Experience-based Learning, Stock Market Participation and Portfolio Choice

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NHH Norwegian School of Economics

CEPR European Conference on Household Finance

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Motivation

Stock market participation "puzzle"

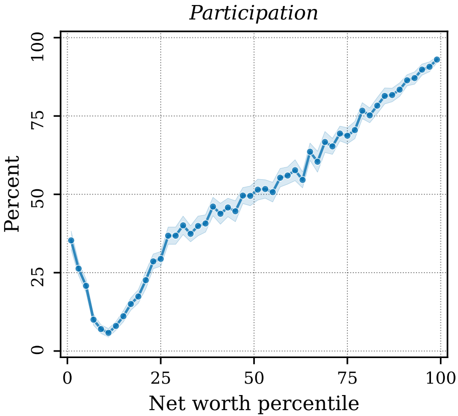

Figure 1: Participation rates by gross total wealth. Data source: SCF 1989–2022.

Risky shares | Life cycle | Other wealth measures | Asset classes

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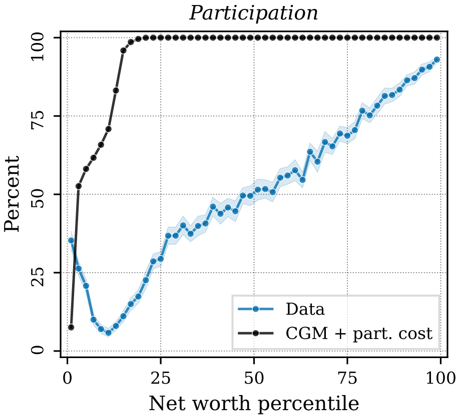

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Risky shares Life cycle Other wealth measures Asset classes

How to reconcile models and data?

Literature so far

1. Participation or entry costs

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3. Deviations from FIRE (Bayesian learning, ambiguity aversion)

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This paper

Subjective beliefs from experience-based learning (Malmendier and Nagel 2011, 2016)

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This paper

Subjective beliefs from experience-based learning (Malmendier and Nagel 2011, 2016)

1. Estimates dynamics of stock market beliefs from panel data on beliefs
2. Embeds subjective beliefs & learning in structural household finance model

   Generates realistic levels of non-participation even with low participation cost ($\approx$ \$90 per year)

Related literature

1. Empirical papers on stock market beliefs (and portfolio choice)

Vissing-Jorgensen (2003), Dominitz and Manski (2007, 2011), Kaustia and Knüpfer (2008), Choi et al. (2009), Hudomiet, Kézdi, and Willis (2011), Kézdi and Willis (2011), Malmendier and Nagel (2011, 2016), Hurd and Rohwedder (2012), Greenwood and Shleifer (2014), Kleinjans and Soest (2014), Dimmock et al. (2016), Ameriks et al. (2020), Das, Kuhnen, and Nagel (2020), Briggs et al. (2021), Giglio et al. (2021), von Gaudecker and Wogrolly (2022), Heiss et al. (2022), Meyer and Pagel (2022), Sias, Starks, and Turtle (2023), Jiang et al. (2024)

This paper: estimates Malmendier-Nagel model of stock market beliefs on panel data

2. Structural portfolio choice models (risk-free/risky asset)

Haliassos and Bertaut (1995) Cocco, Gomes, and Maenhout (2005), Gomes and Michaelides (2005), Fagereng, Gottlieb, and Guiso (2017), — Krusell and Smith (1997), Storesletten, Telmer, and Yaron (2007), Gálvez and Paz-Pardo (2022), Chang, Hong, and Karabarbounis (2018), Catherine (2021) — Gomes and Michaelides (2003), Polkovnichenko (2006) Wachter and Yogo (2010), Meeuwis (2022) — Campanale (2011), Peijnenburg (2018), Macaulay and Shi (2023)

This paper: incorporates learning from experience into life cycle model of portfolio choice

3. Heterogeneous returns & wealth inequality

Benhabib, Bisin, and Luo (2019), Bach, Calvet, and Sodini (2020), Fagereng et al. (2020), Kuhn, Schularick, and Steins (2020), Hubmer, Krusell, and Smith (2021)

This paper: belief heterogeneity as additional channel to explain heterogeneous returns & wealth inequality

Outline of the talk

1. Illustrative three-period model
2. Survey evidence on subjective beliefs about stock market returns
3. Quantitative life cycle model of portfolio choice

Three-period model

Illustrative example

Three-period model

- Agents live for three periods, $t = 1, 2, 3$
- Can save in two assets:
  1. Risk-free bond with gross return R_f
  2. Risky asset with gross return R_{it+1},

$$R_{it+1} - R_f = \overline{\mu} + z_{it+1} \qquad z_{it+1} \overset{\text{iid}}{\sim} \mathcal{N}\left(0, \sigma^2\right)$$

- Investors are uncertain about true $\overline{\mu}$, have belief $\widehat{\mu}_{it}$
- Known variance σ^2
- Risky return realizations are i.i.d. across agents (relaxed in paper)

Investor's problem

Period 1

- All investors are identical ex ante
- They choose total savings b_1 and **risky share ξ_1**

$$V_1\left(a_1, \widehat{\mu}_1\right) = \max_{b_1,\, \xi_1 \in [0,1]} \left\{ \frac{c_1^{1-\gamma}}{1-\gamma} + \beta \mathbf{E} V_2\left(a_2, \widehat{\mu}_{i2}\right) \right\}$$

$$a_2 = \left[\xi_1 R_{i2} + (1-\xi_1) R_f\right] b_1$$

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Period 2

- Belief updating: new observation R_{i2} weighted by α

$$\widehat{\mu}_{i2} = (1-\alpha)\widehat{\mu}_{i1} + \alpha\left(R_{i2} - R_f\right)$$

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$$\widehat{\mu}_{i2}=(1-\alpha)\widehat{\mu}_{i1}+\alpha\left(R_{i2}-R_f\right)$$

- Belief distribution at the beginning of $t=2$:

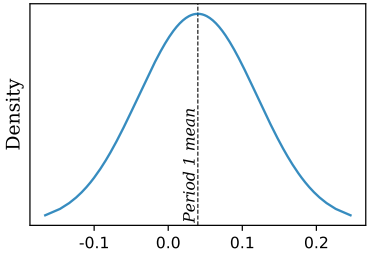

Figure 2: Distribution of beliefs $\widehat{\mu}_{i2}$

Period 2: Optimal risky share

Mechanism: positive sorting of wealth and beliefs

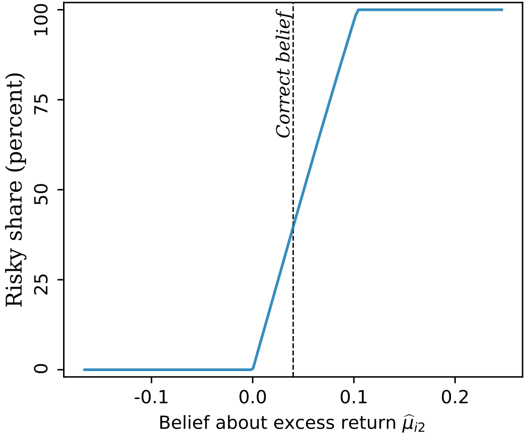

Figure 3: Distribution of risky shares int $t = 2$

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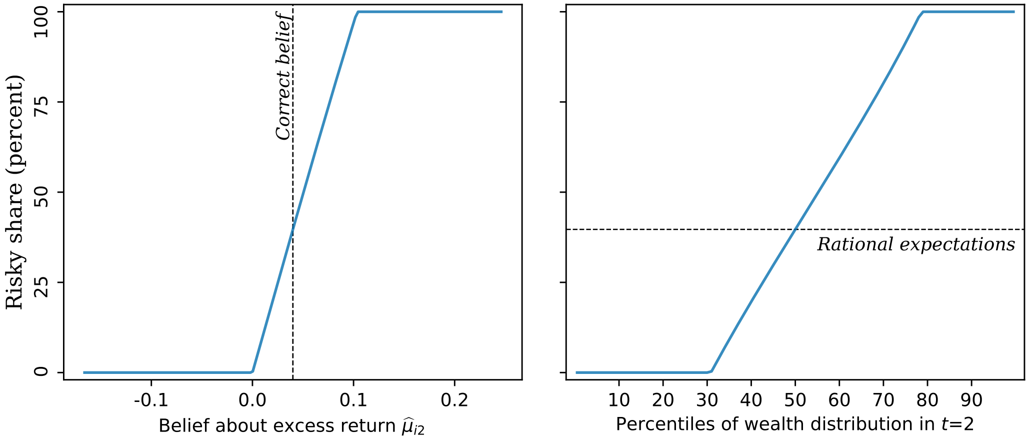

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Subjective beliefs in US household surveys

RAND American Life Panel (ALP)

Focus on subset of waves called Effects of the Financial Crisis (EFC) initiated by Hurd and Rohwedder (2012)

Estimation sample

- 60 waves administered from 2008/11 to 2016/01
- $\approx$ 90,000 obs. of $\approx$ 3,900 individuals

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Questions about stock market beliefs

1. Prob. that Dow Jones will have <u>increased</u> one year from now
2. Prob. that Dow Jones will have <u>increased by more than 20%</u> one year from now
3. Prob. that Dow Jones will have <u>fallen by more than 20%</u> one year from now

Beliefs by month Beliefs by age Beliefs in SCE Beliefs in HRS

Descriptive statistics

	All	Respondents
N. obs	130,692	89,583
N. indiv	4,773	3,875
Female	51.9%	51.5%
Age	46.8	46.9
Education		
Less than HS	7.9%	7.6%
Highschool	35.5%	34.9%
Some college	28.4%	28.5%
College	28.1%	29.0%
Stock market knowledge		
Good	7.9%	8.1%
Some	55.7%	55.8%
Poor	36.4%	36.1%
Follows stock market		
Very closely	4.5%	4.9%
Somewhat	39.0%	39.4%
Not at all	56.5%	55.7%
Holds stocks (incl. indirect)	48.6%	49.7%

Table 1: Sample size and demographics. "Respondents" sample restricted to observations with responses to *all* three belief questions. Data source: ALP/EFC 2008/11–2016/01.

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Average responses by month

Raw data

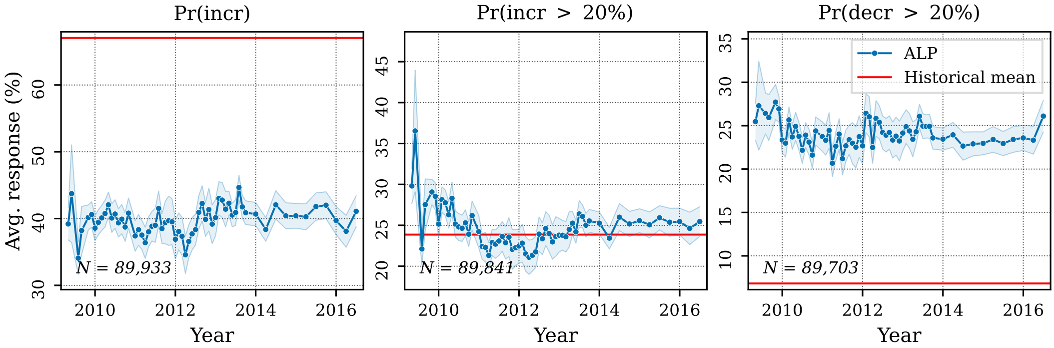

Figure 4: Average probabilistic answers by survey wave. Data source: ALP/EFC 2008/11–2016/01.

Beliefs by month Beliefs by age Beliefs in SCE Beliefs in HRS

Nonparametric return beliefs vs. historical returns

Combine 3 points on CDF & historical returns to get "nonparametric" return beliefs

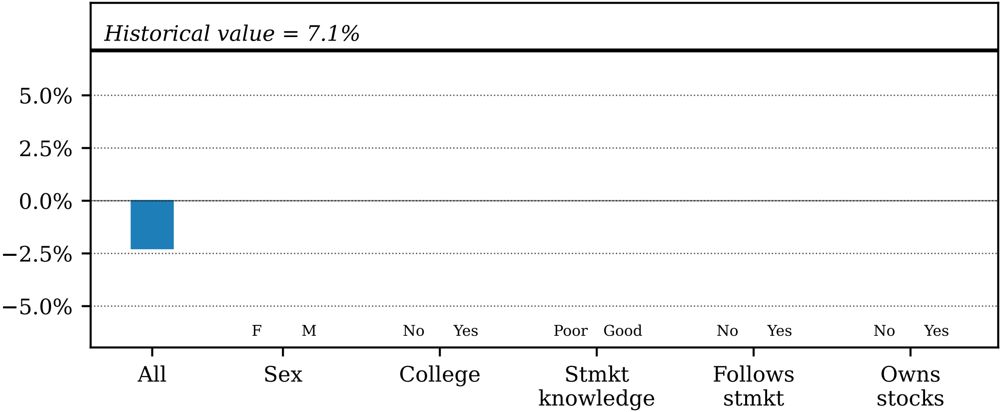

Figure 5: Expected return of the Dow Jones over the next 12 months

Definition Table All moments

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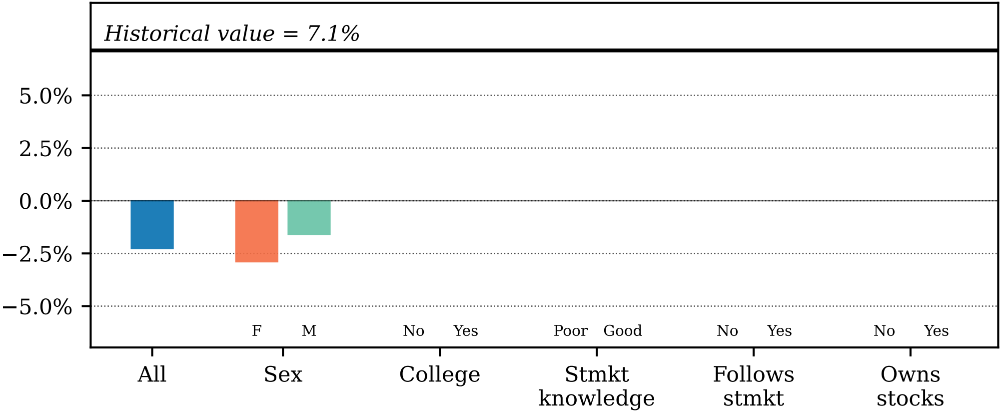

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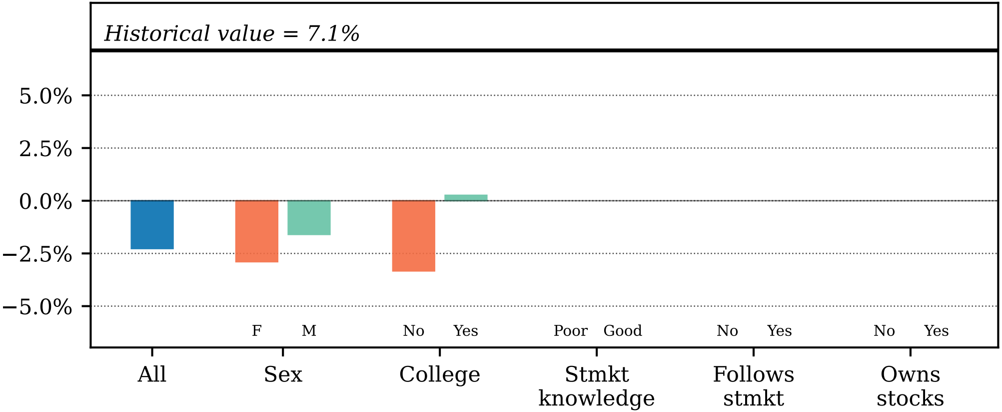

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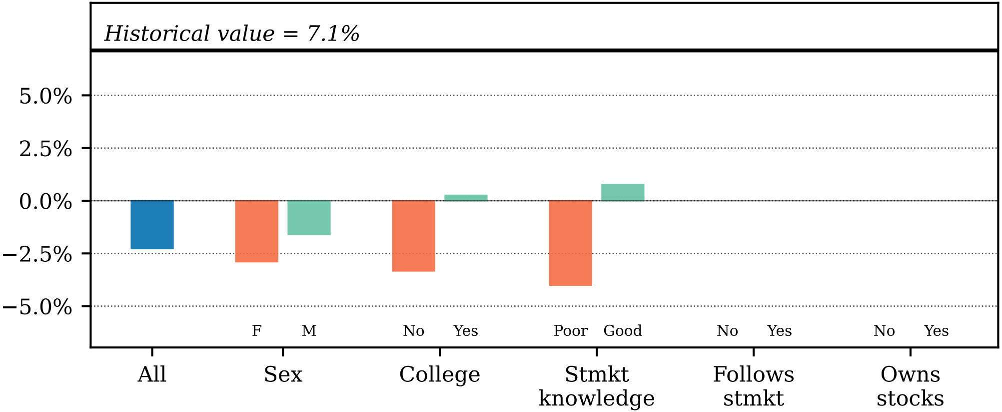

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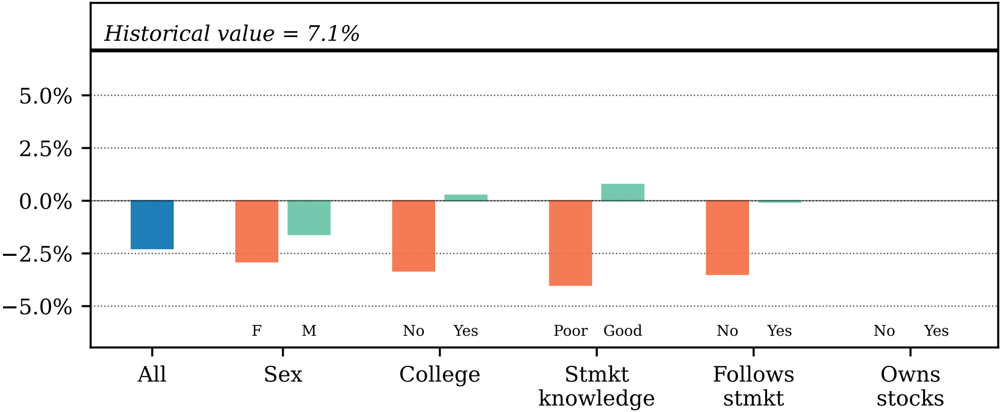

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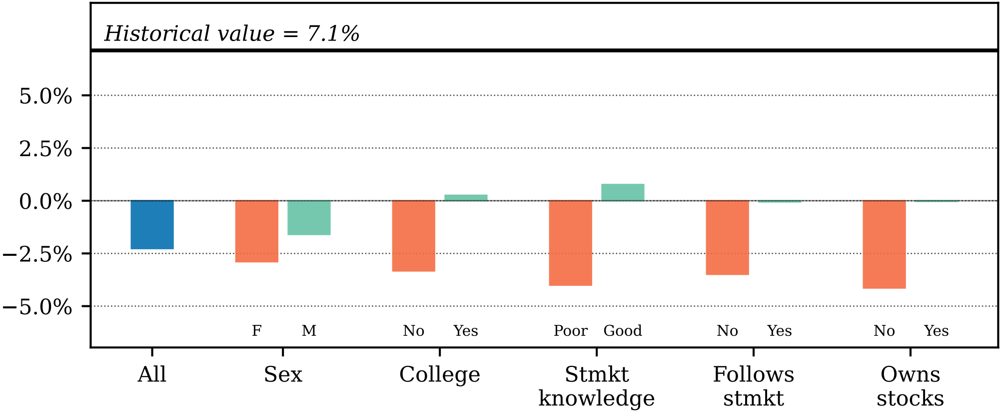

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Sorting in the data?

Beliefs vs. income & wealth

Individuals with higher income or wealth are more optimistic about stock returns.

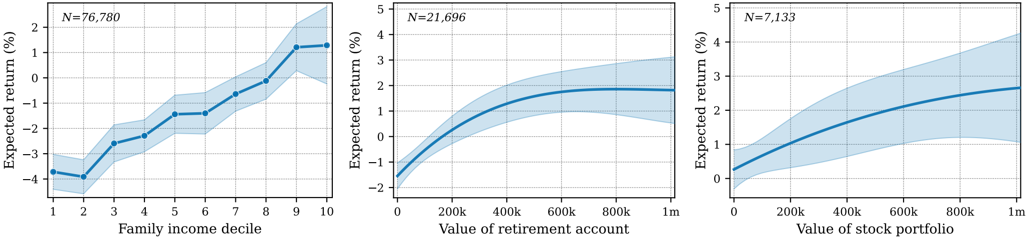
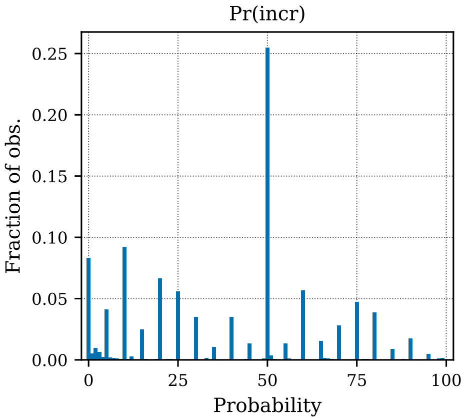


Figure 6: Average beliefs about returns in RAND American Life Panel. Shaded areas show 95% CIs (SE clustered at household level). Data source: ALP/EFC 2008/11–2016/01.

Structural estimation of return beliefs

Estimation challenges

1. Beliefs about mean risky returns are not directly observed
2. Three probabilistic answers *jointly*
   - violate laws of probability (15%)
   - imply zero-mass intervals (24%)
3. 50-50 answers due to "epistemic uncertainty"
4. Rounding to focal answers



Response patterns

Maximum likelihood estimator of belief updating

Based on Kézdi and Willis (2009, 2011), Hudomiet, Kézdi, and Willis (2011), Kleinjans and Soest (2014), and Heiss et al. (2022)

Beliefs about stock returns

$$\log R_{it} \sim \mathcal{N}\left(\mu_{it}^{*}, \sigma^{2}\right)$$

$$\mu_{it}^{*} = \nu_i + \boldsymbol{x}_{it}' \boldsymbol{\beta}$$

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Estimation

⇒ Map into 3 responses (via CDF)

\+ Survey errors

\+ Rounding

\+ 50-50 responses

= Likelihood function

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Historical return index

$$\overline{\mathcal{R}}_{it}(\lambda) = \sum_{k=1}^{age_{it}-1} \boldsymbol{w}\left(age_{it}, k \mid \lambda\right) \log R_{-k}$$

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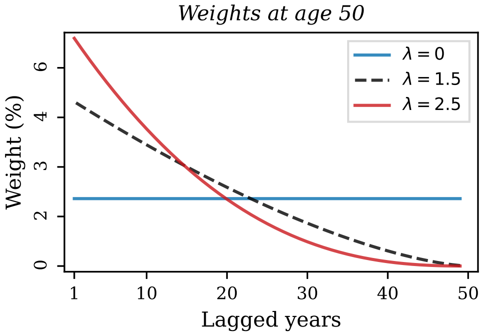

Estimation results

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Return index: λ					
Constant					1.622
					(0.297)
College					0.973
					(0.494)
Beliefs about mean returns					
Constant	−4.169	−3.871	−3.473	−3.070	−9.192
	(0.353)	(0.345)	(0.239)	(0.264)	(0.336)
College	3.828	2.222	2.730	2.527	3.198
	(0.559)	(0.557)	(0.452)	(0.448)	(0.535)
Correlated survey noise		✓	✓	✓	✓
Random effects		✓	✓	✓	✓
Rounding (center/tail)			✓	✓	✓
Epistemic uncertainty				✓	✓
N. individuals	3,436	3,436	3,436	3,436	3,436
N. observations	12,350	12,350	12,350	12,350	12,350
N. parameters	9	14	64	115	117

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Malmendier and Nagel find $\lambda \approx 1.5$

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Full results

Quantitative life cycle model

Model overview

Standard features

Cocco, Gomes, and Maenhout (2005), Gomes and Michaelides (2005), and others...

- Imperfectly insurable earnings risk
- Inelastic labor supply & fixed retirement age
- Portfolio choice over riskless/risky asset with participation costs
- Partial equilibrium: exogenous asset returns

Extension I: Underdiversification

- Risky returns have idiosyncratic component due to underdiversification
- Gives rise to experienced returns that differ across individuals

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- Risky returns have idiosyncratic component due to underdiversification
- Gives rise to experienced returns that differ across individuals

Extension II: Subjective beliefs & learning

- Agents do not know mean of risky returns, form beliefs based on individual histories

Investor's problem Belief updating Market returns

Extension I: Underdiversification

- Individual excess returns consist of idiosyncratic term and market return:

$$r^e_{it+1} = u_{it+1} + \beta_m r^e_{mt+1}$$

- Investors cannot choose composition of the risky portfolio

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- **Two scenarios:**

(1) $\beta_m = 0$ Returns are i.i.d. in the cross-section of investors

(2) $\beta_m = 1, \mathbf{E}u_{it+1} = 0$ Idiosyncratic risk not compensated but adds volatility. Variance shares from Calvet, Campbell, and Sodini (2007)

Extension I: Underdiversification

- Individual excess returns consist of idiosyncratic term and market return:

$$r^e_{it+1} = u_{it+1} + \beta_m r^e_{mt+1}$$

- Investors cannot choose composition of the risky portfolio

- **Two scenarios:**

(1) $\beta_m = 0$ Returns are i.i.d. in the cross-section of investors

(2) $\beta_m = 1, \mathrm{E}u_{it+1} = 0$ Idiosyncratic risk not compensated but adds volatility. Variance shares from Calvet, Campbell, and Sodini (2007)

Excess return mean & volatility fixed to be identical in both scenarios!

Extension II: Subjective beliefs & learning (i.i.d. case)

- Excess returns on risky asset:

$$\log\left(1 + r^e_{it+1}\right) \equiv \log\left(1 + u_{it+1}\right) \overset{\text{iid}}{\sim} \mathcal{N}\left(\widetilde{\mu}^u, \widetilde{\sigma}^2_u\right)$$

- Investors are uncertain about true $\widetilde{\mu}^u$, have belief $\widehat{\mu}_{it}$ (and know variance $\widetilde{\sigma}^2_u$)
- Belief updating:

$$\widehat{\mu}_{it} = \begin{cases} (1-\alpha_t)\widehat{\mu}^u_{it-1} + \alpha_t \log\left(1 + r^e_{it}\right) & \text{if invested in stocks} \\ \widehat{\mu}_{it-1} & \text{else} \end{cases}$$

- Belief updating weight α_t depends on age (Malmendier and Nagel 2011, 2016)

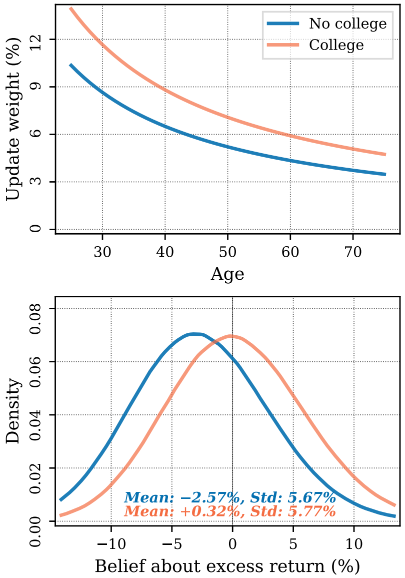
Model parameters

1. Update weight parameters estimated from from ALP/EFC
2. Initial beliefs estimated from ALP/EFC on sample aged 18–27
3. Preference parameters and participation cost determined by SMM

   Moments by education:

   - Average wealth below/above median
   - Average wealth in six 10-year age bins
   - Participation rate
   - Average conditional risky share

Moments Other parameters



Results from life cycle model

Portfolio composition along the wealth distribution

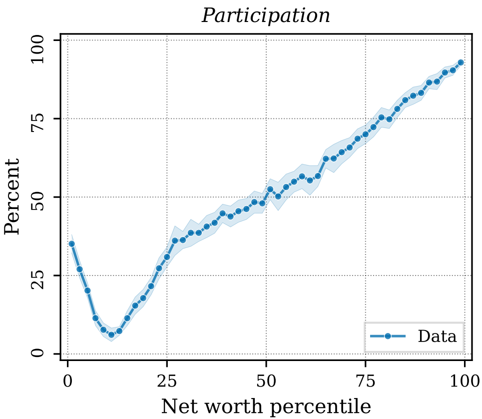


Figure 7: Portfolio composition along the wealth distribution

Life cycle Policy functions

Portfolio composition along the wealth distribution

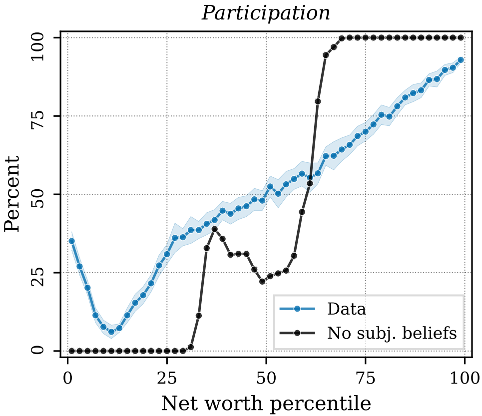


Figure 7: Portfolio composition along the wealth distribution

Life cycle Policy functions

Portfolio composition along the wealth distribution

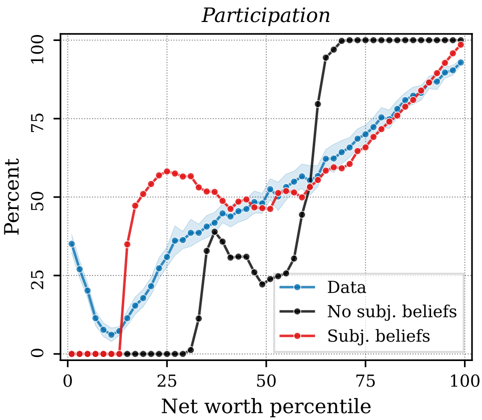


Figure 7: Portfolio composition along the wealth distribution

Life cycle Policy functions

Portfolio composition along the wealth distribution

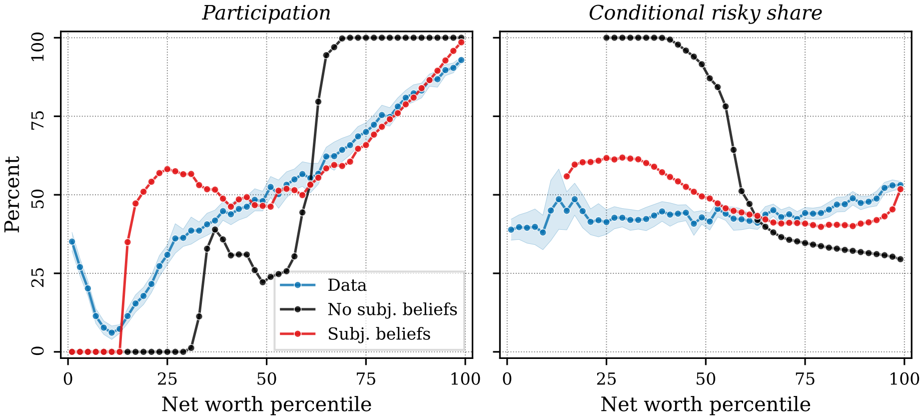


Figure 7: Portfolio composition along the wealth distribution

Life cycle Policy functions

Portfolio composition: age 65+

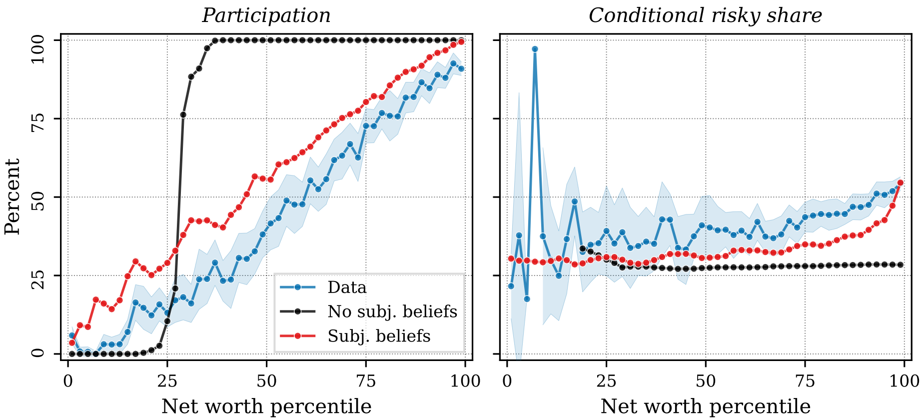


Figure 8: Portfolio composition along the wealth distribution for ages 65–89

Full sample

Mechanism: Positive sorting over beliefs & wealth

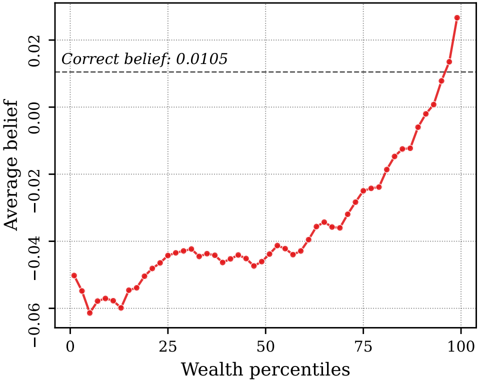


Figure 9: Average belief about mean excess returns along the wealth distribution

Conclusion

Main take-aways

1. Subjective beliefs & learning offer a plausible way to explain limited stock market participation
2. Supported by US survey evidence on beliefs

Additional slides

Additional slides — SCF & Life cycle model

Portfolio allocation in the US

- Portfolios along the wealth distribution
- Portfolios over the life cycle
- Portfolios along the wealth distribution, age 65+
- Alternative wealth definitions
- By asset class (wealth)
- By asset class (life cycle)
- By education (wealth)
- By education (life cycle)
- By home ownership (wealth)
- By home ownership (life cycle)

Life cycle model (i.i.d. case)

- Household problem
- Belief updating
- Benchmark calibration
- Average wealth by quintile
- Average wealth over the life cycle
- Risky share policy functions
- Portfolios over the life cycle

Model with market returns

- Risky portfolio returns
- Portfolios across the wealth distribution
- Portfolios over the life cycle
- Beliefs across the wealth distribution

Additional slides — ALP & Belief estimation

Subjective beliefs in the ALP

- Descriptive statistics
- Table: Response patterns
- Average responses by month
- Average responses by month (controls)
- Average responses by age
- Average responses by age (controls)
- Definition: Nonparametric return beliefs
- Table: Return beliefs vs. historical returns
- Beliefs by group vs. historical moments
- Estimating return moments with NLS

Other survey evidence

- SCE: Probability of positive returns
- HRS: Average responses by month
- HRS: Average responses by month (controls)
- HRS: Average responses by age
- HRS: Average responses by age (controls)

Structural estimation

- Estimation results
- Predicted epistemic uncertainty
- Predicted rounding

Portfolio allocation in the US

Financial portfolios in US data

Along the wealth distribution

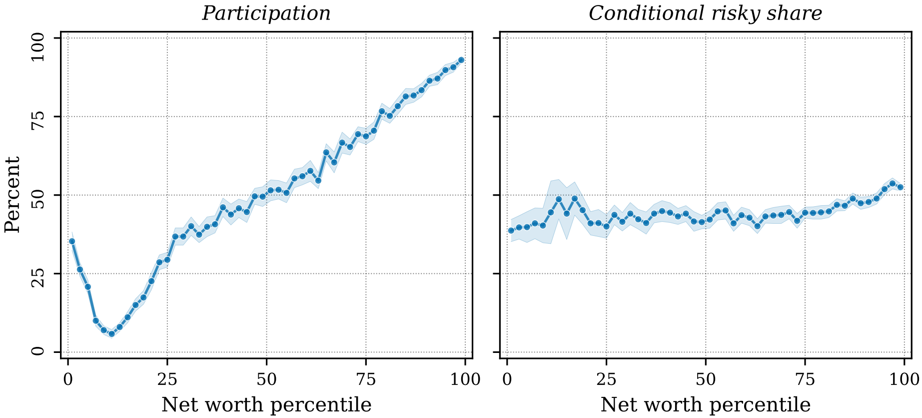


Figure 10: Participation rates and risky shares by net worth. Data source: SCF 1989–2022.

Motivation Appendix overview

Financial portfolios in US data

Over the life cycle

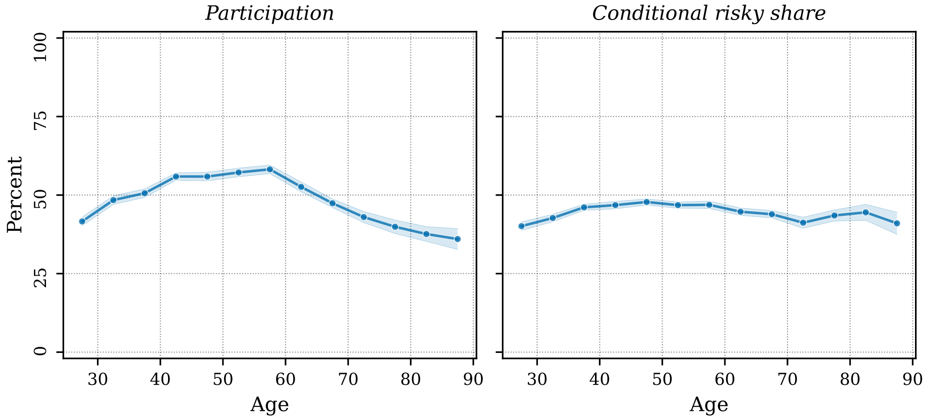


Figure 11: Participation rates and risky shares over the life cycle. Data source: SCF 1989–2022.

Financial portfolios in US data

Along the wealth distribution for **age 65–89**

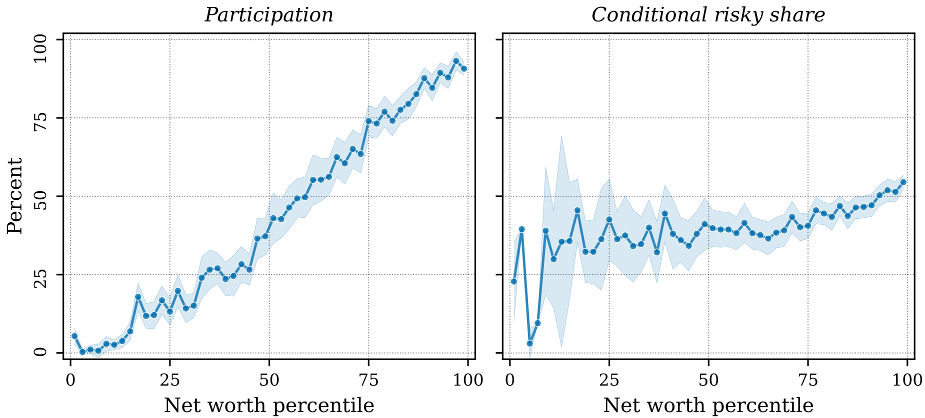
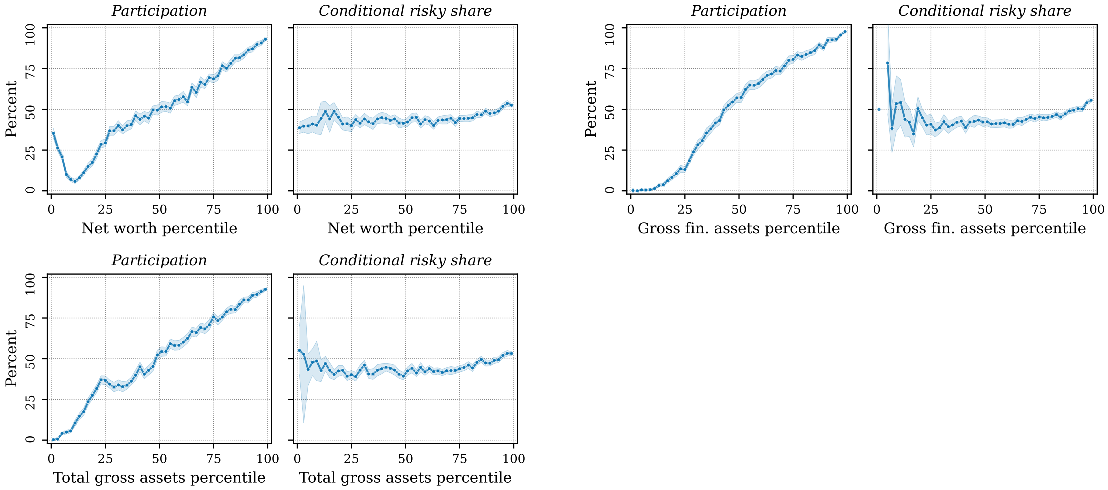


Figure 12: Participation rates and risky shares by net worth conditional on age 65–89. Data source: SCF 1989–2022.

Appendix overview

Financial portfolios in US data

Alternative wealth definitions



Motivation Appendix overview

Financial portfolios in US data

Disaggregated by asset class

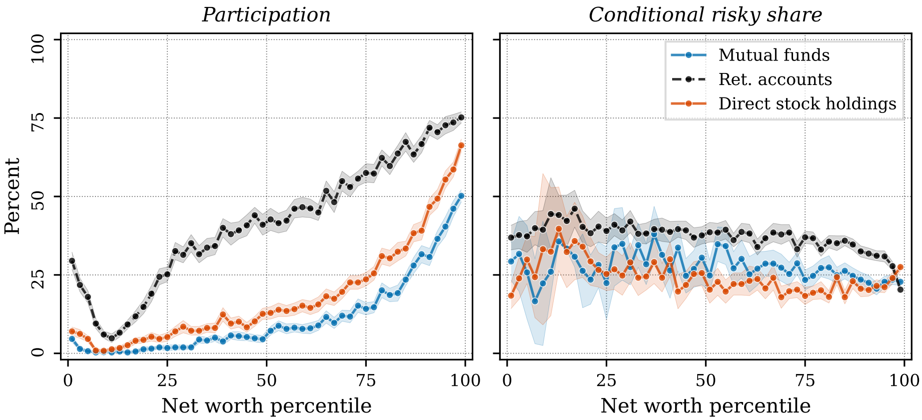


Figure 13: Disaggregated participation rates and conditional shares by net worth. Data source: SCF 1989–2022.

Financial portfolios in US data

Disaggregated by asset class: Life cycle

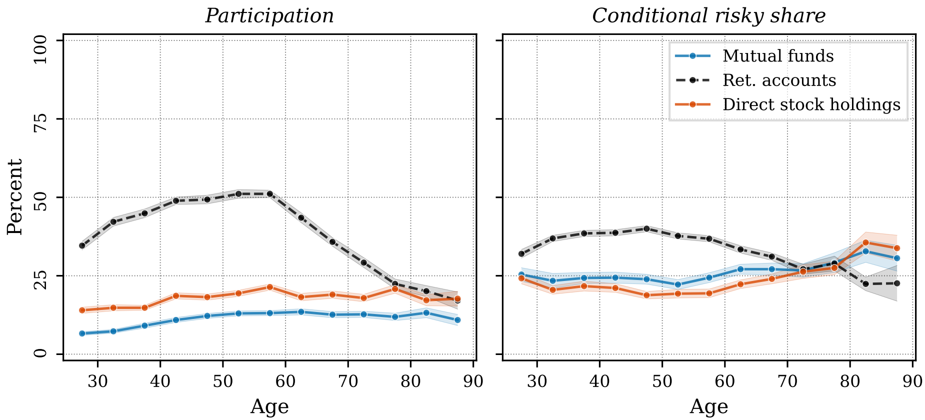


Figure 14: Participation rates and risky shares over the life cycle. Data source: SCF 1989–2022.

Appendix overview

Financial portfolios in US data

Disaggregation by home-ownership status

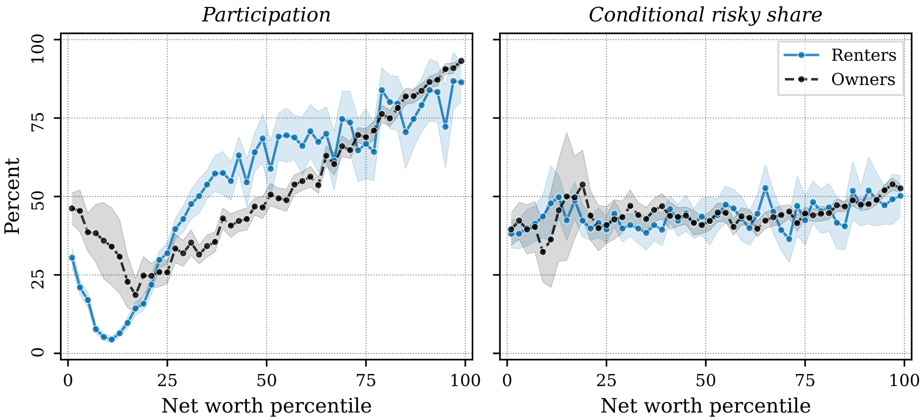


Figure 15: Participation rates and conditional shares by home ownership status and by net worth. Data source: SCF 1989–2022.

Financial portfolios in US data

Disaggregation by home-ownership status: Life cycle

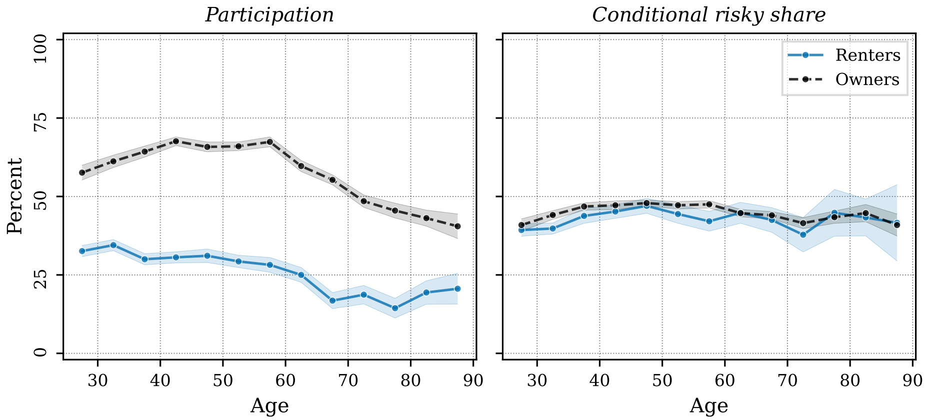


Figure 16: Participation rates and risky shares over the life cycle by home-ownership status. Data source: SCF 1989–2022.

Financial portfolios in US data

Disaggregated by education

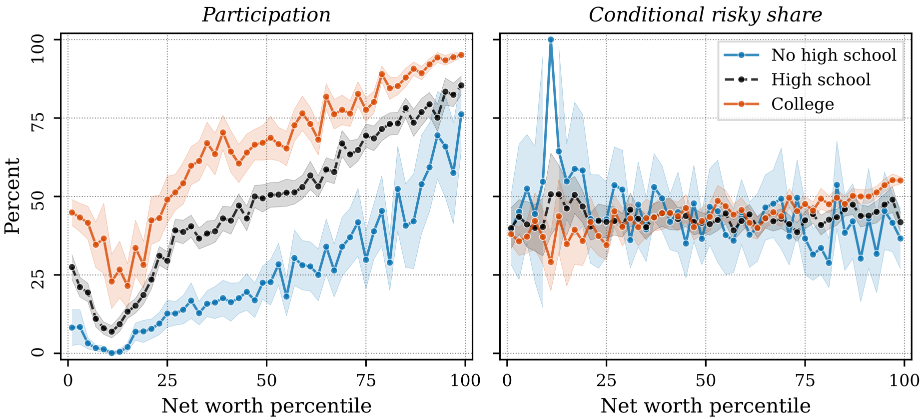


Figure 17: Participation rates and conditional shares by education and by net worth. Data source: SCF 1989–2022.

Financial portfolios in US data

Disaggregated by education: Life cycle

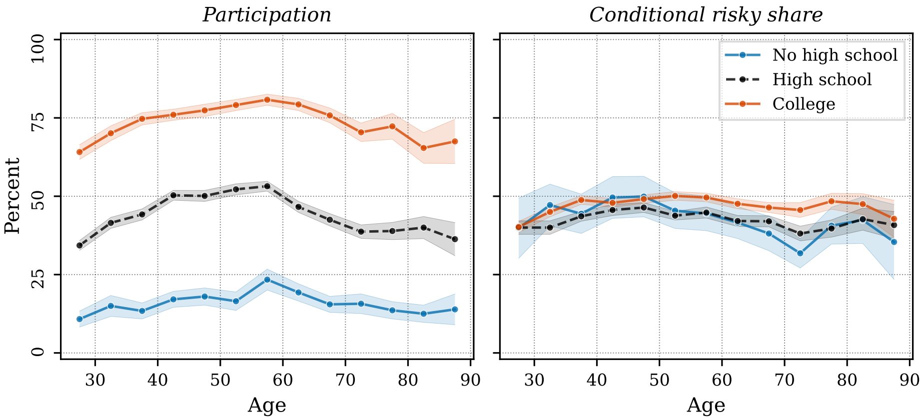


Figure 18: Participation rates and risky shares over the life cycle by education. Data source: SCF 1989–2022.

Appendix overview

Subjective beliefs in the ALP

Descriptive statistics

	All	Respondents	Estimation
N. obs	130,692	89,583	12,350
N. indiv	4,773	3,875	3,436
Female	51.9%	51.5%	51.9%
Age	46.8	46.9	48.7
Education			
Less than HS	7.9%	7.6%	7.4%
Highschool	35.5%	34.9%	33.5%
Some college	28.4%	28.5%	27.9%
College	28.1%	29.0%	31.3%
Stock market knowledge			
Good	7.9%	8.1%	8.6%
Some	55.7%	55.8%	56.7%
Poor	36.4%	36.1%	34.7%
Follows stock market			
Very closely	4.5%	4.9%	4.9%
Somewhat	39.0%	39.4%	40.4%
Not at all	56.5%	55.7%	54.7%
Holds stocks (incl. indirect)	48.6%	49.7%	53.1%

Figure 19: Sample size and demographics. Estimation sample restricted to observations with responses to *all* three belief questions. Data source: ALP/EFC 2008/11–2016/01.

ALP overview

Response patterns

	All	Sex		College		Stmkt knowledge		Follows stmkt		Owns stocks	
		Female	Male	No	Yes	Poor	Good	Not at all	Very closely	No	Yes
Inconsistencies (nonmissing subsample)											
Violates laws of probability	15.3%	14.9%	15.7%	15.9%	13.8%	14.8%	13.6%	15.0%	14.4%	16.3%	14.1%
Zero mass	24.1%	28.8%	19.1%	27.6%	15.4%	33.8%	10.7%	29.7%	12.3%	31.0%	16.1%
Epistemic uncertainty (nonmissing subsample)											
50/50 response	24.9%	27.0%	22.7%	25.5%	23.4%	27.7%	19.4%	26.6%	21.6%	26.8%	23.0%
50/50 means unsure	53.6%	57.8%	48.2%	56.9%	44.5%	68.5%	29.3%	61.5%	37.4%	65.0%	41.1%
Focal responses (nonmissing subsample)											
Rounded to 5%	97.9%	98.2%	97.6%	97.6%	98.6%	96.9%	98.0%	97.1%	98.5%	97.1%	98.9%
Rounded to 10%	89.1%	89.5%	88.7%	88.7%	90.0%	88.0%	88.6%	87.9%	89.6%	88.4%	90.2%
Rounded to 50%	47.4%	49.2%	45.5%	50.5%	39.7%	51.4%	38.7%	49.3%	44.0%	53.7%	41.2%
Item nonresponse											
Pr(incr)	32.5%	32.9%	32.1%	33.2%	30.5%	29.8%	27.6%	30.3%	24.0%	32.1%	29.2%
Pr(incr > 20%)	32.5%	33.0%	32.1%	33.4%	30.5%	30.0%	27.6%	30.4%	23.8%	32.2%	29.2%
Pr(decr > 20%)	32.7%	33.2%	32.2%	33.5%	30.6%	30.2%	27.7%	30.6%	24.0%	32.3%	29.4%
Any of the above	32.9%	33.4%	32.3%	33.7%	30.7%	30.4%	27.8%	30.8%	24.4%	32.5%	29.5%

Table 2: Response patterns for probabilistic questions. Data source: ALP/EFC 2008/11–2016/01.

Descriptive statistics Estimation challenges

Average responses by month

Raw data

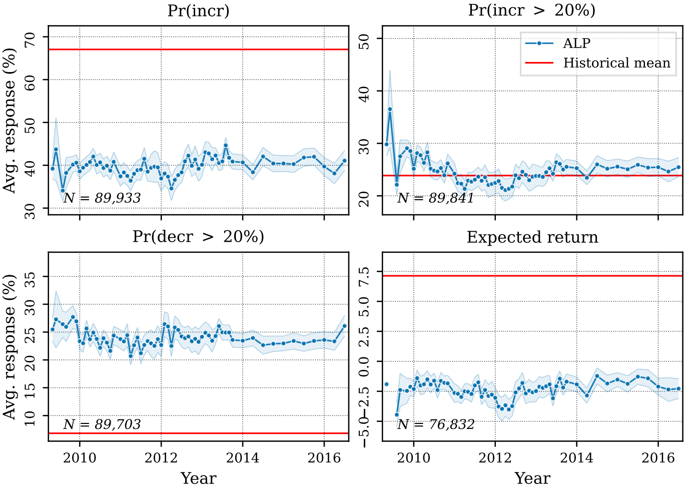


Figure 20: Average probabilistic answers by survey wave. Data source: ALP/EFC 2008/11–2016/01.

Average responses by month

Including demographic controls

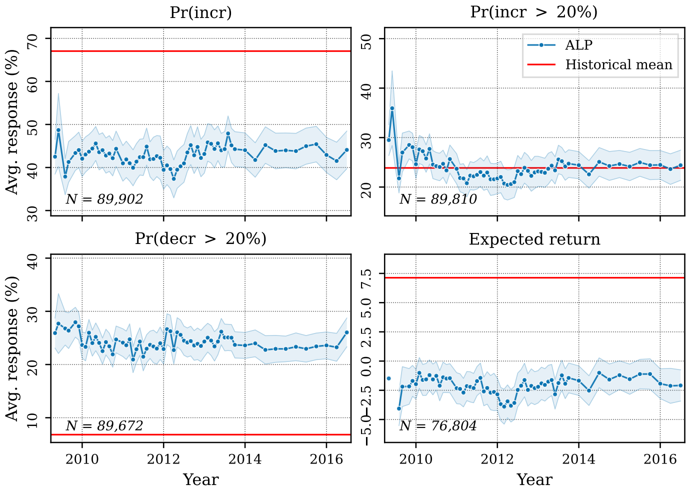


Figure 21: Average probabilistic answers by survey wave, controlling for race, sex, education, household type, and birth cohort. Data source: ALP/EFC 2008/11–2016/01.

ALP overview ALP raw data

Average responses by age

Raw data

Figure 22: Average probabilistic answers by age. Data source: ALP/EFC 2008/11–2016/01.

ALP overview ALP raw data

Average responses by age

Including demographic controls

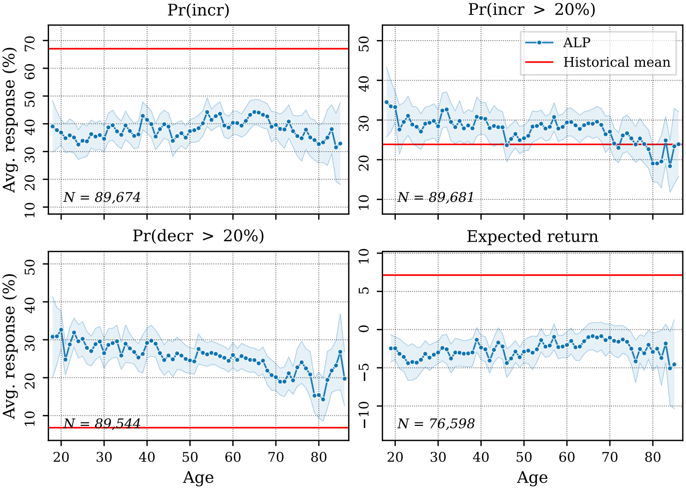


Figure 23: Average probabilistic answers by age, controlling for race, sex, education, household type, and birth cohort. Data source: ALP/EFC 2008/11–2016/01.

ALP overview ALP raw data

Return beliefs vs. historical returns

	All	Sex		College		Stmkt knowledge		Follows stmkt		Owns stocks	
		Female	Male	No	Yes	Poor	Good	Not at all	Very closely	No	Yes
Expected return	−2.3%	−2.9%	−1.6%	−3.3%	0.3%	−4.0%	0.8%	−3.5%	−0.1%	−4.1%	−0.0%
Pr(incr)	39.8%	37.1%	42.6%	35.5%	50.2%	32.1%	53.1%	34.5%	51.9%	32.4%	48.5%
Pr(incr > 20%)	24.8%	25.1%	24.4%	24.4%	25.6%	24.3%	24.9%	24.0%	24.7%	24.4%	25.4%
Pr(decr > 20%)	24.0%	24.7%	23.2%	24.7%	22.1%	25.1%	21.1%	24.5%	23.0%	25.9%	21.7%

Table 3: Reported stock market beliefs. Data source: ALP/EFC 2008/11–2016/01.

	Avg. return	Std. dev.	Pr(incr)	Pr(incr > 20%)	Pr(decr > 20%)
S&P 500	7.4%	19.3%	65.9%	27.3%	6.8%
DJIA	7.1%	19.6%	67.0%	23.9%	6.8%

Table 4: Historical annual stock market returns, 1928/01–2015/12

Nonparametric return beliefs

Nonparametric beliefs about returns

Construct beliefs about returns implied by p_0, p_{20} and p_{-20}:
(Hurd and Rohwedder 2012; von Gaudecker and Wogrolly 2022)

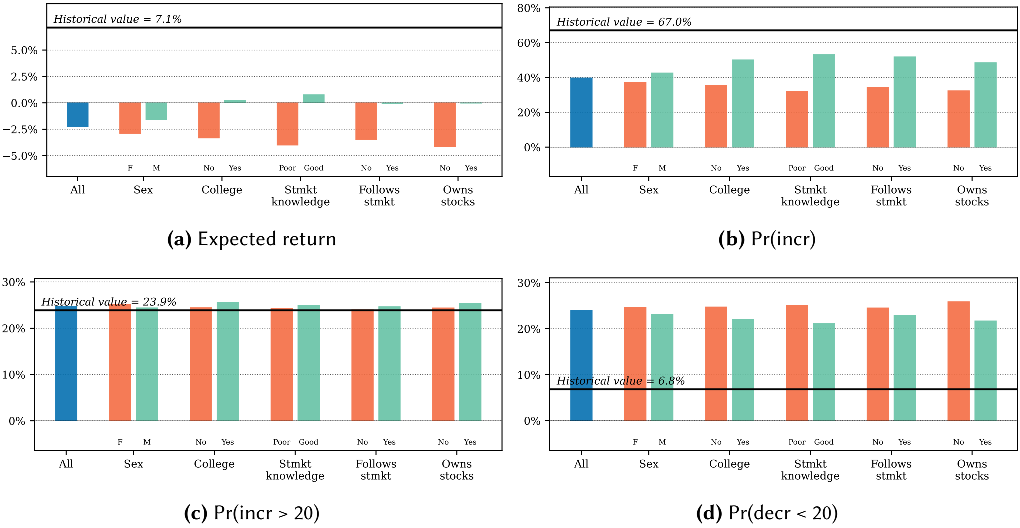
$$\mathbf{E}_{it}\left[R_{t\to t+12}\right] = \sum_{j=1}^{4} \underbrace{\Pr_{it}\left(R_{t\to t+12} \in I_j\right)}_{\text{survey beliefs}} \times \underbrace{\widehat{\mathbf{E}}_t\left[R_{s\to s+12} \,\middle|\, R_{s\to s+12} \in I_j,\ s \leq t-12\right]}_{\text{historical conditional returns}}$$

for intervals I_j:

$$I_1 = (-\infty, -20\%) \qquad I_2 = [-20\%, 0] \qquad I_3 = (0, 20\%] \qquad I_4 = (20\%, \infty)$$

Nonparametric return beliefs

Beliefs by group vs. historical moments



Estimating return belief moments with NLS

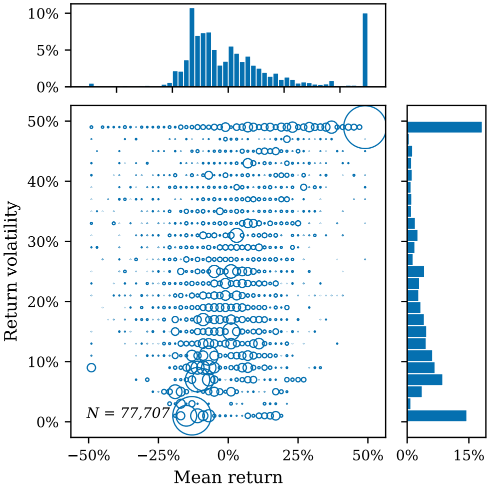


Figure 25: Distribution of estimated mean returns and return volatility. Data source: ALP/EFC 2008/11–2016/01.

Survey of Consumer Expectations

Question: *What do you think is the percent chance that 12 months from now, on average, stock prices in the U.S. stock market will be higher than they are now?*

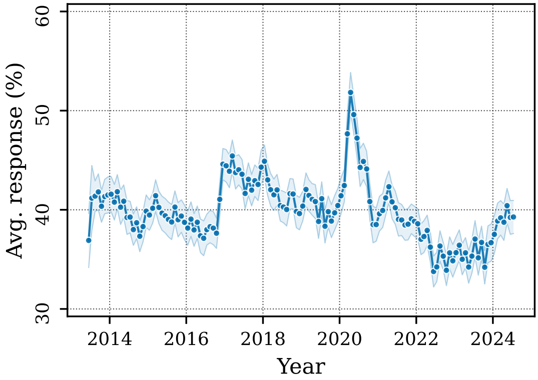


Figure 26: Average probabilistic answers by survey wave. Data source: SCE 2013/06–2024/08

ALP overview ALP raw data

HRS: Average responses by year

Raw data

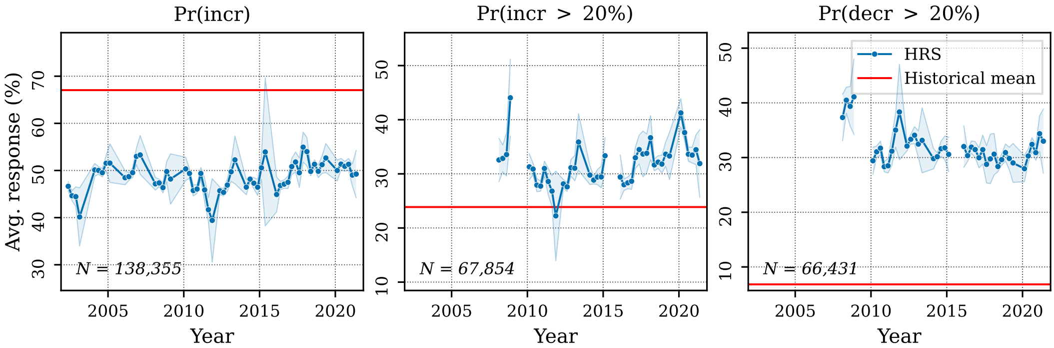


Figure 27: Average probabilistic answers by quarter. Data source: HRS 2002–2022.

ALP overview ALP raw data

HRS: Average responses by month

Including demographic controls

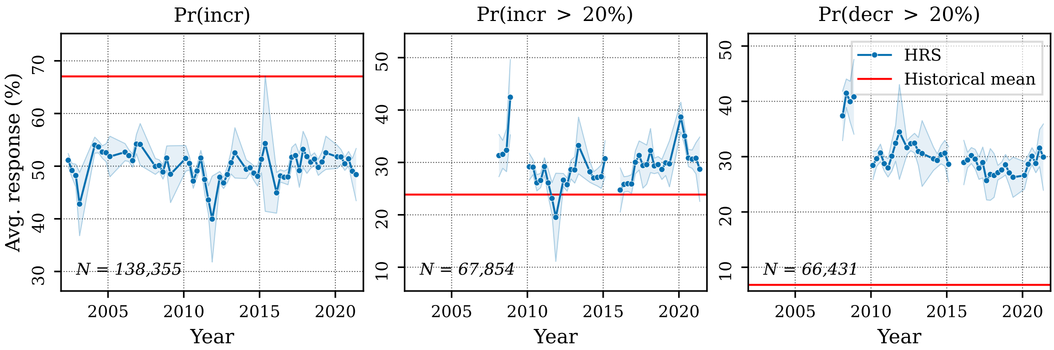


Figure 28: Average probabilistic answers by quarter, controlling for race, sex, education, household type, and birth cohort. Data source: HRS 2002–2022.

ALP overview ALP raw data

HRS: Average responses by age

Raw data

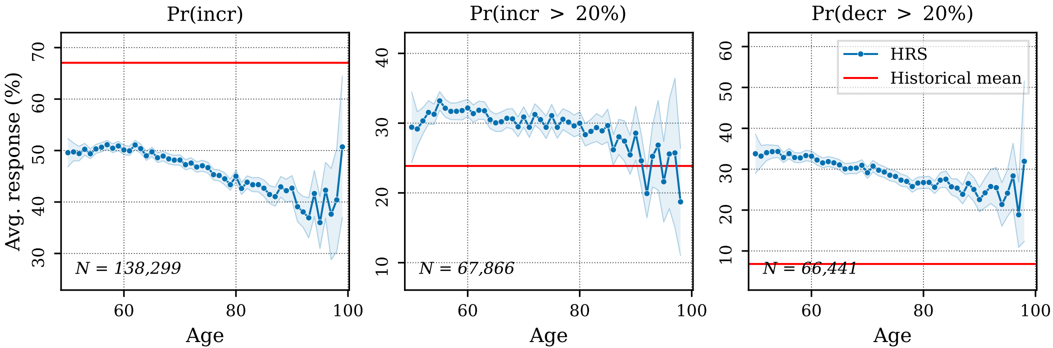


Figure 29: Average probabilistic answers by age. Data source: HRS 2002–2022.

ALP overview ALP raw data

HRS: Average responses by age

Including demographic controls

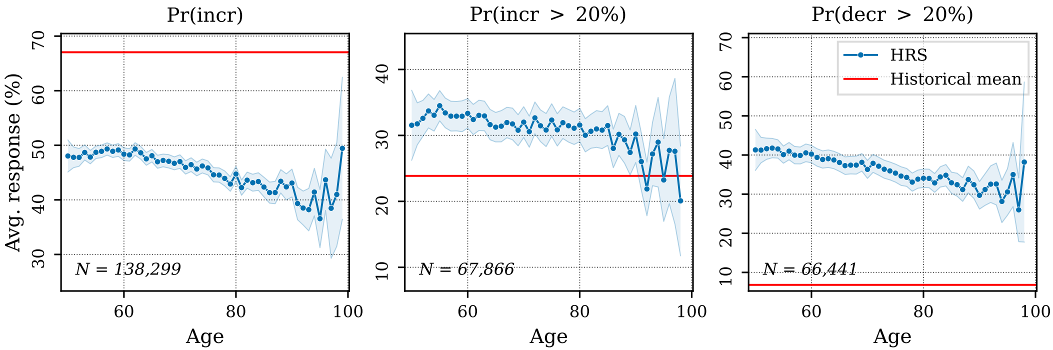


Figure 30: Average probabilistic answers by age, controlling for race, sex, education, household type, and birth cohort. Data source: HRS 2002–2022.

ALP overview ALP raw data

MLE results

Estimation results

	(1)	(2)	(3)	(4)	(5)
Return index: λ					
Constant					1.622
					(0.297)
College					0.973
					(0.494)
Beliefs about mean returns					
Constant	−4.169	−3.871	−3.473	−3.070	−9.192
	(0.353)	(0.345)	(0.239)	(0.264)	(0.336)
College	3.828	2.222	2.730	2.527	3.198
	(0.559)	(0.557)	(0.452)	(0.448)	(0.535)
Female	−1.732	−2.222	−1.287	−1.279	−1.378
	(0.457)	(0.469)	(0.310)	(0.353)	(0.365)
Return volatility σ		19.590	24.730	22.785	22.786
		(0.343)	(0.294)	(0.266)	(0.267)
Correlated survey noise		✓	✓	✓	✓
Random effects		✓	✓	✓	✓
Rounding (center/tail)			✓	✓	✓
Epistemic uncertainty				✓	✓
N. individuals	3,436	3,436	3,436	3,436	3,436
N. observations	12,350	12,350	12,350	12,350	12,350
N. parameters	9	14	64	115	117
Log likelihood	-1.4789×10^5	-1.4335×10^5	-8.6624×10^4	-8.5765×10^4	-8.5724×10^4

Estimation results

Predicted probability of being unsure

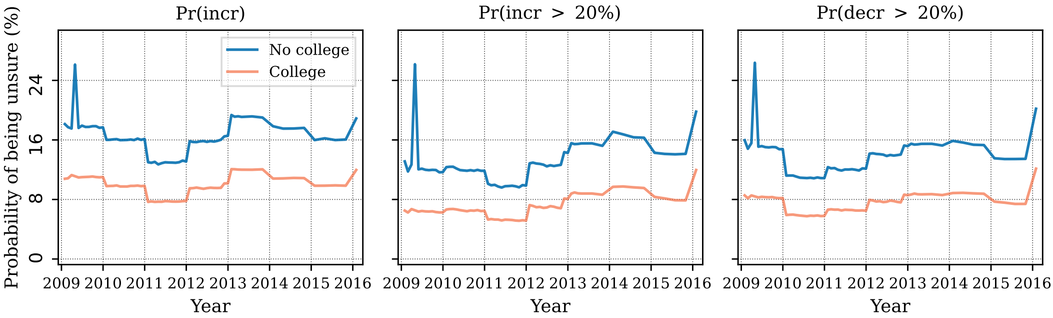


Figure 31: Average predicted probability of being unsure, by education.

Estimation results

Predicted rounding type distribution

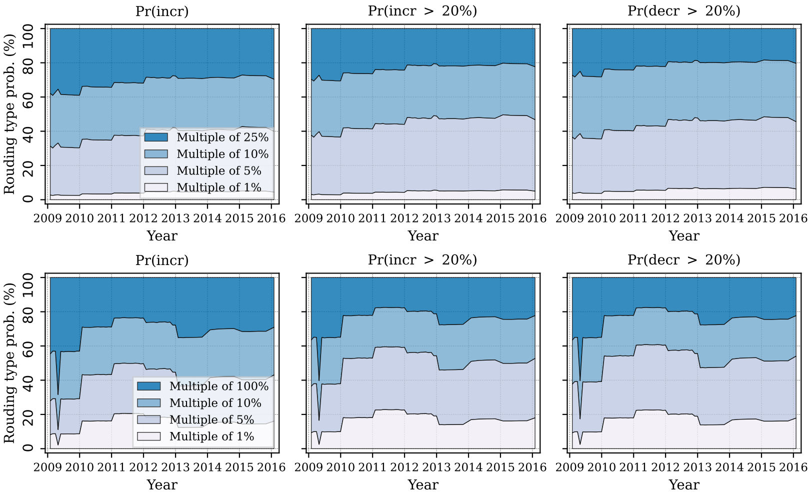


Figure 32: Average predicted distribution over rounding types (top: center; bottom: tail rounding)

Life cycle model

Retired agent

State vector $\boldsymbol{x} \equiv (h, a, p, j, \widehat{\mu})$

- Age h, cash-at-hand a, last permanent labor productivity p, education j, belief about average excess return $\widehat{\mu}$

Household chooses consumption c, total savings b and risky share ξ:

$$V_r(\boldsymbol{x}) = \max_{c,b,\xi} \left\{ c^{1-\psi} + \beta \left(\pi^s_{jh} \mathbf{E} V_r(\boldsymbol{x}')^{1-\gamma} + (1 - \pi^s_{jh}) \mathbf{E} V^b_j(a'_b)^{1-\gamma} \right)^{\frac{1-\psi}{1-\gamma}} \right\}^{\frac{1}{1-\psi}}$$

$$a = c + b + \mathbf{1}_{\{\xi>0\}}\kappa \quad \text{[Budget constraint]}$$

$$a' = R'_p b + \text{ret. income} \quad \text{[Next-period CAH]}$$

$$a'_b = R'_p b \quad \text{[Bequests]}$$

$$R'_p = \xi\left(R' - R_f\right) + R_f \quad \text{[Portfolio return]}$$

$$b \geq 0, \quad \xi \in [0, 1]$$

γ_j	Relative risk aversion
ψ_j^{-1}	EIS
β_j	Discount factor
π^s_{jh}	Survival prob. at age h
V^b_j	Bequest utility

Model overview

Beliefs about excess returns (i.i.d. case)

- Excess returns on risky asset:

$$\log\left(1 + r^e_{it+1}\right) \equiv \log(1 + u_{it+1}) \overset{\text{iid}}{\sim} \mathcal{N}\left(\widetilde{\mu}^u, \widetilde{\sigma}^2_u\right)$$

- Investors are uncertain about true $\widetilde{\mu}^u$, have belief $\widehat{\mu}_{ih}$ (and know variance $\widetilde{\sigma}^2_u$)
- Beliefs are updated in case of stock market participation:

$$\widehat{\mu}_{ih} = \begin{cases} (1 - \alpha_h)\widehat{\mu}^u_{ih-1} + \alpha_h \log(1 + r^e_{ih}) & \text{if } \xi > 0 \\ \widehat{\mu}_{ih-1} & \text{if } \xi = 0 \end{cases}$$

- Belief updating depends on age: (Malmendier and Nagel 2011, 2016)

$$\alpha_h = \frac{\left(\text{age}_h - 1\right)^{\lambda}}{\sum_{k=1}^{h-1}\left(\text{age}_h - k\right)^{\lambda}}$$

Model overview

Calibration: Other parameters

Model with i.i.d. returns

Returns

Gross risk-free return	R_f	1.02	[1]
Risk premium	$\overline{\mu}$	0.04	[1]
Std. dev. of risky returns	σ	0.253	
Part. cost	κ	0.00087	

Preferences

RRA	γ_j	2.370, 2.847, 2.402	
Discount factor	β_j	0.708, 0.872, 0.962	
EIS	ψ_j^{-1}	CRRA	
Bequest weight	ϕ_j	916.0, 2244.4, 1026.0	

Demographics

Distr. educ. types		0.111, 0.599, 0.290	[2]
Initial age	$\underline{h}$	25	
Maximum age	H	99	
Retirement age	H_r	65	
Survival prob.	π_{jh}^s		[3]

Earnings

Var perm shock	σ_v^2	0.011, 0.011, 0.017	[1]
Var trans shock	σ_ϵ^2	0.106, 0.074, 0.058	[1]
Earn profile	ω_{jh}		[1]
Ret repl rate	ρ_j^{ret}	0.890, 0.682, 0.939	[1]

Preferences

Avg tax rate	λ_T	0.092	[4]
Tax progressivity	τ	0.066	[4]

Sources

[1]	Cocco, Gomes, and Maenhout (2005)
[2]	SCF 1989–2022
[3]	Estimated from HRS
[4]	Borella et al. (2023)

Calibration

Average wealth by quintile

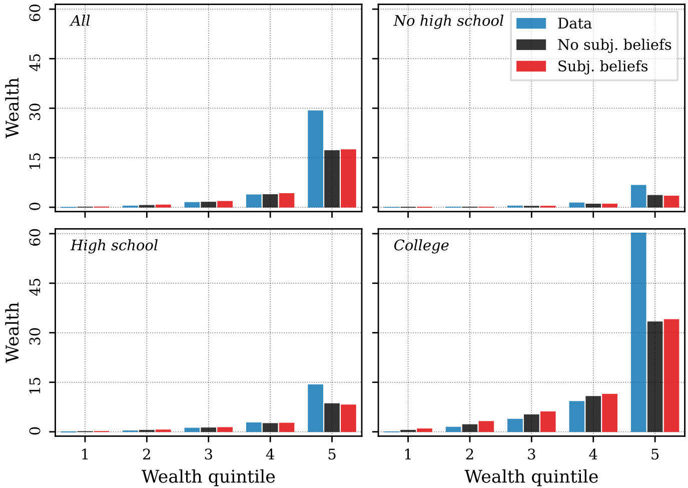


Figure 33: Average wealth by wealth quintile (in terms of average annual gross household income)

Calibration

Average wealth over the life cycle

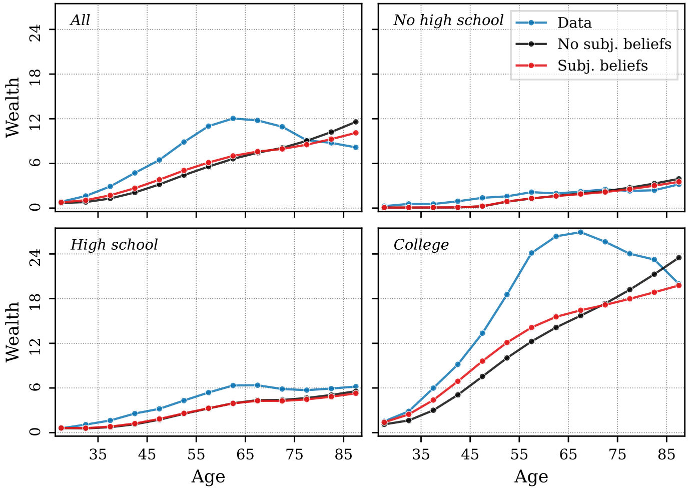


Figure 34: Average wealth over the life cycle (in terms of average annual gross household income)

Calibration

Risky share policy functions

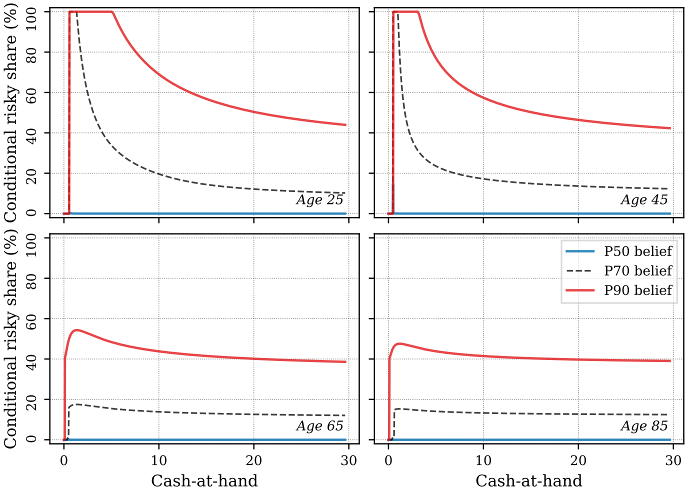


Figure 35: Risky share policy function

Portfolios over wealth

Portfolio composition over the life cycle

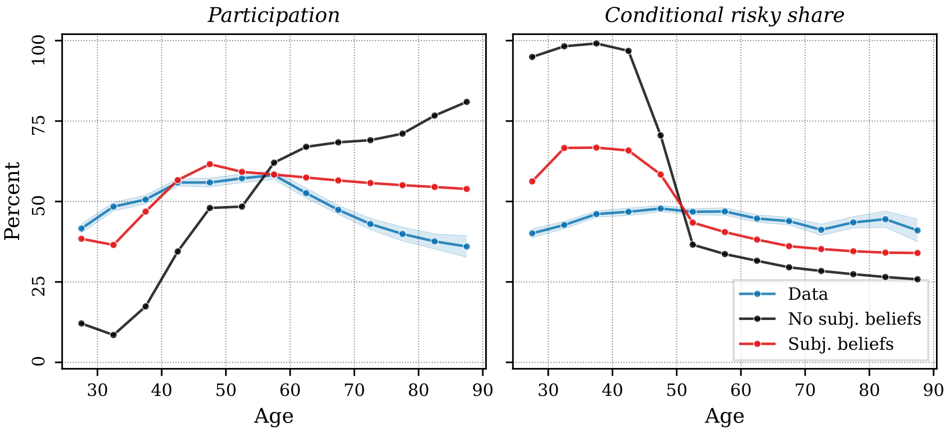


Figure 36: Portfolio composition over the life cycle

Portfolios over wealth

Quantitative life cycle model
with
market returns

Common market return

- Individual excess return consist of idiosyncratic term and market return:

$$r^e_{it+1} = u_{it+1} + \beta_m r^e_{mt+1}$$
$$\log(1 + u_{it+1}) \overset{\text{iid}}{\sim} \mathcal{N}\left(\widetilde{\mu}^u, \widetilde{\sigma}^2_u\right)$$
$$\log(1 + r^e_{mt+1}) \overset{\text{iid}}{\sim} \mathcal{N}\left(\widetilde{\mu}^m, \widetilde{\sigma}^2_m\right)$$

- Allows for cross-sectional correlation between investor i's and k's returns:

$$\text{Corr}\left(R_{it}, R_{kt}\right) = \frac{\beta^2_m \sigma^2_m}{\beta^2_m \sigma^2_m + \sigma^2_u} \approx 40\%$$

  based on Calvet, Campbell, and Sodini (2007).
- Investors form beliefs about $\widetilde{\mu}^m$ and $\widetilde{\mu}^u$
- Augmented state vector $\boldsymbol{x} \equiv (h, a, p, j, \widehat{\mu}^m, \widehat{\mu}^u)$
- Calibration (in levels): $\beta_m = 1$, $\mu^m = 0.04$, $\sigma_m = 0.16$, $\mu^u = 0$, $\sigma_u = 0.196$

Model overview

Portfolios along the wealth distribution

Model with market returns

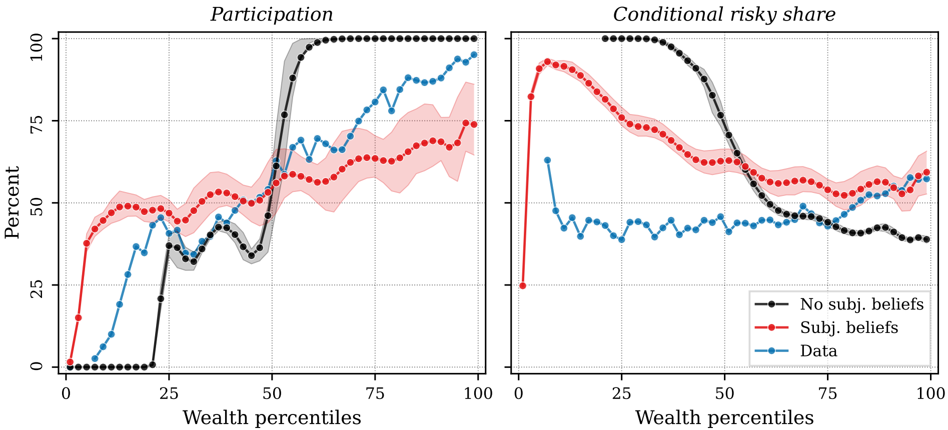


Figure 37: Portfolio composition along the wealth distribution.

Life cycle

Portfolio composition over the life cycle

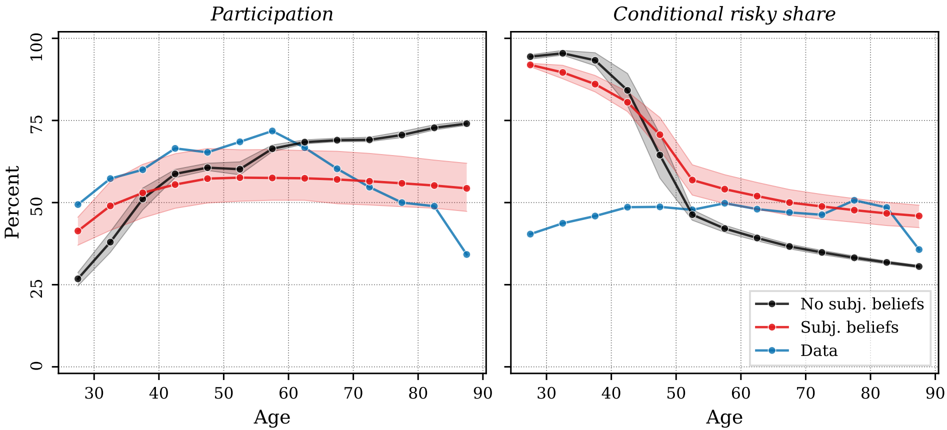
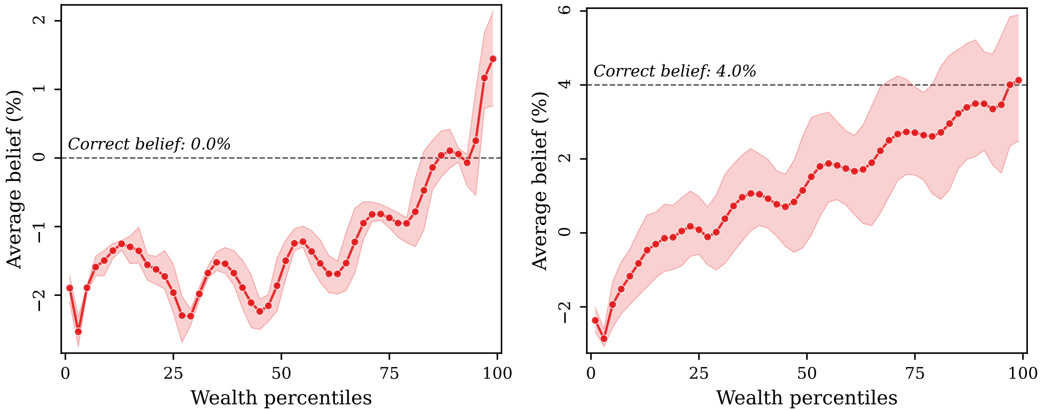


Figure 38: Portfolio composition over the life cycle

Portfolios over wealth

Mechanism: Positive sorting over beliefs & wealth

Model with market returns



(a) Idiosyncratic return $\widehat{\mu}_i^u$ **(b)** Market return $\widehat{\mu}_i^m$

Figure 39: Beliefs about the excess idiosyncratic return μ^u and the excess market return μ^m.

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