Rethinking the Annuity Puzzle: The Role of Loss Aversion and Money-Back Guarantees

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Motivation

- Milevsky and Salisbury (2022) document a switch from life-only to refundable annuities in U.S. annuity price quotes over the last decade. Payout guarantees are also common in Germany.

- Refraining from life-only annuities due to a fear of not recouping the annuity premium?
  - Hu and Scott (2007): „*So, retirees may tend to evaluate annuities from the gamble perspective: Will I live long enough to make back my initial investment in this annuity?*“

- In a life-cycle model of consumption and portfolio choice, we steer annuitization behavior in deferred life-only and refundable annuities by penalizing anticipated losses from life-only annuities directly in the preference structure.
  - Flexibly controls life-only annuity demand; shifts demand to refundable annuities.
  - Not resolving the annuity puzzle, but overcomes dominance of life-only annuities.

Life-Only vs. Refundable Annuities

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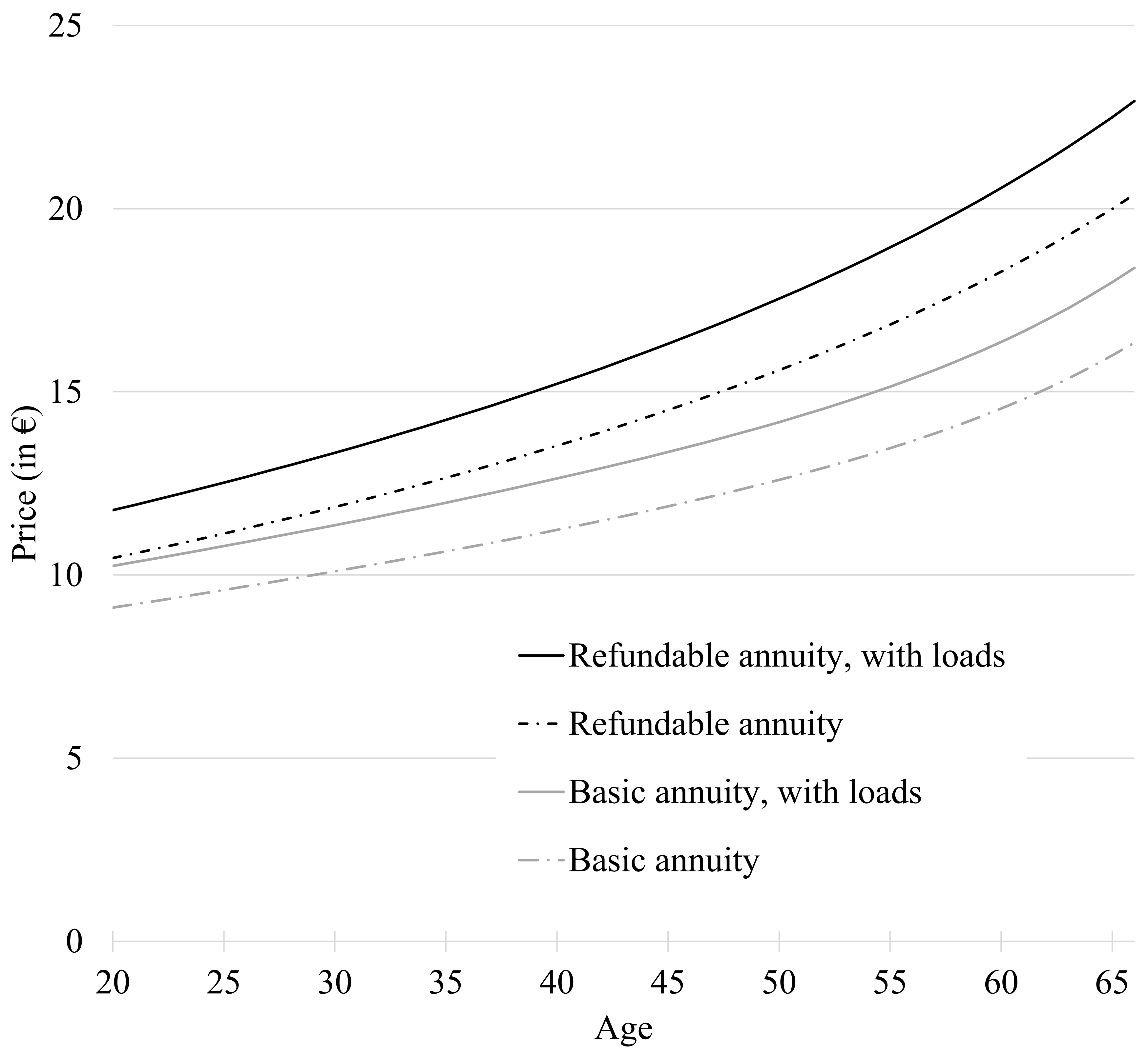
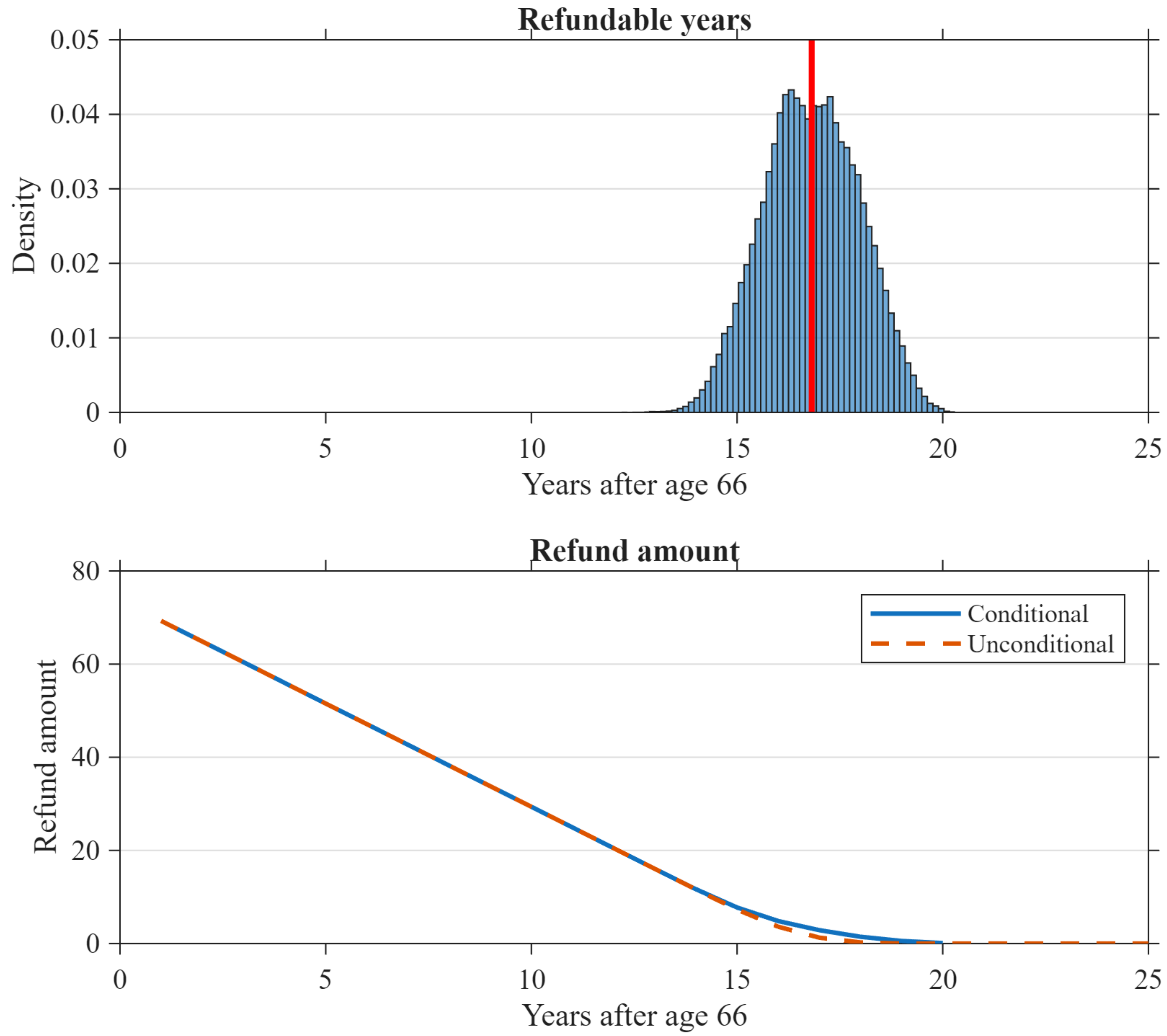
- Life-only (basic) annuity: constant, lifelong payout of one currency unit (life component). ▶ Pricing

- Refundable annuity: complemented by a refund component:
  - If annuitant dies before annuity payouts exceed the paid premiums: lump-sum cash payment of the difference to heirs.
  - Refundable annuity price = Life-only price + probability-weighted PV of refund payments.
  - Discretized version of Milevsky and Salisbury's (2022) pricing equation. ▶ Pricing

- Our life-cycle model:
  - Can buy deferred annuities during working periods $t < K$.
  - Payouts start from the retirement period $t = K$ onward.
  - Expense loading factor δ = 12.5% charged.

Annuity Prices ($\delta = 0.125$)





- Deferred until retirement age 67.
- Duration of refundable period depends on annuity prices and timing of purchases.

Model with Life-Only Annuities

- Individuals decide on consumption and investments in stocks, risk-free bonds, and the life-only annuity ($t < K$) that pays after retirement ($t \geq K$).
- Institutional framework of Germany:
  - Taxation of income, capital gains, annuity payouts, and inheritance
  - Social security (contributions to health, unemployment, and pension insurance; pension benefits)
  - Housing costs (% of net income)
  - $$X_{t+1} = \begin{cases} (Y_{t+1} - \tau_{t+1}^{SST})(1-\eta_{t+1}) + S_t R_{t+1} + B_t R^f - \tau_{t+1}^{CG} & \text{for } t < K-1 \\ (Y_K - \tau_{t+1}^{SST})(1-\eta_{t+1}) + A_{t+1} - \tau_{t+1}^{A_{t+1}} + S_t R_{t+1} + B_t R^f - \tau_{t+1}^{CG} & \text{for } t \geq K-1 \end{cases}$$
- CRRA preferences, with a bequest motive (following Kraft et al. (2022)).

▶ Details

$$V_t(X_t, s_t, A_t) = \max_{C_t, S_t, B_t, (D_t)} \left\{ C_t^{1-\gamma} + \beta \sum_s q_{s_t,s}\, \mathbb{E}_t \left[p_t \left(V_{t+1}(X_{t+1}, s_{t+1} = s, A_{t+1}) \right)^{1-\gamma} + (1-p_t)\tilde{b}^{\gamma} Q_{t+1}^{1-\gamma} \right] \right\}^{\frac{1}{1-\gamma}}$$

▶ Numerics

Model with Refundable Annuities

- Can instead buy lump-sum refundable annuities during working life
  $\Rightarrow$ investment amount (W_t) as control variable, and number of annuities (L_t) as state variable.

- Refundable amount (Z_{t+1}) as additional continuous state variable with dynamics:

$$Z_{t+1} = \begin{cases} Z_t + \dfrac{W_t}{(1+\delta)} & \text{for } t < K \\ \max(Z_t - L_t, 0) & \text{for } t \geq K \end{cases}$$

- The refundable amount is added to the bequest amount:

$$Q_{t+1} = S_t R_{t+1} + B_t R^f + Z_{t+1} - \tau_{t+1}^{inh} - \tau_{t+1}^{CG}$$

- The Bellman equation:

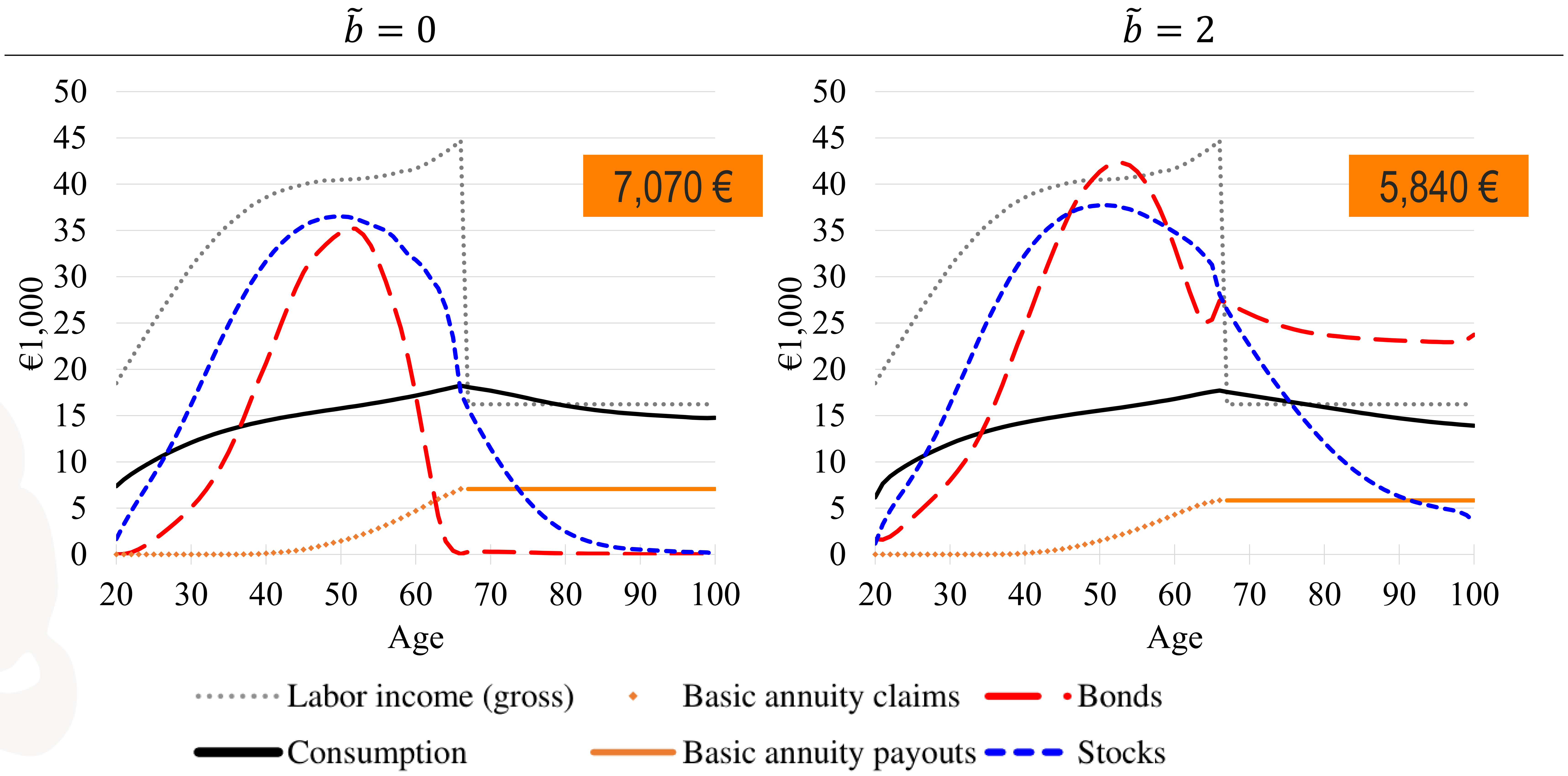
$$V_t(X_t, s_t, L_t, Z_t) = \max_{C_t, S_t, B_t, (W_t)} \left\{ C_t^{1-\gamma} + \beta \sum_s q_{s_t,s}\, \mathbb{E}_t \left[p_t \big(V_{t+1}(X_{t+1}, s_{t+1} = s, L_{t+1}, Z_{t+1})\big)^{1-\gamma} + (1-p_t)\tilde{b}^{\gamma} Q_{t+1}^{1-\gamma} \right] \right\}^{\frac{1}{1-\gamma}}$$

Model Calibration

Parameter	Calibration
T	81
K	48
β	0.96
γ	5
m	0.0363
v^2	$0.21^2 = 0.0441$
R^f	$e^{0.01} \approx 1.01$
δ	0.125

- Discretized labor income process calibrated using SOEP data (► Details).
- Age-dependent housing costs also estimated using SOEP data, range $\eta_t \in [0.3132; 0.4215]$.
- Tax rates, tax exemptions, contributions to social security system as well as pension system rules are calibrated according to German laws.
- German population unisex mortality table (laws of 2018).

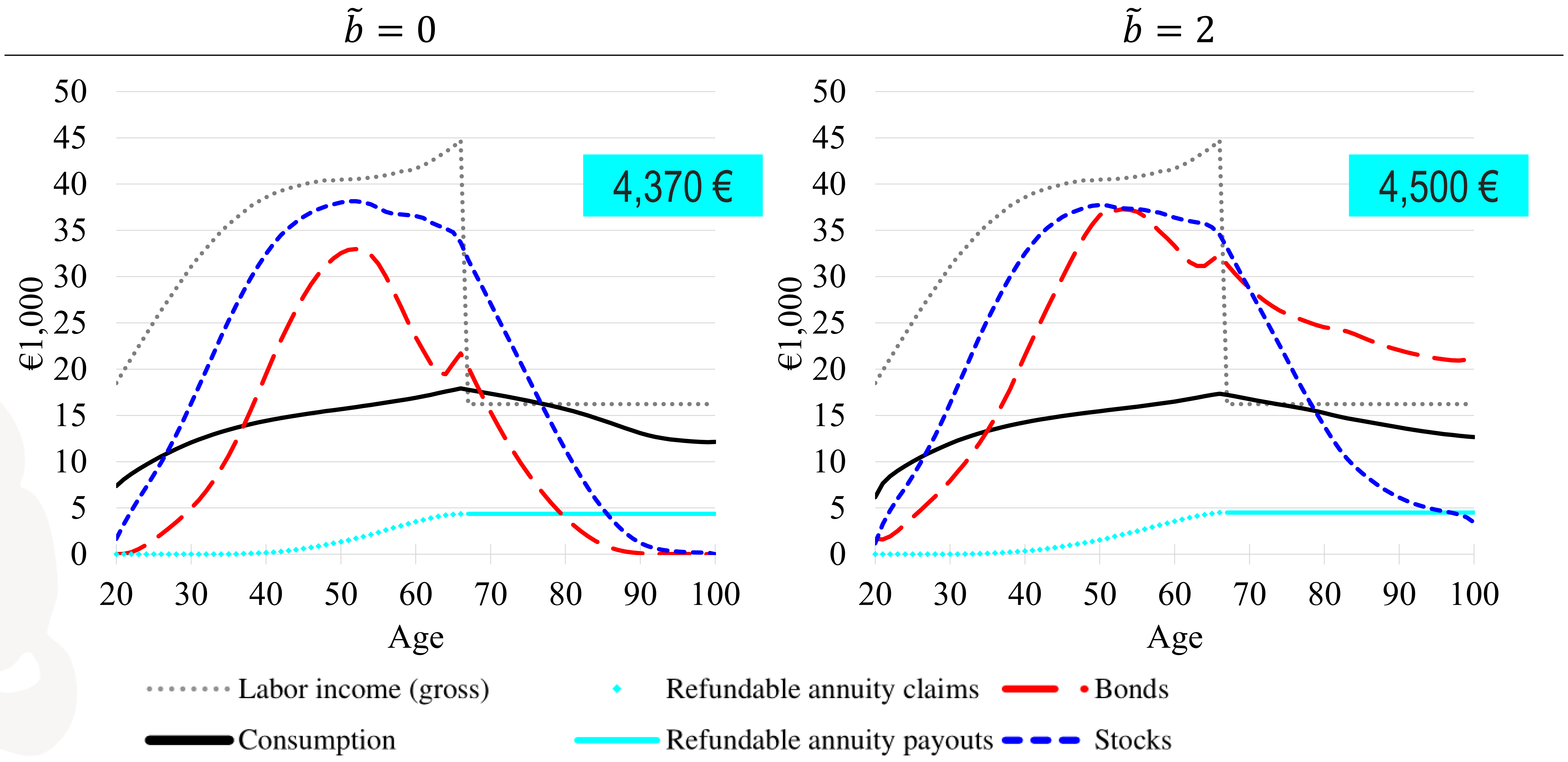
Model with Life-Only Annuities: Role of a Bequest Motive
(assuming no loss aversion)



▶ Asset allocation

- A bequest motive indeed lowers annuity demand (Friedman and Warshawsky 1990; Lockwood 2012).
- Holdings still remain too high given the low empirical uptake.

Model with Refundable Annuities
(assuming no loss aversion)



► Asset allocation

- Higher refundable annuity prices yield lower accumulation, even with a bequest motive.
- With a bequest motive, the refund component increases attractiveness of refundable annuities (≠ life-only).

Loss Aversion in an Annuity Context (1)

- Demand for annuities is considerable due to benefits in consumption smoothing and attractive returns under CRRA preferences.

- Idea: incorporate a loss aversion term in the preference structure to account for reluctance to buy annuities due to fear of dying before recouping the paid premium.
  - Consistent with the deliberations of Hu and Scott (2007)

- Applies differently to life-only and refundable annuities.
  - Life-only annuities: Both losses from the annuity and charged price loadings are subject to loss aversion.
  - Refundable annuities: Only price loadings are subject to loss aversion. We assume the refundable annuity only makes compensatory payments up to the "unloaded" (fair) premium.

Loss Aversion in an Annuity Context (2)

- Modified Bellman equation with parameter λ measuring the strength of loss aversion and Λ_t^{basic} and Λ_t^{ref} representing the two loss amounts at time t.

- Value function in its most general form (under accumulation of both annuity types)

$$V_t\left(X_t, s_t, A_t, L_t, Z_t, \Lambda_t^{basic}\right)$$
$$= \max_{C_t, S_t, B_t, D_t, W_t} \left\{ C_t^{1-\gamma} \right.$$
$$+ \beta \sum_s q_{s_t,s}\, \mathbb{E}_t \left[p_t \vartheta_t \left(V_{t+1}\left(X_{t+1}, s_{t+1} = s, A_{t+1}, L_{t+1}, Z_{t+1}, \Lambda_{t+1}^{basic}\right)\right)^{1-\gamma} + (1-p_t)\tilde{b}^{\gamma} Q_{t+1}^{1-\gamma} \right.$$
$$\left.\left. + (1-p_t)\left(\frac{1}{\lambda \cdot \left(\Lambda_{t+1}^{basic} + \Lambda_{t+1}^{ref}\right)}\right)^{1-\gamma}\right]\right\}^{\frac{1}{1-\gamma}}.$$

► More details

Annuity accumulation: The Role of Bequest and Loss Aversion

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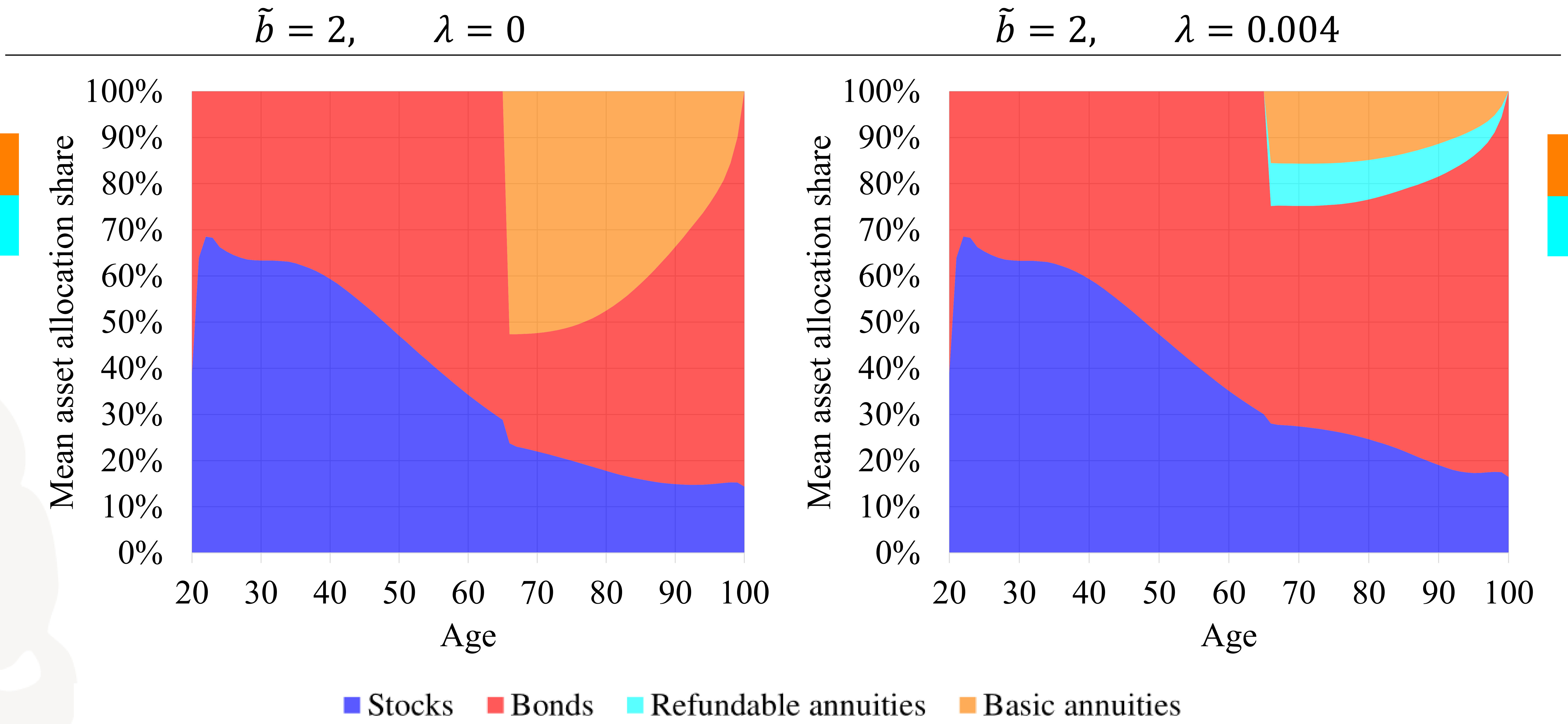
Loss aversion scale λ	Basic annuities			Refundable annuities		
	Bequest strength $\tilde{b}$			Bequest strength $\tilde{b}$		
	0	2	4	0	2	4
0.000	7.07	5.84	4.79	4.37	4.50	4.43
0.001	4.87	4.42	3.98	4.36	4.50	4.42
0.002	3.34	3.07	2.92	4.27	4.49	4.44
0.003	2.68	2.60	2.52	4.22	4.47	4.44
0.004	2.15	2.07	2.01	4.16	4.44	4.45
0.005	1.80	1.74	1.70	3.97	4.30	4.43
0.006	1.51	1.51	1.50	3.77	4.18	4.36
0.007	1.34	1.34	1.33	3.60	3.98	4.31
0.008	1.22	1.20	1.19	3.46	3.81	3.96
0.009	1.09	1.11	1.10	3.36	3.56	3.63
0.010	0.99	1.01	0.99	3.17	3.36	3.50

- Flexibly steering life-only annuity accumulation, but refundable annuities demand more robust.
- Powerful when other factors (e.g., bequest, health risks, …) suggest too high annuity demand.

Model with Both Annuity Types and Annuitization only in $t = K - 1$

5,250 €

0 €



1,010 €

1,160 €

▶ LC profiles

- For $\tilde{b} = 2$, loss scaling $\lambda = 0.004$ induces dominance of refundable annuities over life-only annuities (in present values, not in payouts).
- Consistent with evidence in Germany: 55% of annuities include guarantees.

Conclusion

- Research still finds widespread under-annuitization despite the appeal of annuities in normative models:
  "*The annuity puzzle remains a puzzle*" (Peijnenburg et al. 2016).
- Trend towards refundable annuities in the U.S. market. Guarantees also embedded in the majority of annuities in Germany.
- Do investors refrain from annuities due to fear of not recouping the premiums?
- Introduce annuity-related loss aversion as a mechanism to steer their appeal.
  - Can flexibly reduce the demand for life-only annuities.
  - In a model with basic and refundable annuities, reduces investment in basic annuities and brings relation between annuity types closer to observed data.
  - **However:** still too much total annuity demand.

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Thank you very much!

Do you have any questions?

BACKUP

Annuity Pricing: Life-Only Annuities

- In our model, household can buy deferred annuities during working periods $t < K$
- Annuity payout of 1 starting in first retirement period $t = K$, constant payouts to annuitant until death
- Following Horneff et al. (2010), the fair annuity factor h_t is given by:

$$h_t = ({}_{K-t}p_t)\left(R^f\right)^{-(K-t)} \sum_{u=0}^{T-K} ({}_{u}p_K)\left(R^f\right)^{-u}, \qquad t < K$$

where ${}_d p_a$ denotes the probability of living for another d periods conditional on still being alive in period a, R^f represents the gross risk-free rate, T is the deterministically chosen final model period

- We use identical mortality tables for annuity pricing and in Bellman equation, thus actuarial and household-subjective survival probabilities coincide by assumption
- Expense loading factor $\delta = 0.125$ charged on fair price.

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Annuity Pricing: Lump-Sum Refundable Annuities

- Annuity payout of 1 starting in first retirement period $t = K$, constant payouts to annuitant until death
- In case of death, heirs receive the following lump-sum cash payment: annuity premium minus benefits already paid out ⇒ “money-back guarantee”
- A discretized version of the fair annuity factor of Milevsky and Salisbury (2022) for a lump-sum refundable annuity (h_t^*) reads ($t < K$):

$$h_t^* = h_t + \sum_{u=0}^{K-t-1} h_t^* ({}_u p_t)(1 - p_{t+u}) \left(R^f\right)^{-(u+1)}$$
$$+ \sum_{u=1}^{T-K+1} \max(h_t^* - u, 0)({}_{u-1} p_K)(1 - p_{K+u-1}) \left(R^f\right)^{-(K+u-t)}$$

where p_t denotes the probability to survive until period $t + 1$ conditional on still being alive in period t

- Expense loading factor $\delta = 0.125$ charged on fair price.

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Empirical Observations: U.S.

- Milevsky and Salisbury (2022) document that refundable income annuities made up the majority of price quotes in the U.S. in Q1-2021.

Market quotes for Income Annuities (IA) in the U.S., compiled directly by the authors based on aggregate data provided by CANNEX Financial Exchanges from their quarterly distributor activity survey experience. Note over the last decade the sharp increase in demand for *cash refund* and *instalment refund* IAs, and corresponding decline in *life only* IAs.

Type of income Annuity	Q1.2021	Q4.2011
Life Only (with no guarantee)	10.6%	25.3%
Life with Period Certain	30.0%	56.2%
Refundable: Cash or Instalment	59.4%	18.5%
TOTAL:	**100%**	**100%**

- Note: Number of price quotes ≠ number of purchases

Empirical Observations: Germany

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- Refundable annuities not exactly available in the German annuity market. Instead and closely related: annuities with a guaranteed number of payout periods

- Distribution of the guarantee periods in the portfolio of a major German insurance company:

Guarantee period (in years)	Share	
None	44.6%	*Basic annuities*
1 – 5	14.8%	*Annuities with a guarantee component*
6 – 10	16.2%	
11 – 15	12.0%	
16 – 20	8.6%	
> 20	3.8%	
Total	**100%**	

- Use the 45:55% relationship as a benchmark/target for our model

Annuity Puzzle

- Behavioral explanations:
  - Bequest motives: Friedman and Warshawsky (1990), Lockwood (2012)
  - Loss aversion: Thaler and Benartzi (2004), Hu and Scott (2007)
  - Narrow framing: Brown et al. (2008)
- Intra-family insurance: Kotlikoff and Spivak (1981)
- Health cost risk: Sinclair and Smetters (2004), Peijnenburg et al. (2015)
- Ambiguous life expectancy: Han and Hung (2021)
- Risk aversion: Bommier and Le Grand (2014)
- Market imperfections: Finkelstein et al. (2013), Milevsky and Salisbury (2022)
- Subjective survival beliefs: Inkmann et al. (2011) , O'Dea and Sturrock (2023), Jeong et al. (2025)
- …

Matching Empirical Observations?

- Calibrate model to German financial market data, labor income data and institutional setup
- Use time discount factor, relative risk aversion parameter and bequest parameters based on related literature
- **Run model with both annuity types and loss aversion and see whether loss aversion helps to better match the German data on annuity holdings of private households**

Utility Specification

- Standard CRRA preferences for consumption (C_t), where γ measures relative risk aversion:

$$u(C_t) = \begin{cases} \frac{{C_t}^{1-\gamma}}{1-\gamma} & \gamma > 0, \gamma \neq 1 \\ \log(C_t) & \gamma = 1 \end{cases}$$

- Utility specification for bequest amount (Q_{t+1}) following Cocco et al. (2005):

$$v(Q_{t+1}) = \frac{b}{1-\gamma}(Q_{t+1})^{1-\gamma}$$

where b intended to measure strength of bequest motive

- However, Kraft et al. (2022) find that a more appropriate representation reads (formally proven only for deterministic bequest in $t = T + 1$):

$$v(Q_{T+1}) = \frac{\tilde{b}^{\gamma}}{1-\gamma}(Q_{T+1})^{1-\gamma}$$

where $\tilde{b}$ specifies the strength of the bequest motive

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Labor Income Process

- Like in Liebler (2022), the labor income process is discretized to $n_s = 10$ different labor income states

- Labor income $Y_{i,t,s}$ of individual i in labor income state s in period t is given by:

$$Y_{i,t,s} = \begin{cases} \exp\big(f_s(t)\big) \cdot U_{i,t,s} \quad \mid s_t = s & \text{for } t < K \\ \exp\big(f_i(K)\big) & \text{for } t \geq K \end{cases}$$

  where $\exp\big(f_s(t)\big)$ is the age- and state-dependent deterministic income component and $U_{i,t,s}$ denotes an individual-specific transitory income shock conditional on being in state s

- Stochastic migration between states according to first-order Markov process during working life

- Transitory shocks during working life assumed to be i.i.d. lognormally distributed with mean of 1:

$$\ln\big(U_{i,t,s}\big) \sim \mathcal{N}\left(-\sigma_{u,s}^2/2\,,\sigma_{u,s}^2\right)$$

- Constant retirement income $\exp\big(f_i(K)\big)$ determined for individual i by German pension point system

◄ Back

Baseline Model: Investment Universe and Institutional Set-Up

- Household can invest in:
  - Bonds with gross return R^f assumed to be both default-free and constant over time
  - Stocks with gross return R_{t+1}, which is i.i.d. lognormally distributed:

$$R_{t+1} \sim \mathcal{LN}(m, v^2)$$

  - During working life: Life-only annuities with payouts deferred to $t = K$

- Institutional set-up aims to replicate situation in Germany. This includes:
  - Taxation of income, capital gains, annuity payouts, and inheritance
  - Social security (contributions to health-, unemployment-, and pension insurance; pension benefits)

Baseline Model: Budget Constraint and Dynamics

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- Budget constraint w.r.t. cash-on-hand (X_t):

$$X_t = \begin{cases} C_t + S_t + B_t + D_t & \text{for } t < K \\ C_t + S_t + B_t & \text{for } t \geq K \end{cases}$$

- All control variables, i.e. consumption (C_t) as well as investment in stocks (S_t), bonds (B_t) and life-only deferred annuities (D_t) have to be non-negative
- Dynamics of number of life-only annuities (A_{t+1}):

Working period: $A_{t+1} = A_t + \frac{D_t}{\ddot{h}_t}$ Retirement period: $A_{t+1} = A_t$

- Dynamics of cash-on-hand:

$$X_{t+1} = \begin{cases} \left(Y_{t+1} - \tau_{t+1}^{SST}\right)(1 - \eta_{t+1}) + S_t R_{t+1} + B_t R^f - \tau_{t+1}^{CG} & \text{for } t < K-1 \\ \left(Y_K - \tau_{t+1}^{SST}\right)(1 - \eta_{t+1}) + A_{t+1} - \tau_{t+1}^{A_{t+1}} + S_t R_{t+1} + B_t R^f - \tau_{t+1}^{CG} & \text{for } t \geq K-1 \end{cases}$$

where the various τ_{t+1}-terms represent taxation and η_{t+1} measures the share of housing costs

Baseline Model: Optimization Problem in Recursive Form

- The optimization problem can be written in recursive form (Bellman, 1957):

$$V_t(X_t, s_t, A_t) = \max_{C_t, S_t, B_t, (D_t)} \left\{ C_t^{1-\gamma} + \beta \sum_s q_{s_t,s} \, \mathbb{E}_t \left[p_t \big(V_{t+1}(X_{t+1}, s_{t+1} = s, A_{t+1}) \big)^{1-\gamma} + (1 - p_t) \tilde{b}^{\gamma} Q_{t+1}^{1-\gamma} \right] \right\}^{\frac{1}{1-\gamma}}$$

- Value function ($V_t(\cdot)$) depends on time, two continuous state variables and the labor income state
- $q_{s_t,s}$ denotes the conditional migration probability between labor income states
- Entire equation expressed in certainty equivalence form (e.g. Gomes and Michaelides, 2005)
- The bequest amount (reduced by inheritance tax (τ_{t+1}^{inh}) and capital gains tax (τ_{t+1}^{CG})) is given by:

$$Q_{t+1} = S_t R_{t+1} + B_t R^f - \tau_{t+1}^{inh} - \tau_{t+1}^{CG}$$

Numerical Solution Methods

- **Backward recursion** after initial optimization in final period T
- **Discretization of state space** (grid equidistant in logs):
  - Cash-on-hand: $X \in [0.01; 500]$, 17 grid points
  - Number of life-only annuities: $A \in [0; 300]$, 15 grid points
  - Number of lump-sum refundable annuities: $L \in [0; 30]$, 11 grid points
  - Refundable amount: $Z \in [0; 300]$, 11 grid points
- Evaluate expectation operator in Bellman equation via **Gauss-Hermite quadrature** with 8 discrete nodes per variable (Miranda and Fackler, 2004; Cai, 2009)
- **Multivariate cubic spline interpolation** to approximate next period's value function (Judd, 1999; Cai, 2009; Anton and Rorres, 2013)
- **Optimization** algorithm behind **"fmincon"** determines policy functions
- Finally, **Monte Carlo simulations** over the lifecycle with $100{,}000$ paths based on policy functions and assumption of zero initial wealth

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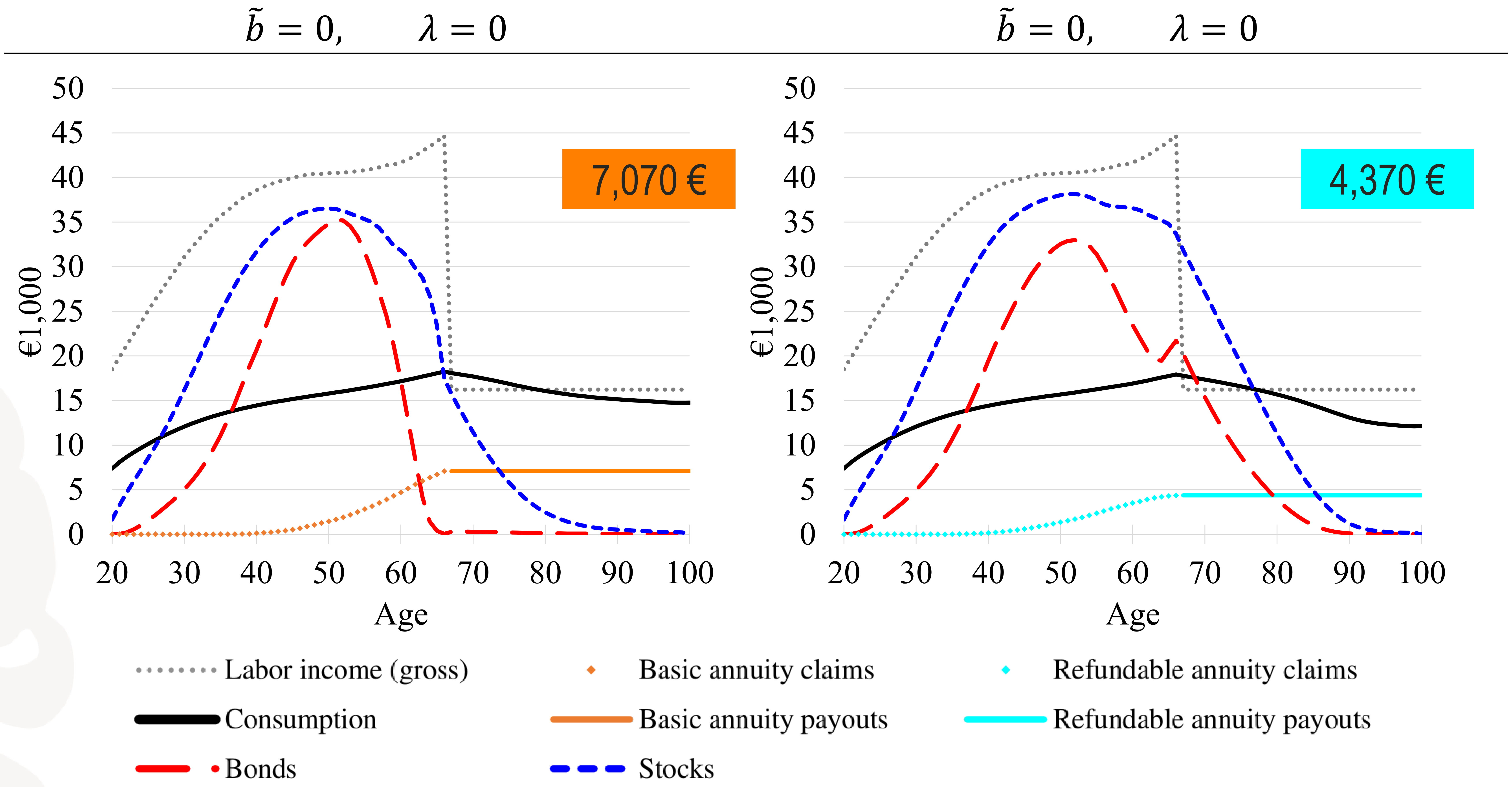
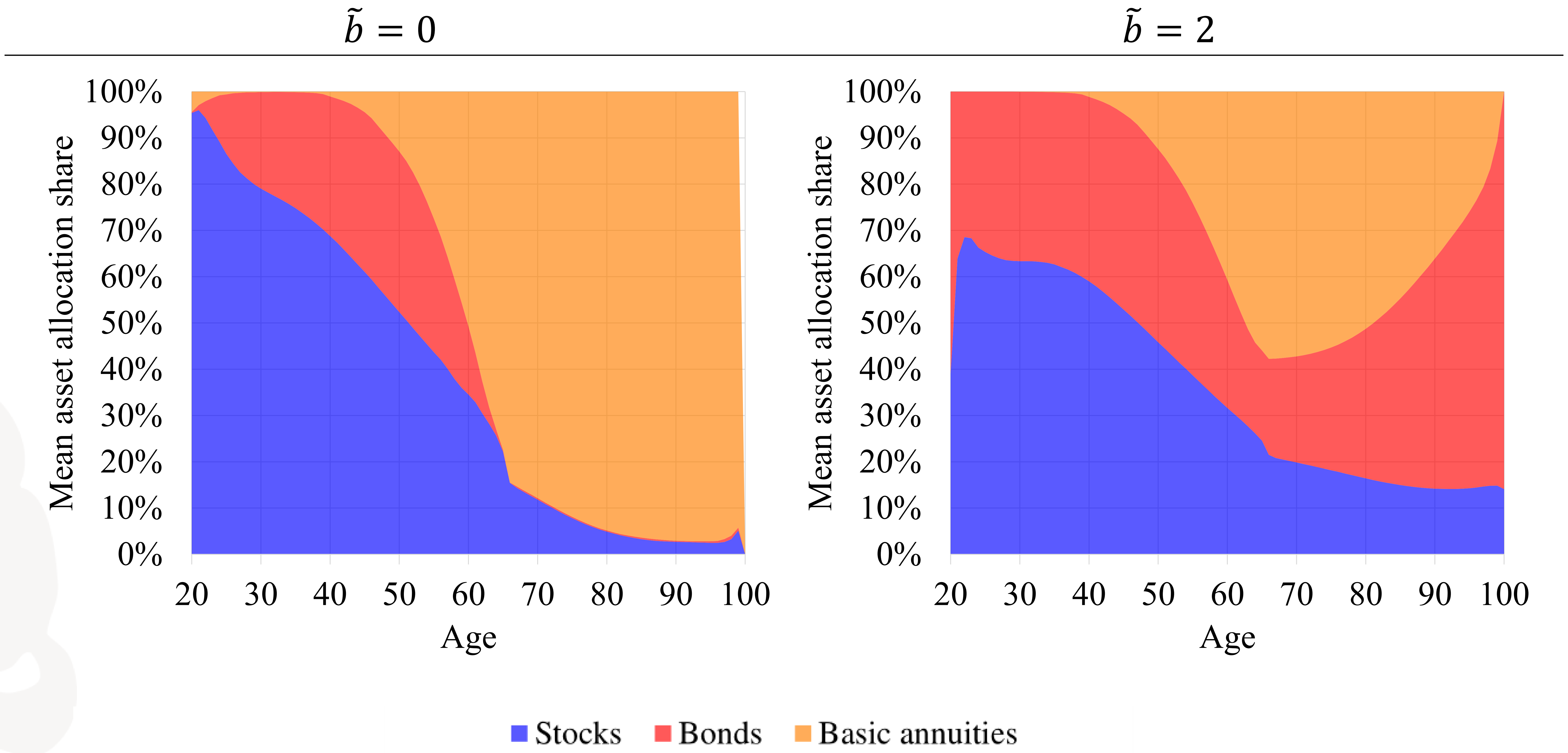
Isolating the Importance of the Annuity Price: No Bequest



⟹ Utility from bequest motive must offset the negative impact of higher refundable annuity prices

Model with Life-Only Annuities: Role of a Bequest Motive (2)



⟹ Big changes in the post-retirement asset allocation

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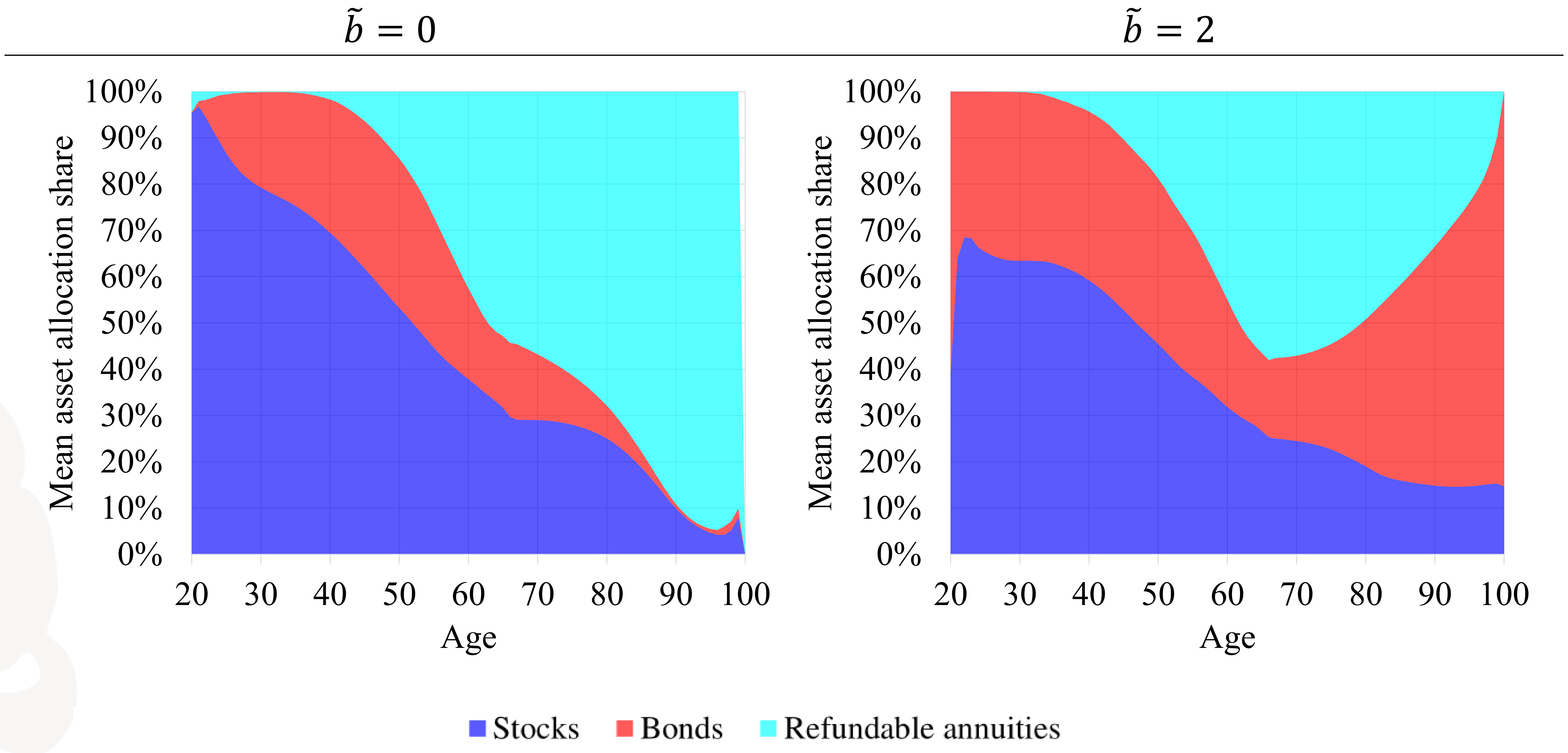
Model with Lump-Sum Refundable Annuities (2)



⟹ Big changes in the post-retirement asset allocation, almost identical to life-only annuities.

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Loss Aversion in an Annuity Context (3)

- A more formal representation of the probability-weighted lifetime loss of buying one life-only annuity at time t at price $\ddot{h}_t$ reads ($t < K$):

$$\text{lifetimeLoss}_t = \sum_{u=0}^{K-t-1} \ddot{h}_t ({}_u p_t)(1 - p_{t+u})\beta^{u+1} + \sum_{u=1}^{T-K+1} \max\left(\ddot{h}_t - u, 0\right)({}_{u-1}p_K)(1 - p_{K+u-1})\beta^{K+u-t}$$

- This is closely related to the pricing formula of the lump-sum refundable annuity (discounting with β instead of R^f)
- The loss term is scaled up by the number of life-only annuities purchased (D_t: investment amount):

$$\Lambda_t = \frac{D_t}{\ddot{h}_t} * \text{lifetimeLoss}_t$$

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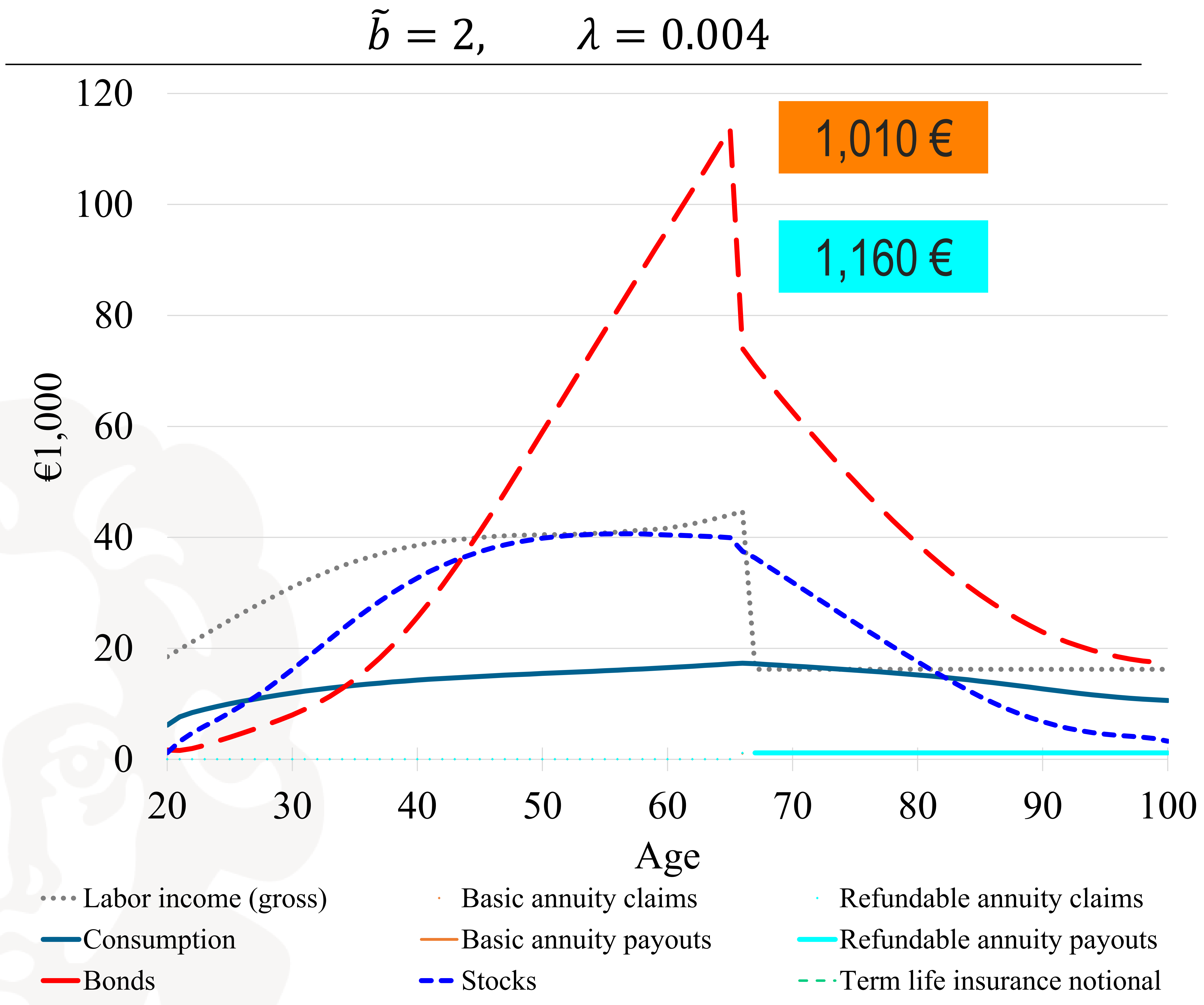
Model with Both Annuity Types



- With loss aversion, almost equal holdings in lump-sum refundable annuities and life-only annuities
- Aligning with empirical findings

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Do We Really Need Loss Aversion or Does a Very Strong Bequest Motive Suffice?

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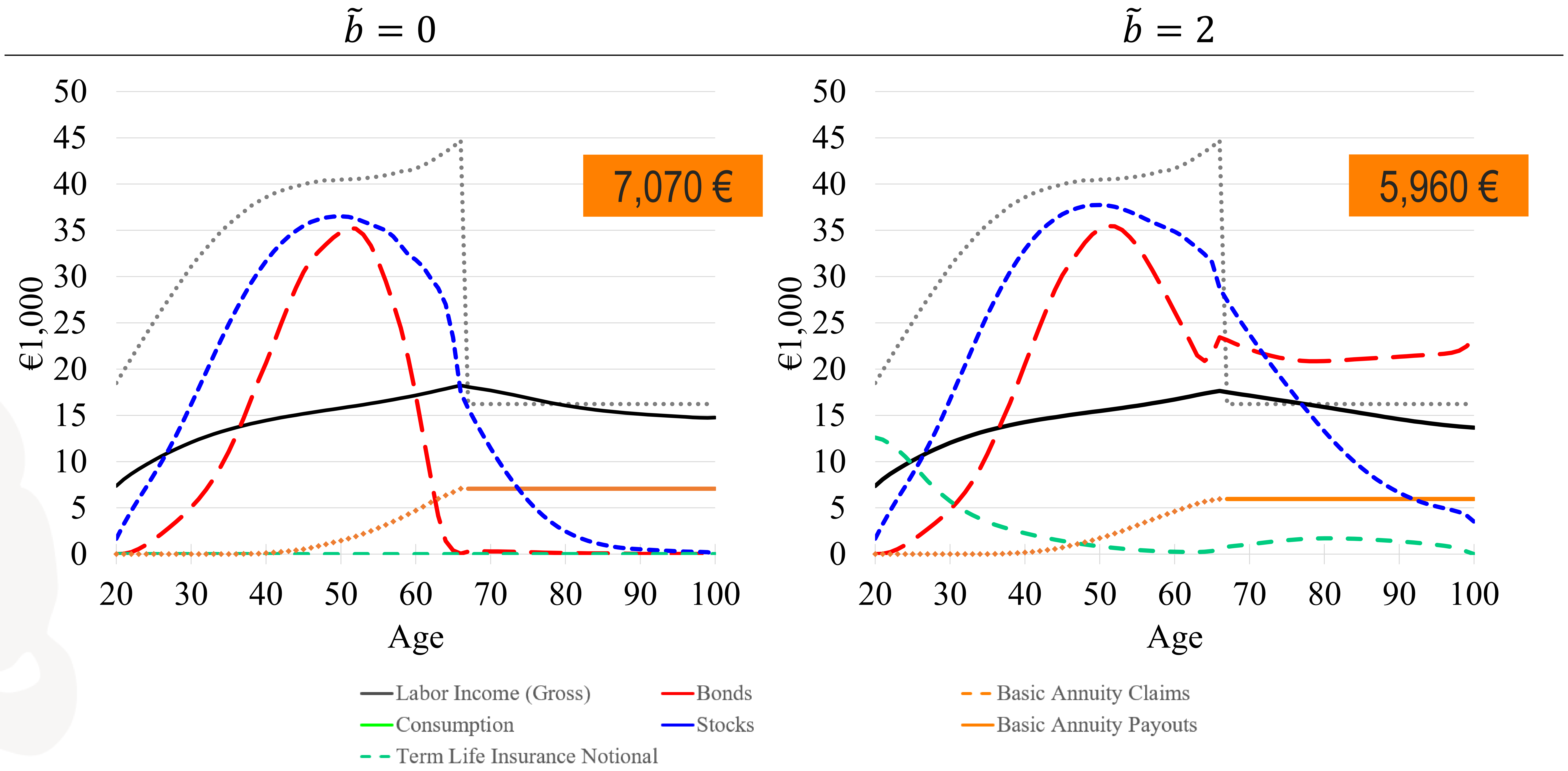
Bequest strength: $\tilde{b}$	0	2	10
Loss aversion scale: λ	0	0.004	0
Stocks			
Age 20–42	18.05	18.14	16.97
Age 43–66	32.92	37.70	40.78
Age 67–84	6.56	23.81	31.08
Age 85–100	0.45	6.54	18.32
Bonds			
Age 20–42	8.44	11.34	31.61
Age 43–66	23.74	60.62	104.16
Age 67–84	0.20	57.19	133.73
Age 85–100	0.03	23.45	115.83
Basic annuity payout			
Age 67–100	7.07	2.07	2.26

Leaving a bequest as main purpose of living?

Introduction of Term Life Insurance Contracts



⟹ Only small role for life insurances. Implications for lump-sum refundable annuities?