high for the top and bottom income deciles, but for middle income receivers remaining in the same level is also the most likely event.

Table C.2 compares the empirical moments of the SOEP data and simulated labor income from applying the Markovian and Carroll and Samwick (1997) methods. Despite simplifications with respect to age-independence of transitory shock components and migration probabilities, the empirical moments over age ranges of 10 years are sufficiently close to infer that the Markov method adequately simulates labor income.

[35] Increasing the number of income levels n_s is expected to improve the fit between raw data and simulated income data, but also increases model runtime. Overall, we find that for the total population and subsamples of females and males $n_s = 10$ achieves a satisfactory fit of the distribution parameters of the SOEP data (see Online Appendix Table C.2).

Table C.1: Gross Labor Income Parameters Estimated by Deciles using SOEP

Income decile s_t	1	2	3	4	5	6	7	8	9	10
***Panel A:* Regression of Log Labor Income on Personal Characteristics**										
Constant	2.002	2.638	2.847	3.042	3.198	3.313	3.410	3.511	3.622	3.861
	(74.96)	(277.26)	(414.51)	(610.29)	(857.69)	(1083.60)	(1229.67)	(1114.66)	(834.66)	(339.37)
Number of children	-0.041	-0.006	-0.002	-0.002	0.000	0.001	0.001	0.001	0.001	0.001
	(-7.17)	(-3.65)	(-1.56)	(-1.65)	(-0.16)	(1.75)	(1.18)	(0.99)	(0.82)	(0.29)
Partnership	-0.006	0.001	0.000	0.001	-0.001	-0.001	0.001	0.001	0.008	0.003
	(-0.48)	(0.31)	(-0.07)	(0.66)	(-0.53)	(-0.68)	(0.94)	(0.51)	(2.73)	(0.41)
East Germany	0.057	0.001	-0.003	-0.007	-0.004	0.000	0.002	0.011	-0.008	0.000
	(1.25)	(0.06)	(-0.25)	(-1.04)	(-0.62)	(0.00)	(0.40)	(1.72)	(-1.00)	(0.00)
Number of obs.	29,903	29,772	29,756	29,779	29,806	29,789	29,793	29,792	29,803	29,772
F	13.44	50.46	96.13	168.40	336.85	544.43	766.12	729.22	512.88	107.03
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Adj. R-squared	0.051	0.183	0.260	0.344	0.485	0.577	0.638	0.645	0.611	0.377
***Panel B:* Deterministic Trend Income**										
Constant	2.434	3.577	2.984	2.693	2.353	1.877	1.533	1.085	0.954	0.412
	(6.53)	(5.70)	(6.88)	(7.58)	(8.23)	(8.12)	(8.40)	(6.84)	(6.14)	(4.55)
Age / 100	-4.618	-8.002	-1.632	2.069	5.540	9.793	12.823	16.532	17.743	21.969
	(-1.80)	(-1.76)	(-0.54)	(0.84)	(2.83)	(6.19)	(10.33)	(15.40)	(16.80)	(33.15)
$Age^2 / (100)^2$	18.010	24.256	8.650	-0.392	-8.402	-18.259	-24.749	-32.430	-33.399	-39.117
	(3.12)	(2.26)	(1.28)	(-0.07)	(-1.93)	(-5.20)	(-9.05)	(-13.80)	(-14.32)	(-25.30)
$Age^3 / (100)^3$	-17.914	-21.834	-9.308	-2.146	3.976	11.550	16.288	21.685	21.603	23.973
	(-4.24)	(-2.65)	(-1.87)	(-0.53)	(1.26)	(4.56)	(8.33)	(13.00)	(12.88)	(20.61)
***Panel C:* Standard Deviation: Difference of Actual from Predicted Log Labor Income**										
$\sigma_{u,s}$	0.176	0.057	0.044	0.035	0.028	0.027	0.029	0.035	0.047	0.112

***Panel D:* Transition Probabilities between Labor Income Deciles s_t, s_{t+1} (%)**

s_{t+1} \ s_t	1	2	3	4	5	6	7	8	9	10
1	63.55	21.93	6.44	3.43	1.83	1.16	0.75	0.44	0.38	0.36
2	18.58	45.57	20.76	6.51	3.32	2.06	1.12	0.91	0.58	0.56
3	8.03	16.82	42.06	18.91	6.25	3.18	1.81	1.33	0.79	0.56
4	4.00	6.48	16.60	40.06	19.46	6.39	3.35	1.90	1.02	0.75
5	2.11	3.46	6.15	17.31	39.33	19.88	6.75	2.92	1.33	0.79
6	1.36	2.06	3.31	6.82	18.10	39.81	18.95	6.17	2.30	1.09
7	0.78	1.32	1.87	3.33	6.54	18.06	42.30	19.10	5.05	1.67
8	0.67	0.98	1.36	1.81	3.10	6.02	18.41	46.62	17.69	3.34
9	0.54	0.78	0.84	1.12	1.37	2.43	4.86	17.16	56.26	14.67
10	0.38	0.60	0.63	0.70	0.70	1.01	1.69	3.43	14.60	76.21

Note: Panel A of Table C.1 reports regression coefficients and t-statistics for level-wise regressions of log labor income on age dummies and personal characteristics using the SOEP (see text). Panel B provides results from regression the age dummies on polynomials of age. Panel C shows the standard deviation of differences between annual log labor income and the regression's fitted values by income level. Panel D depicts the conditional transition probabilities $q_{s_t,s_{t+1}}$ from the individual's current income level s_t to all possible future income levels s_{t+1}. The darkness of the shading is proportional to the transition probability. Standard deviations and transition probabilities are assumed to be age-invariant.

Table C.2: Moments of Labor Income (Entire Workforce)

Age	25–34	35–44	45–54	55–64
***Panel A:* Mean**				
SOEP	30.82	37.96	41.70	43.12
Markov chain	31.35	38.24	41.50	43.00
Carroll and Samwick (1997)	25.88	33.06	36.65	34.51
***Panel B:* Standard deviation**				
SOEP	15.09	23.03	27.14	30.75
Markov chain	14.64	21.61	25.17	28.29
Carroll and Samwick (1997)	10.34	18.92	26.32	29.55
***Panel C:* Skewness**				
SOEP	0.63	1.35	1.68	1.76
Markov chain	0.51	1.01	1.22	1.22
Carroll and Samwick (1997)	1.26	1.88	2.50	3.50
***Panel D:* Kurtosis**				
SOEP	3.33	5.37	6.92	7.39
Markov chain	3.05	3.73	4.18	4.08
Carroll and Samwick (1997)	6.11	9.75	15.83	39.12

Note: Table C.2 reports the empirical moments of labor income for observed SOEP data as well as for two data-generating processes. Annual labor income measured in €1,000 refers to the total workforce. The method denoted 'Markov chain' is employed in the model (see Section 3.3). The benchmark method is from Carroll and Samwick (1997) using the regression model $\ln Y_{i,t} = \gamma_0 + \gamma_1 \cdot \frac{age_{i,t}}{100} + \gamma_2 \cdot \frac{age_{i,t}^2}{(100)^2} + u_{i,t}$ and resulting coefficients $\gamma_0 = 2.0153, \gamma_1 = 5.2494, \gamma_2 = -1.9142$, and $\gamma_3 = -4.3890$; the variance of the permanent income shock $\sigma_n^2 = 1.352\%^2$ and variance of the transitory income shock $\sigma_u^2 = 7.236\%^2$. Using Carroll and Samwick's method, Fuchs-Schündeln et al. (2010) and Krebs and Yao (2016) find similar permanent but higher transitory shock components for Germany. The lower transitory shock in our model is attributed to the additional data filters applied (outlined in the note on Table C.1). Reported numbers are mean values over age ranges of 10 years from 100,000 simulation paths.

Online Appendix D: Results with Epstein-Zin-Weil Preferences, and with Front-End Loads on Contributions

The use of CRRA preferences links the coefficient of risk aversion (γ) and the elasticity of intertemporal substitution (EIS), inasmuch as one is the inverse of the other. To free up these parameters, we also investigate results using the Epstein-Zin-Weil utility formulation (Epstein and Zin 1989, Weil 1989). This approach allows independent preferences for smoothing across time and states. Here, consumption differences for the alternative guarantee designs are affected in two ways. First, lowering (increasing) the EIS means relative risk aversion is smaller (larger) than 1/EIS, so the individual will devote less (more) emphasis to consumption smoothing across states, compared to CRRA preferences. This should decrease (increase) the overall demand for saving and narrow (increase) differences in resulting retiree consumption under the guarantee. Second, the relative attractiveness of the scheme with/without guarantee changes. The guaranteed IRA provides smaller variation in payouts, but it also pays off less compared to the non-guaranteed IRA. For lower (higher) levels of EIS, this makes the guaranteed IRA less (more) attractive relative to the non-guaranteed IRA, due to the consumer's weaker (stronger) preference for smoothing across states.

These two effects work in opposite directions, so it is theoretically unclear which effect dominates. To resolve this, the first four columns of Table D.1 provide results using Epstein-Zin-Weil preferences (as defined in Eq. (1)) for the base case calibration. Holding fixed the coefficient of relative risk aversion, we then reduce (increase) the CRRA-implied $EIS = 1/\gamma = 1/7$ to 0.1 (0.2), to permit an assessment of changing the EIS on IRA and liquid savings demand, and on resulting consumption opportunities. Lowering the EIS produces a substantial decline in total savings, by about 13% between ages 60–79 (Panels B and C) relative to the CRRA case with the IRA guarantee, and an even larger reduction, of about 18%, relative to the CRRA case and no guarantee (Table 6, columns 1 and 2).[36] Moreover, for both guarantee designs, the IRA share as a percentage of total assets falls between 3.3 and 6.5 percentage points.[37] Accordingly, removing the guarantee enhances savers' wellbeing less, driven by the substantial reduction in overall savings more than by a change in the relative attractiveness of the two guarantee designs.

When the EIS is increased to 0.2, the opposite effects obtain. Total saving rises by 25% for the guarantee case, due to the stronger demand for smoothing across states compared to results using CRRA parameters. The IRA provides better smoothing across states than liquid savings due to the embedded deferred annuity, so a higher EIS value translates to more of the portfolio being held in the IRA. The IRA share as a percent of total assets rises slightly more, by 6.4% for the guaranteed IRA versus 5.7% for the non-guaranteed scheme. The consumption improvement resulting from removing the IRA guarantee is greater when the EIS rises, relative to the CRRA case.

In sum, of the two channels through which EIS affects consumption, the adjustment in total savings dominates the effect of changing the guarantee's attractiveness. Also, the positive effect of abolishing the guarantee rises when the EIS is higher, meaning that individuals favor consumption smoothing more strongly across states. Somewhat counterintuitively, the guaranteed IRA that smooths consumption more loses ground to the non-guaranteed alternative, because the increased consumption gained by abolishing the guarantee compensates for the individual's benefit of smoother consumption. In summary, then, results using Epstein-Zin-Weil preferences confirm the conclusions of prior sections: a non-guaranteed IRA considerably enhances consumption relative to that feasible with a guaranteed IRA.

[36] As the IRA is fully depleted beyond age 84, asset holdings in the final periods cannot be analyzed accurately.
[37] For the guarantee case, it falls from 70.4% to 67.0%, and with no guarantee, from 73.6% to 67.1%.

Moreover, thus far we have abstracted from sales charges levied on IRA contributions, yet in the German context, investing in an IRA requires payment of front-end loads (no fees are charged on redemptions during the payout phase). Such fees could affect the demand for guarantees for two reasons. First, the loads might render the IRAs so unattractive that savers could contribute little or nothing. In such a case, the guarantee specifications become irrelevant. Second, the loads could interact with expensive guarantee costs and discourage IRA investors from contributing. In the latter case, the IRA's appeal would be enhanced by abolishing the guarantee, and consumption without a guaranteed IRA might be even greater than with the guarantee (as illustrated in Section 4).

The final two columns of Table D.1 document that IRA investments are still substantial, even with a front-end load of 5% on contributions. Yet unsurprisingly, Panels C and D show that such loads lead to less IRA wealth accumulated for the base calibration. As a consequence, payouts are also lower than in the absence of such fees (compare the first two columns of Table 6). Importantly, participant contributions do not decline symmetrically. Given the front-end load, lifetime contributions with the guarantee fall by 6.9% (to €20,850); without the guarantee, contributions drop by only about 3.2% (to €22,400).[38] IRA payouts differ by 10–11% without the extra loads, but by 13% when front-end loads are taken into account. As a result, old-age consumption differences are greater than without fees. Overall, with realistic sales loads, the negative consequences of the IRA guarantees are slightly worse.

[38] Intuitively, with fees, the average timing of contributions is a bit earlier to give invested capital more time to earn return (about 0.74 years earlier with a money-back guarantee and 0.32 years in absence of a guarantee).

Table D.1: Sensitivity Analysis for Different Preferences and Fees: Base Case

Specification	EZW: lower EIS		EZW: higher EIS		Front-end load: 5%	
Guarantee	With	Without	With	Without	With	Without
***Panel A:* Consumption** (in €1,000 or percent of guarantee case)						
Age 25–45	15.16	100%	14.86	100%	15.03	100%
Age 46–66	16.93	100%	17.22	100%	17.00	100%
Age 67–84	15.57	101%	17.48	101%	16.16	100%
Age 85–100	13.29	102%	16.79	102%	14.26	101%
***Panel B:* Liquid Savings** (in €1,000 or percent of guarantee case)						
Age 25–45	11.43	99%	13.92	100%	12.71	101%
Age 46–66	33.04	98%	32.55	98%	34.30	99%
Age 67–84	31.54	96%	28.31	93%	32.57	95%
Age 85–100	2.31	90%	2.68	88%	2.82	87%
***Panel C:* IRA Balance** (in €1,000 or percent of guarantee case)						
Age 25–45	2.31	106%	7.05	100%	3.60	98%
Age 46–66	39.09	105%	75.14	103%	48.65	104%
Age 67–84	32.08	107%	60.06	105%	38.86	106%
***Panel D:* IRA Payouts** (in €1,000 or percent of guarantee case)						
Age 67: lump sum	12.67	106%	21.10	104%	14.85	104%
Age 68–84: drawdown	3.74	106%	6.99	105%	4.53	106%
Age 85–100: annuity	6.03	106%	11.04	105%	7.25	106%
***Panel E:* Share of Consumption and Housing Costs Financed by IRA Payouts** (%)						
Age 68–84: drawdown	15.1	16.0	25.2	26.3	17.6	18.6
Age 85–100: annuity	26.5	27.9	39.9	41.1	30.2	31.4
***Panel F:* IRA Shortfall Probability** (%)						
Age 67	0.0	2.5	0.0	1.3	0.0	2.6
***Panel G:* Change in Cash on Hand Providing the Same Utility as the Guarantee Case** (%)						
Age 25	–	–0.2	–	–0.7	–	–0.6

Note: Panels A–D of Table D.1 report mean values of annual non-housing consumption, liquid assets, IRA balances, and payouts, by age ranges (in €1,000), for three different cases with and without the guarantee (the latter as a percent of the guarantee case). Panel E quantifies the share (in %) of both consumption and housing costs financed by after-tax payouts from the IRA. Panel F reports the share of simulations where the IRA value at retirement falls short of the sum of contributions and subsidies. Panel G presents the percentage change in cash on hand at age 25 for which a switch to the alternative plan design yields the same lifetime utility as the guarantee. In the first and second case, we allow for Epstein-Zin-Weil (EZW) preferences to disentangle risk aversion and elasticity of intertemporal substitution (EIS). Starting from the CRRA-implied EIS of $\psi = 1/7 = 0.1429$ in the first (second) specification, EIS is decreased (increased) to 0.1 (0.2) while holding relative risk aversion constant at $\gamma = 7$. In the third specification, a front-end load of 5% is charged for each contribution (including subsidies). In all specifications, the nominal risk-free rate and inflation rate are assumed constant at i_f = 3% and π = 1.75%, and the equity risk premium is 5.68% (with volatility of 15.96%).

Online Appendix E: Determination of Γ_{t+1} under Loss Aversion

In the preference specifications embedding loss aversion in Section 5.2, the variable Γ_{t+1} measures the expected profit and loss from stock market exposures in the numerical integration. Following the assumption that gains do not cause additional utility, in Eq. (9) only negative values of Γ_{t+1} are considered in $\upsilon(\Gamma_{t+1})$, which then enters the value function in Eq. (10). In general, we posit that unprotected losses in liquid stock holdings S_t are always penalized. Concerning the IRA, verbally elucidating the calculation of Γ_{t+1} is simple, but in fact it differs substantially across plan designs and phases of the life cycle, so it shall be elaborated further.

For notational convenience, we define the worklife post-contribution IRA balance as $IRA_t^+ = IRA_t + (A_t + b_t)(1-\zeta) - P_t$; meaning the plan has a balance of IRA_t at the beginning of the period, and the individual contributes A_t, which is matched by a subsidy of b_t (which could be subject to a proportional front-end load ζ), and put premiums P_t are deducted.

During the worklife and with a money-back guarantee, we use an approximation of penalized losses to resolve the conflict between the usual period-to-period horizon assumed under loss aversion (e.g., Barberis and Huang 2009) and the money-back nature of the guarantee. We thus assume that losses are only considered if the post-contribution balance IRA_t^+ exceeds the guarantee amount, and only up to the guarantee amount G_t:

$$\begin{aligned}\Gamma_{t+1} = {} & S_t \cdot (R_{t+1} - 1) \\ & + \max\left(IRA_t^+ \cdot (R_{t+1} - 1), (G_t - IRA_t^+) \cdot \mathbb{1}_{\{G_t < IRA_t^+\}}\right).\end{aligned} \tag{E.1}$$

Without the guarantee, stock market losses are fully penalized, irrespective of whether attributed to liquid stocks or IRA holdings:

$$\Gamma_{t+1} = (S_t + IRA_t^+) \cdot (R_{t+1} - 1). \tag{E.2}$$

For life cycle funds and during the worklife we slightly modify previous definitions and consider the performance of the IRA holistically. Given the time-t equity share ϖ_t, the IRA return is given by $R_{t+1}^{IRA} = \varpi_t \cdot R_{t+1} + (1 - \varpi_t) \cdot R_f$ such that

$$\Gamma_{t+1} = S_t \cdot (R_{t+1} - 1) + IRA_t^+ \cdot (R_{t+1}^{IRA} - 1), \tag{E.3}$$

and now Eq. (9) checks for $R_{t+1} < 1$ and $R_{t+1}^{IRA} < 1$ separately. For consistency with the counterfactual cases, during retirement, we define Γ_{t+1} for the life cycle funds identically to the guarantee and no-guarantee cases.

After retirement, when investment guarantees no longer exist, the equity proportion of the post-outflow IRA balance is considered jointly with liquid stock holdings. At age 67, the starting balance IRA_t is lowered by annuity purchases H_t and lump sum withdrawals W_{LS}. From age 68–84, payout plan distributions W_t are deducted, and after age 85 the IRA is depleted. Thus, post-retirement it holds

$$\Gamma_{t+1} = \begin{cases} \left(S_t + \varpi_t \cdot (IRA_t - H_t - W_{LS})\right) \cdot (R_{t+1} - 1) & \text{for } t = K \\ \left(S_t + \varpi_t \cdot (IRA_t - W_t)\right) \cdot (R_{t+1} - 1) & \text{for } K < t \leq K + 17 \\ S_t \cdot (R_{t+1} - 1) & \text{for } t > K + 17. \end{cases} \tag{E.4}$$

Online Appendix F: Extended Results on Loss Aversion

This Online Appendix extends our results from Section 5.2, by reporting how behaviors change if either of the two life cycle funds were adopted instead of the guaranteed IRA when workers exhibit loss aversion as in Eq. (10). In particular, we investigate how consumption, liquid savings, IRA balances, and lifetime utility change under loss aversion when life cycle funds replace the IRA guarantee.

For the two life cycle funds evaluated, '*100 minus age*' and '*100-until-54, –5*', Table F.1 shows consumption, asset holdings, and payouts without the guarantee, given loss framing with $\Lambda = 0.006$ in both capital market scenarios. Panels A–D report how outcomes change, as a percentage of the guarantee case in Table 8. In a normal return world, the loss-averse prefer the IRA guarantee over both life cycle funds. By comparison, in a low return world, both life cycle funds also lose ground compared to the guarantee, because their bonds that earn zero returns cannot offset potential losses from the equity proportions.

In Table F.2, Subpanel 1 compares liquid savings (in €1,000) and the allocation to liquid stocks for both capital market environments, and for standard versus loss aversion preferences. Under loss aversion in the normal rate world, the loss-averse hold more in liquid savings (except for two old-age cases), and they generally invest more in bonds. With low interest rates, the loss-averse have similar amounts of savings outside their IRAs as their counterparts, but they allocate less to stocks.

Table F.1: Model Results with Life Cycle Funds under Loss Aversion

Plan design	*'100–age'*	*'100-until-54, –5'*	*'100–age'*	*'100-until-54, –5'*
i_f	3%		0%	
π	1.75%		0%	
***Panel A:* Consumption** (percent of guarantee case)				
Age 25–45	100%	100%	100%	100%
Age 46–66	99%	100%	100%	101%
Age 67–84	94%	96%	98%	101%
Age 85–100	85%	91%	96%	105%
***Panel B:* Liquid Savings** (percent of guarantee case)				
Age 25–45	114%	109%	106%	97%
Age 46–66	126%	110%	107%	87%
Age 67–84	126%	112%	100%	86%
Age 85–100	139%	114%	96%	77%
***Panel C:* IRA Balance** (percent of guarantee case)				
Age 25–45	41%	59%	78%	181%
Age 46–66	56%	83%	82%	155%
Age 67–84	57%	76%	82%	135%
***Panel D:* IRA Payouts** (percent of guarantee case)				
Age 67: withdrawal	57%	76%	85%	120%
Age 68–84: drawdown	57%	76%	82%	135%
Age 85–100: annuity	57%	76%	83%	132%
***Panel E:* Share of Consumption and Housing Costs Financed by IRA Payouts** (%)				
Age 68–84: drawdown	12.1	15.9	8.2	13.1
Age 85–100: annuity	21.6	27.1	15.4	22.6
***Panel F:* IRA Shortfall Probability** (%)				
Age 67	0.5	0.8	12.6	10.9
***Panel G:* Change in Cash on Hand Providing the Same Utility as the Guarantee Case** (%)				
Age 25	+1.8	+0.2	+2.3	+0.5

Note: Table F.1 displays model outcomes for two IRA life cycle fund glide paths, and both capital market scenarios, if savers exhibit loss aversion. The strength of the loss framing motive in Eq. (10) is $\Lambda = 0.006$. This table complements Table 8, which shows the same for IRA designs with and without a guarantee. For Panels A–D, all values are reported as a percent of the guarantee case from Table 8.

Table F.2: Model Results on Asset Allocation for CRRA and Loss-Averse Individuals

Utility	CRRA				Loss aversion			
Plan design	With guarantee	Without guarantee	Life cycle funds		With guarantee	Without guarantee	Life cycle funds	
			'100–age'	*'100-until-54, –5'*			*'100–age'*	*'100-until-54, –5'*
Panel A: **'Normal' Capital Markets (i_f = 3%, π = 1.75%)**								
Panel A.1: **Liquid Savings** (in €1,000)								
Age 25–45	12.74	12.39	13.92	12.31	12.98	14.26	14.78	14.14
Age 46–66	33.39	32.03	41.90	33.82	33.97	39.25	42.82	37.29
Age 67–84	30.20	28.40	40.17	32.25	27.28	30.43	34.37	30.57
Age 85–100	2.36	2.05	3.96	2.66	1.62	1.78	2.25	1.84
Panel A.2: **Stocks** (in percent of liquid savings)								
Age 25–45	84.2	79.2	83.2	78.5	80.5	96.1	97.4	96.0
Age 46–66	60.2	60.0	68.6	65.8	47.9	46.4	69.9	55.8
Age 67–84	89.4	89.9	87.9	88.8	71.2	70.9	70.9	71.2
Age 85–100	98.2	98.1	97.7	98.1	96.1	99.2	99.2	99.2
Panel B: **'Low Return' Capital Markets (i_f = 0%, π = 0%)**								
Panel B.1: **Liquid Savings** (in €1,000)								
Age 25–45	14.45	13.27	14.80	13.02	13.79	13.67	14.64	13.42
Age 46–66	47.90	37.36	50.73	41.50	43.17	41.81	46.20	37.45
Age 67–84	47.82	36.55	47.06	41.46	40.74	36.67	40.73	35.17
Age 85–100	5.12	3.01	4.81	3.86	3.46	2.62	3.33	2.68
Panel B.2: **Stocks** (in percent of liquid savings)								
Age 25–45	98.5	98.2	98.8	99.3	96.6	95.5	97.4	97.2
Age 46–66	78.8	77.5	90.5	85.7	61.5	58.6	76.5	73.6
Age 67–84	85.0	88.5	86.6	87.2	76.3	78.0	77.7	79.0
Age 85–100	95.7	97.8	96.9	97.2	97.5	98.5	98.2	98.3

Note: Table F.2 reports liquid savings (in €1,000, Subpanels 1) and the allocation to stocks within liquid savings (in percent of liquid savings, Subpanels 2) for all four IRA plan designs, and both capital market scenarios (Panel A: 'Normal' capital markets, Panel B: 'Low return' capital markets). Columns (1)–(4) show results for standard CRRA preferences as in Eq. (1), and Columns (5)–(8) present outcomes if participants exhibit loss aversion according to Eq. (10), with the strength of the loss framing motive being $\Lambda = 0.006$. Panel A shows results for the historically 'normal' capital market environment with nominal interest rates of 3%, and inflation of 1.75%; Panel B addresses the 'low return' capital market scenario with interest rates and inflation of 0%. Bond allocations are implicitly given by 100% minus the stock share.

Online Appendix G: Alternative Guarantee Mechanism

For the models embedding a money-back guarantee in the IRA, we use a put hedge approach to implement and price the guarantee. This approach implies shortcomings, yet, unlike other strategies, it can easily be integrated into a dynamic life cycle model since it requires no state variables on top of tracking the guarantee amount. In this appendix, we address the shortcomings and benefits of the approach in more detail, and we provide model results for an alternative strategy to implement the guarantee.

The put approach is naïve in the sense that at-the-money put options are purchased irrespective of the current ratio of IRA assets to the guarantee amount. In return for the premiums all risk is transferred to the product provider which will compensate for any shortfalls below the guarantee amount at retirement, but it can run profits or losses due to the non-perfect hedge (see Section 2.2). Strategies considering the surplus/deficit could decrease costs or the frequency of cases in which the provider suffers losses, but setting up this strategy would require efficient tracking of the entire history of option purchases as state variables.[39]

An alternative mechanism yielding the guarantee amount at retirement with certainty is to split IRA assets across stocks and risk-free bonds, such that the bond investment grows to the contribution's face value at retirement. Hence, the share of the contribution and subsidies that is allocated to bonds at any time t is given by

$$x_t^{bonds} = \left(1 + i_f\right)^{-(K-t)}, \tag{G.1}$$

and the remaining share is then invested in the stock market, so even a 100% decline in the risky asset until retirement could be sustained without jeopardizing the guarantee. This approach leaves the product provider neither with the potential for gains nor losses, yet the disadvantage is that less capital can be invested in the equity market.

For both interest rate scenarios and different investment horizons, Table G.1 compares the average guarantee costs charged to the participants for the baseline model's put hedge approach (Panel A, identical to Panel A of Table 1) and the share of the IRA contributions and subsidies allocated to bonds under the alternative strategy (Panel B). Note the difference, that with the put approach the guarantee costs are traded against portfolio insurance, whereas in the alternative strategy the bonds still belong to the participant.

With the alternative guarantee strategy and nominal interest rates of 3%, on average 56.4% of the contributions and subsidies must be allocated to risk-free bonds to ensure growth to the guarantee amount at retirement, and 43.6% can be allocated to stocks. If the investment horizon shortens, allocations to bonds increase, e.g., to 85.3% for a ten-year horizon, but this goes to the detriment of then even lower equity shares of only 14.7%. Compared to the equity allocations under the put hedge approach, the alternative guarantee mechanism severely limits the opportunities to benefit from a substantial equity risk premium. For the 0% interest rate scenario, all IRA capital must be allocated to risk-free bonds to provide for the guarantee, leaving no opportunity to invest in equities within the IRA.

Table G.2 compares consumption, liquid asset holdings, IRA balances, and IRA payouts generated from the model under the two strategies to provide for the guarantee, and for both interest rate and inflation scenarios. The columns labeled '*Put hedge approach*' repeat the values from the columns labeled '*With guarantee*' in Table 6.

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[39] Buying portfolio protection at plan initiation using a single premium (to be financed on top of the contribution) is also infeasible due to uncertainty about the size of future contributions.

The results demonstrate that the alternative guarantee mechanism in terms of consumption opportunities is much more expensive than the put hedge approach. In the scenario with nominal interest rates of 3% and inflation of 1.75% p.a., average consumption during the worklife is unaltered but post-retirement consumption is 3–9% lower. This results from a lower accumulation of IRA assets (down by 5–13% during the worklife and 22–23% during retirement), which cannot be fully compensated by higher liquid savings (up by 2–4% during the worklife and 1–8% during retirement).

For the scenario with interest and inflation rates of 0% p.a., the results suggest that the alternative guarantee mechanism is also inferior to the put hedge approach, though in relative terms it is associated with lower consumption losses than under the normal interest rate scenario (down by 2–6% during retirement versus 3–9% with the put hedge approach). This may be surprising given that the IRA then uses zero equity exposures. Here the fact becomes relevant that with the put hedge approach the participant trades the put premiums against compensation for losses below the guarantee amount (so the premium is no longer part of the IRA assets), but with the alternative mechanism, the bond investment in the IRA still belongs to the participant. The strong decrease in IRA balances (down by 52–65% during retirement and 38–39% post-retirement) is accompanied by a stronger increase in liquid savings (by about 7–17% during the worklife and 9–10% after retirement) than under the normal interest and inflation regime.

Hence, if the product provider instead of the put hedge approach used the alternative strategy to invest as much in risk-free bonds as required to achieve the guarantee amount at retirement, the improvement from abolishing the money-back guarantee from the IRA would increase even more. Noteworthy, the guarantee under the alternative mechanism becomes very costly in the normal interest rate scenario, too, so high guarantee costs are no longer primarily a concern only in the low return scenario.

Table G.1: Guarantee costs under Different Guarantee Mechanisms (as a % of total contributions)

Investment horizon (years)	42	30	20	10
***Panel A:* Guarantee Costs Charged under the Put Hedge Approach**				
$i_f = 3\%$	4.6	5.3	5.9	6.3
$i_f = 0\%$	25.7	22.0	18.3	13.4
***Panel B:* Required Bond Investment under the Alternative Mechanism**				
$i_f = 3\%$	56.4	65.3	74.4	85.3
$i_f = 0\%$	100.0	100.0	100.0	100.0

Note: Table G.1 reports, as a % of total contributions, the average guarantee costs under the put hedge approach (Panel A), and the average share allocated to risk-free bonds under the alternative guarantee mechanism (Panel B). The remaining capital in both cases is allocated to the stock market.

Table G.2: Model Results under Different Guarantee Mechanisms

Guarantee	Put hedge approach	Alternative mechanism	Put hedge approach	Alternative mechanism
i_f	3%		0%	
π	1.75%		0%	
***Panel A:* Consumption** (in €1,000 or percent of guarantee case)				
Age 25–45	15.05	100%	14.89	100%
Age 46–66	17.06	99%	16.50	100%
Age 67–84	16.26	96%	15.04	98%
Age 85–100	14.56	90%	11.78	96%
***Panel B:* Liquid Savings** (in €1,000 or percent of guarantee case)				
Age 25–45	12.74	104%	14.45	107%
Age 46–66	33.39	117%	47.90	122%
Age 67–84	30.20	124%	47.82	104%
Age 85–100	2.36	150%	5.12	108%
***Panel C:* IRA Balance** (in €1,000 or percent of guarantee case)				
Age 25–45	3.68	98%	1.20	9%
Age 46–66	51.70	72%	21.69	34%
Age 67–84	42.11	67%	16.27	69%
***Panel D:* IRA Payouts** (in €1,000 or percent of guarantee case)				
Age 67: lump sum	15.74	72%	9.57	79%
Age 68–84: drawdown	4.90	67%	1.86	69%
Age 85–100: annuity	7.83	68%	3.06	71%

Note: Table G.2 reports model results for both interest rate and inflation scenarios and both mechanisms to provide for the money-back guarantee. The tables reports consumption (Panel A), liquid and IRA asset holdings (Panels B and C), and IRA payouts (Panel D) in €1,000 for the put hedge approach, and as a percentage of that for the alternative guarantee strategy.

Online Appendix H: Changes in Capital Market Parameters

Our main analysis uses a moderate equity volatility of about 16% per annum, derived from euro-denominated total return data of the MSCI World, a globally diversified equity index that reflects the funds typically accumulated in Riester IRAs. To assess the impact of higher equity volatility on our model results, we also solve our model using an equity volatility of 21.41% and a slightly higher equity risk premium of 6%. These parameters align with investments in German blue chip stocks (represented by the DAX) estimated for the same period as the MSCI World return data (06/1991 – 12/2015).

Under the put hedge approach described in Section 2.2, the higher equity volatility directly increases the cost of providing the guarantee. Compared to earlier estimates from Panel A of Table 1, for plan horizons of 42 / 30 / 20 / 10 years in a normal interest rate scenario, guarantee costs rise to 9.7 / 10.7 / 11.2 / 10.9 percent of contributions, reducing the funds flowing into capital markets by 4.7–5.4 percentage points. In the low interest rate scenario, guarantee costs increase even more sharply to 35.8 / 30.8 / 25.7 / 19.0 percent of contributions, reducing capital market investments by 5.6–10.1 percentage points.

Compared to Table 6, in both interest rate scenarios, IRA balances and payouts with the guarantee are lower due to higher guarantee costs, and even the slightly higher equity risk premium cannot offset this negative impact. To compensate for reduced IRA savings, liquid savings are increased, but this is insufficient to maintain the old-age consumption levels shown in Table 6. However, abandoning IRA guarantees would result in even greater improvements in old-age consumption under higher equity volatility, albeit with worsening shortfall measures.

In utility terms, participants in the normal interest rate scenario would be willing to pay 0.7% (instead of 0.3%) of their age-25 cash on hand to opt out of the guarantee. For low interest rates, they would still be willing to give up 0.8% of age-25 financial resources to opt out of the guarantee. In accordance with the relative improvements in consumption with lower equity volatility, utility measures for all life cycle funds improve. Notably, the risk-tolerant life cycle glide path becomes particularly attractive, with investors willing to give up 1.6% (1.8%) of their age-25 cash on hand to switch from the guaranteed IRA to this life cycle strategy in the normal (low return) capital market environment due to a favorable balance of consumption and shortfall risk.

Further analyses of changes in capital market parameters show that our main conclusions remain robust even with a lower equity risk premium of only 4% per annum and in a scenario of persistent zero interest rates accompanied by positive inflation of 1.75% per year. Results are available upon request.

Table H.1: Model Results for a Higher Equity Volatility

Plan design	With guarantee	Without guarantee	Life cycle funds '100–age'	Life cycle funds '100-until-54, –5'	With guarantee	Without guarantee	Life cycle funds '100–age'	Life cycle funds '100-until-54, –5'
i_f	3%				0%			
π	1.75%				0%			
***Panel A:* Consumption** (in €1,000 or percent of guarantee case)								
Age 25–45	14.97	100%	100%	100%	14.83	100%	100%	100%
Age 46–66	16.67	101%	99%	100%	16.09	101%	100%	101%
Age 67–84	15.78	102%	94%	99%	14.29	103%	98%	102%
Age 85–100	14.19	104%	88%	100%	11.35	109%	99%	106%
***Panel B:* Liquid Savings** (in €1,000 or percent of guarantee case)								
Age 25–45	12.56	99%	104%	98%	14.11	96%	100%	93%
Age 46–66	34.44	98%	99%	90%	44.10	90%	93%	86%
Age 67–84	27.35	92%	101%	88%	36.94	83%	89%	83%
Age 85–100	1.58	89%	78%	70%	2.27	65%	74%	66%
***Panel C:* IRA Balance** (in €1,000 or percent of guarantee case)								
Age 25–45	3.74	109%	80%	117%	1.15	237%	170%	288%
Age 46–66	49.21	112%	79%	115%	21.99	167%	121%	180%
Age 67–84	42.23	113%	69%	101%	18.44	156%	102%	142%
***Panel D:* IRA Payouts** (in €1,000 or percent of guarantee case)								
Age 67: lump sum	14.52	112%	67%	99%	9.32	131%	95%	123%
Age 68–84: drawdown	4.93	113%	69%	101%	2.12	156%	101%	142%
Age 85–100: annuity	7.71	113%	69%	101%	3.33	150%	100%	138%
***Panel E:* Share of Consumption and Housing Costs Financed by IRA Payouts** (%)								
Age 68–84: drawdown	19.5	21.6	14.4	19.9	9.2	13.8	9.5	12.8
Age 85–100: annuity	32.0	34.8	24.5	32.3	16.7	23.4	16.8	21.8
***Panel F:* IRA Shortfall Probability** (%)								
Age 67	0.0	7.5	1.1	3.4	0.0	20.4	19.0	17.2
***Panel G:* Change in Cash on Hand Providing the Same Utility as the Guarantee Case** (%)								
Age 25	–	–0.7	+1.5	–1.6	–	–0.8	+1.9	–1.8

Note: Table H.1 reports model results when using a higher equity volatility of 21.41% and a higher equity risk premium of 6%. The table complements Table 6 which presents outcomes for the baseline scenario of a 15.96% equity volatility and a slightly lower equity risk premium of 5.68%. All other explanations are identical to those of Table 6.

Online Appendix I: Generalizing to International Settings

The results presented in the main part of the paper are based on a model calibration that reflects the specific regulations of the Riester IRA, as well as the German institutional framework. In this appendix, we confirm that the negative implications of a mandatory money-back IRA guarantee are not due to uniquely German economic factors, but rather are relevant to other countries as well.

Despite cross-national differences in tax systems, most developed countries have progressive income taxes under which high earners are subject to higher tax rates than lower earners (see Bunn and Asen 2020, and Online Appendix A for the German case). Most developed nations also require contributions to a mandatory state-run pay-as-you-go plan automatically deducted from payrolls that entitle retirees to a lifelong pension income stream. Access to health insurance usually is gained from automatic payroll deductions, while, of course, the costs and levels of coverage vary. The German multi-payer health insurance system, which is financed via payroll deductions, also has insurers facing competition to attract customers; as such, it falls between the centrally organized single-payer system common in the European Union, and the mostly market-based system of the U.S. (Hussey and Anderson 2003, Thomson et al. 2013). Therefore, the German tax and social security system can be seen as relevant for many developed countries.

To generalize the setup of the IRA beyond the German Riester, here we make two adjustments. First, we assume no payment of subsidies, but we keep the tax deductibility of contributions of up to €2,100 per year. Exclusion of the subsidy is motivated by the argument that IRAs are not always accompanied by matching of contributions by a generous third party (like the government in case of the Riester IRA, or the employer in U.S. 401(k) plans). Second, we allow for flexible withdrawals during the entire decumulation phase. We retain the deferred annuity within the retirement account, as in the German case, since the recent passage of the SECURE Act in the United States has rendered these insurance products an accepted default solution (Horneff et al. 2020). Moreover, the literature agrees that annuities are an effective means of controlling longevity risks (e.g., Davidoff et al. 2005, Horneff et al. 2008). Both adjustments to the IRA harmonize its setup with respect to international standards. The absence of subsidies in the model results in lower demand for the IRA, but the less restrictive withdrawal rules make the account more valuable.

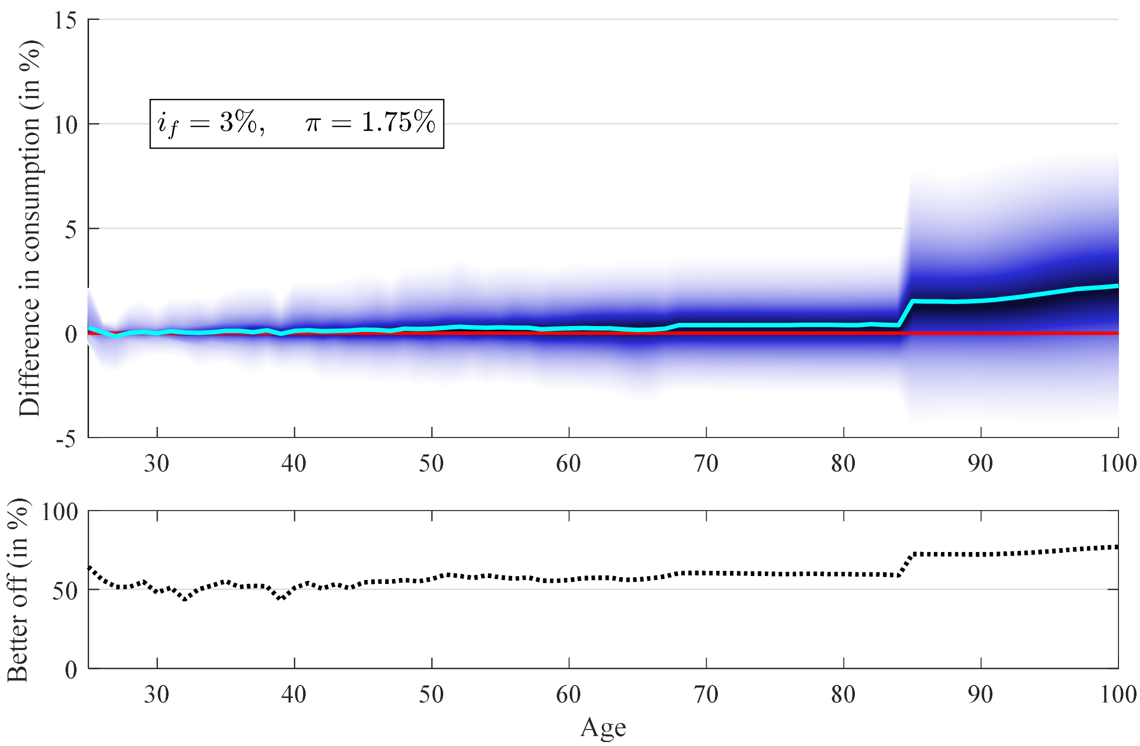
Analogous to Figure 3, the path-wise consumption differences between the internationally harmonized IRA with and without a guarantee are shown in Figure I.1 for the normal interest rate scenario. The average consumption improvement from abolishing the guarantee remains positive and economically significant. By the end of the accumulation phase, the average consumption surplus without a guarantee has grown to 1.04%, and from age 68 to 84 it amounts to about 1.9%. After the deferred annuity starts paying, the consumption surplus increases to 4.6–5.0% per year.

Compared to the German IRA setup, consumption differences until retirement are almost unaltered. Due to the flexible withdrawals permitted in this internationally harmonized IRA, the consumption surplus is about 0.4 percentage points higher in the first 11 years of retirement. Consumption for both the German and the internationally harmonized setup rises strongly at age 85 when the deferred annuity starts paying, yet the increase is stronger for the internationally harmonized IRA. This is the consequence of a seemingly higher relative attractiveness of the no-guarantee versus the guarantee IRA in the international setup. In that context, IRA savings at retirement and annuity payouts without the guarantee compared to the guarantee case are three percentage points higher than in the German setup (14% versus 11%), leading to superior consumption improvements at the oldest ages. In summary, with respect to the variation of consumption surpluses around the mean, there are no substantial differences between results with the Riester model and the internationally harmonized IRA.

Table I.1 quantifies the differences in consumption, liquid asset holdings, and IRA balances and payouts for the internationally harmonized IRA, which may be compared to the Riester results in Table 6. Overall, the effects of abolishing the guarantee on consumption are even larger for the internationally harmonized IRA, yet IRA balances are lower, indicating that the benefits from allowing self-selected withdrawals do not offset the lack of subsidies. The slightly higher consumption difference in the low interest rate scenario for the internationally harmonized IRA from age 60–79 results from the fact that allowing flexible withdrawals causes more front-loaded payouts.

In sum, even using a more general framework for the IRA environment, the results still show that a money-back guarantee erodes most participants' average consumption.

Figure I.1: **Consumption Differences and Percent Better off by Age Without versus With the IRA Guarantee: International Context (Base Case)**



Note: The fan chart at the top of Figure I.1 illustrates path-wise differences in non-housing consumption drawn from 100,000 simulated optimal life cycles for internationally harmonized IRAs without versus with a money-back guarantee. For the internationally harmonized IRA in comparison to the Riester IRA two changes are assumed. First, the account is not subsidized by matching contributions; second, the participant can freely take withdrawals from age 67 until age 84. The cyan line represents the mean consumption difference, while darker areas indicate a higher probability density (between the 5 and 95% quantiles). Differences are expressed as a percent of optimal consumption with the money-back guarantee. The bottom panel shows the percentage of individuals with higher optimal consumption without versus with the money-back guarantee. For further notes on base case parameters see Figure 1.

Table I.1: Impacts of Different Guarantees: International Context

Guarantee	With	Without	With	Without
i_f	3%		0%	
π	1.75%		0%	
***Panel A:* Consumption** (in €1,000 or percent of guarantee case)				
Age 25–45	15.02	100%	14.91	100%
Age 46–66	17.02	100%	16.45	101%
Age 67–84	16.36	100%	14.92	103%
Age 85–100	14.98	102%	11.62	113%
***Panel B:* Liquid Savings** (in €1,000 or percent of guarantee case)				
Age 25–45	11.94	98%	14.76	87%
Age 46–66	31.78	97%	49.99	74%
Age 67–84	34.46	94%	52.34	79%
Age 85–100	2.75	88%	5.65	59%
***Panel C:* IRA Balance** (in €1,000 or percent of guarantee case)				
Age 25–45	4.77	106%	0.67	500%
Age 46–66	54.93	104%	17.28	250%
Age 67–84	35.69	107%	9.13	241%
***Panel D:* IRA Payouts** (in €1,000 or percent of guarantee case)				
Age 67: lump sum	13.86	104%	9.53	144%
Age 68–84: drawdown	5.09	107%	1.48	230%
Age 85–100: annuity	8.18	106%	2.64	205%
***Panel E:* Share of Consumption and Housing Costs Financed by IRA Payouts** (%)				
Age 68–84: drawdown	19.2	20.4	6.0	13.3
Age 85–100: annuity	32.6	34.1	13.0	24.1
***Panel F:* IRA Shortfall Probability** (%)				
Age 67	0.0	1.9	0.0	9.7
***Panel G:* Change in Cash on Hand Providing the Same Utility as the Guarantee Case** (%)				
Age 25	–	–0.5	–	–1.3

Note: Panels A–D of Table I.1 show mean values (in €1,000) by age of annual non-housing consumption, liquid assets, IRA balances, and payouts, for an internationally harmonized IRA. Results for columns labeled '*Without'* indicate the percent of the respective guarantee values. Two changes are assumed compared to the base case. First, the account is not subsidized by matching contributions; second, the participant can freely withdraw from age 67 until age 84. Panel E quantifies the share (in %) of both consumption and housing costs financed by after-tax payouts from the IRA. Panel F reports the share of simulations where the IRA value at retirement falls short of the sum of contributions and subsidies. Panel G presents the percentage change in cash on hand at age 25 for which a switch to the alternative plan design yields the same lifetime utility as the guarantee. IRA assets are held entirely in stocks until retirement (protected with the hedges described above), while after retirement only 20% is allocated to stocks and 80% to bonds. Averages are generated using 100,000 simulation optimal life cycle paths (all in real terms). For further notes on base case parameters see Figure 1.

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