# Perceived Income Risks

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# Outline

1. Motivation
2. Empirical evidence
   - Cross-sectional patterns
   - Permanent versus transitory risks
   - Perceived risks and decisions
   - Summary of empirical findings
3. Model
4. Conclusion
   - Perceived risks and macroeconomic history

# Motivation

- Risks matter for individual decisions
  - precautionary saving
  - stock market participation
  - portfolio choice
- Risks matter for macroeconomic outcomes
  - since idiosyncratic risks are not perfectly insured
    - $\rightarrow$ income/wealth inequality
    - $\rightarrow$ heterogeneous $MPC$s
    - $\rightarrow$ distributional channel of macroeconomic policies
    - $\rightarrow$ business cycle fluctuations
- Income risks are central inputs of any incomplete-market model
- My question: perceptions $\approx$ estimates $\approx$ "the truth"?

# Some macro facts

- Wealth inequality and heterogeneity in $MPC$s
  - a standard incomplete market model generates insufficient inequality seen in the data
  - unless additional features such as preference heterogeneity or costly adjustment are introduced
- Liquid assets holdings
  - too few in data compared to a standard one-asset incomplete market model
- "Excessive sensitivity" to unanticipated transitory shocks
  - high $MPC$s seen in the data than $PIH$ model prediction

# Preview of the findings

1. **Empirics:** subjective risk profiles from a density survey
   - Heterogeneity: sizable difference across/within groups
   - Superior information: on average lower than standard parameterizations used by economists
   - State-dependence: negative correlation with recent/past labor market conditions
   - Extrapolation: correlated with negative labor outcomes
   - History-dependence: positive correlation with experienced volatility/unemployment
   - Decisions: spending plans react to risk perceptions

# Preview of the findings

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   - History-dependence: positive correlation with experienced volatility/unemployment
   - Decisions: spending plans react to risk perceptions
2. **Model**:
   - a survey-informed subjective OLG / incomplete-market GE model
     - With heterogeneous perceived risks (PR)
     - Lower PR $\rightarrow$ lower savings + more wealth inequality
     - State-dependence/extrapolation $\rightarrow$ higher savings
     - Heterogeneity in PR $\rightarrow$ more wealth inequality

# Literature

- income risks and partial insurance: Gottschalk et al. (1994), Carroll and Samwick (1997), Meghir and Pistaferri (2004), Storesletten et al. (2004), Blundell et al. (2008), Moffitt and Gottschalk (2002), Guvenen et al. (2014), Arellano et al. (2017), Bloom et al. (2018)
- subjective/probabilistic survey of beliefs: Manski (2004), Delavande et al. (2011), Manski (2018), Bertrand and Mullainathan (2001), Armantier et al. (2017)
- incomplete market macro: Bewley (1976), Aiyagari (1994), Huggett (1996), Krusell and Smith (1998), Heathcote et al. (2009), Carroll et al. (2017), Krueger et al. (2016), Bayer et al. (2019)
- consumption/saving under incomplete information/imperfect perception: Pischke (1995), Wang (2004), Rozsypal and Schlafmann (2017), Carroll et al. (2018), Lian (2019)

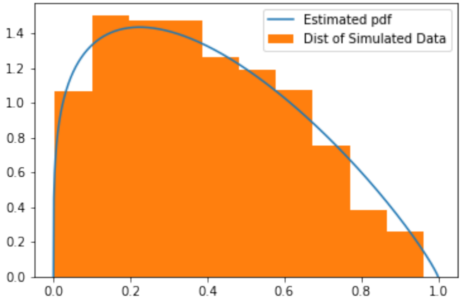
# Data and sample

- Density survey: SCE
    - 2013M6-2020M4 (monthly)
    - 1300 households
    - 12-month panel
- Income panel: SIPP
    - 2014M1-2019M12 (monthly)
    - wage computed for the primary job
    - 900-2700 respondents
    - CPI adjusted
    - age 25-65
    - only job-stayers with the same employer for $\geq$2 years

# Survey question

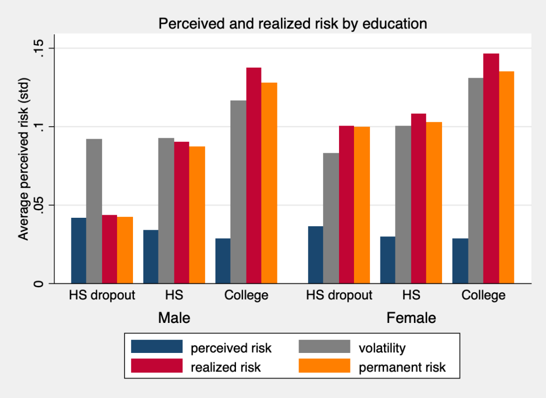
- Individual-specific bin-based forecast on $\Delta w_{i,t+1}$
  - wage growth of the same job/position/hours
  - exl. endogenous labor supply changes/promotion/demotion/separation
- Measurement of PR:
  - variance: $\overline{Var}_{i,t}(\Delta w_{i,t+1})$
  - computed from the density density forecast
- density estimation following Engelberg et al. (2009)
- restricted to attentive/high numeracy score sample
- adjusted into real terms using inflation uncertainty

# An illustration of the density forecast estimation



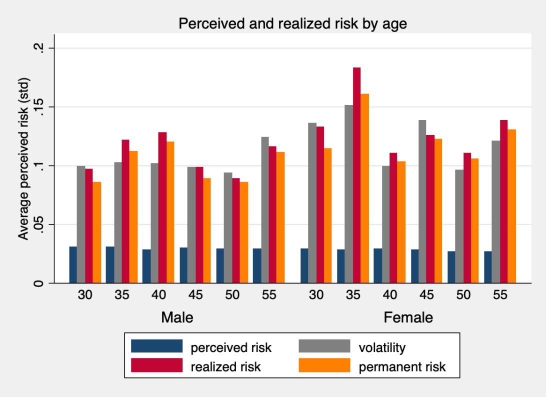

- case 1. 3+ intervals with positive probs, a generalized beta dist
- case 2. exactly 2 adjacent intervals with positive probs: a triangle dist
- case 3. one interval only: a uniform dist

# Observable heterogeneity: by education and gender

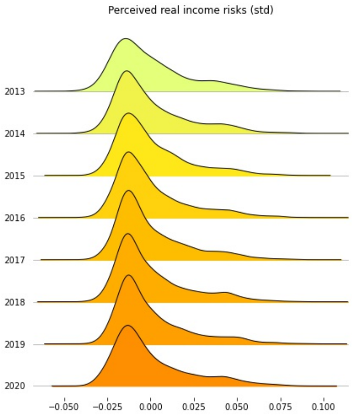



- consistent with Meghir and Pistaferri (2004)

# Observable heterogeneity: by age and gender



# Non-observable heterogeneity




- residuals controlling for observables + time FE ($R^2 = 0.10$)
- average PR: 3.5% in std; 10/90 IQR: 5.2% in std nominal

# Log wage process

$$\underbrace{w_{i,t}}_{\text{log wage}} = \underbrace{z_{i,t}}_{\text{predictable component}} + \underbrace{e_{i,t}}_{\text{stochastic component}}$$

- individual $i$ at time $t$
- $e_{i,t}$: to be specified later

# Perceived risks (PR)

- Wage growth

$$\Delta w_{i,t+1} = \Delta z_{i,t+1} + \Delta e_{i,t+1}$$

- To the agent: **conditional** variance under FIRE

$$Var^*_{i,t}(\Delta w_{i,t+1}) = \sigma^2_{t+1|t}$$

- To econometricians: **approximated unconditional** variance

$$Var^c(\Delta \hat{e}_{i,c,t+1}) = \hat{\sigma}^2_{c,t} + \hat{\sigma}^2_{c,t+1} - 2Cov^c(\hat{e}_{i,c,t}, \hat{e}_{i,c,t+1})$$

- $\hat{e}_{i,c,t+1}$: first step regression residual controlling observable vars
- group $c$: **assumed** to share income process/risks $\sigma^2_{c,t}$
  - i.e. education/year of birth/gender/age

# Possible problems with estimation

- $\hat{e}_{i,c,t} \neq e_{i,c,t}$
  - Intrinsic heterogeneity of individual $i$ beyond $c$
  - Foresight about individual circumstance not available to economists

# Time series structure of wage shocks

$$e_{i,c,t} = \underbrace{p_{i,c,t}}_{\text{permanent}} + \underbrace{\theta_{i,c,t}}_{\text{transitory}}$$

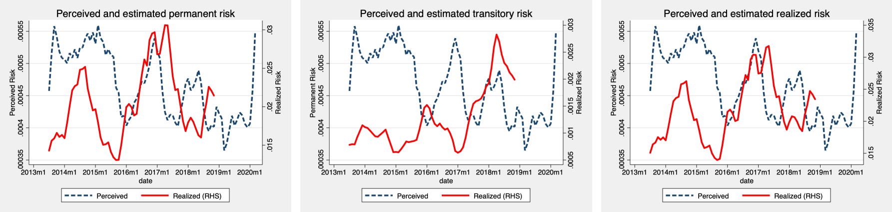
$$p_{i,c,t+1} = p_{i,c,t} + \psi_{i,c,t+1}$$

$$\psi_{i,c,t} \sim N(0, \sigma^2_{c,t,\psi})$$

$$\theta_{i,c,t} \sim N(0, \sigma^2_{c,t,\theta})$$

# Permanent versus transitory risks

(a) permanent (b) transitory (c) volatility




- i.e. one-year-ahead perceived risk at 2014m1 v.s. realized risk over the same period
- wage rate for the same job/hours/position
- estimated monthly risks aggregated into annual frequency

More details PSID

# Perceptions versus economists' estimates

| | PR(mean) | PR(median) | Volatility | RealizedRisk | PRisk | TRisk |
|---|---|---|---|---|---|---|
| gender | | | | | | |
| 1 (50%) | 0.03 | 0.022 | 0.105 | 0.115 | 0.109 | 0.0238 |
| 2 (49%) | 0.028 | 0.022 | 0.118 | 0.131 | 0.122 | 0.0322 |
| education group | | | | | | |
| HS dropout (0%) | 0.036 | 0.022 | 0.088 | 0.071 | 0.07 | 0.0063 |
| HS graduate (42%) | 0.03 | 0.022 | 0.096 | 0.098 | 0.094 | 0.0176 |
| College/above (56%) | 0.028 | 0.021 | 0.124 | 0.142 | 0.132 | 0.0357 |
| 5-year age | | | | | | |
| 20 (2%) | 0.037 | 0.031 | 0.094 | 0.069 | 0.068 | 0.0061 |
| 25 (12%) | 0.032 | 0.027 | 0.111 | 0.157 | 0.156 | 0.0083 |
| 30 (12%) | 0.03 | 0.023 | 0.116 | 0.112 | 0.098 | 0.0372 |
| 35 (13%) | 0.029 | 0.021 | 0.125 | 0.149 | 0.134 | 0.0524 |
| 40 (13%) | 0.028 | 0.02 | 0.1 | 0.119 | 0.111 | 0.0287 |
| 45 (14%) | 0.028 | 0.02 | 0.119 | 0.113 | 0.106 | 0.0224 |
| 50 (15%) | 0.027 | 0.019 | 0.095 | 0.1 | 0.096 | 0.0203 |
| 55 (15%) | 0.027 | 0.018 | 0.122 | 0.128 | 0.121 | 0.0283 |
| Full sample (100%) | 0.029 | 0.021 | 0.112 | 0.123 | 0.115 | 0.0279 |

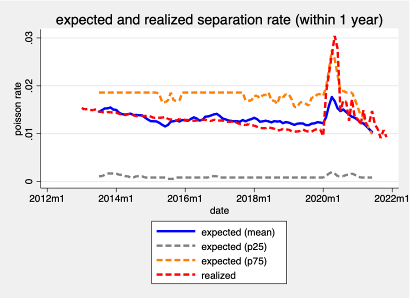
# Perceived risks and household spending

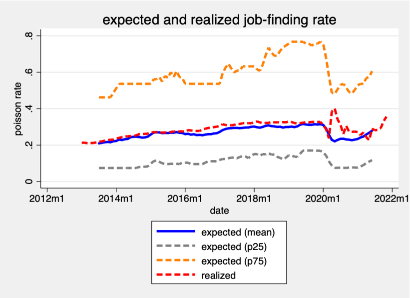
$$E_{i,t}(\Delta c_{i,t+1}) = u_0 + u_1 \overline{\text{risks}}_{i,t}(\Delta y_{i,t+1}) + \xi_{i,t}$$

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| perceived earning risk | 8.394*** | 8.399*** | 3.642*** | 3.243*** | | |
| | (1.175) | (1.176) | (0.533) | (0.537) | | |
| perceived earning risk (nominal) | | | | | 3.656*** | |
| | | | | | (0.990) | |
| perceived ue risk | | | | | | 0.353*** |
| | | | | | | (0.0553) |
| R-squared | 0.0010 | 0.00282 | 0.928 | 0.928 | 0.941 | 0.633 |
| Sample Size | 53178 | 53178 | 53178 | 53178 | 54584 | 6269 |
| Time FE | No | Yes | No | Yes | Yes | No |
| Individual FE | No | No | Yes | Yes | Yes | Yes |

- Higher perceived risks → higher expected spending growth.

# Perceived UE risks and realization




- realization computed from CPS panel of individuals

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    - a resolution to "superior information"/ unobserved heterogeneity
    - heterogeneity in wage risks without grouping people

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- Why not directly use survey-reported PR?!
  - a resolution to "superior information"/ unobserved heterogeneity
  - heterogeneity in wage risks without grouping people
- But need to be careful with measurement errors in PR from survey and behavioral bias.

# Implications for consumption/saving

- On level of aggregate savings
  1. $\downarrow$ lower PR: lower precautionary saving motives $\rightarrow$ less liquid holding $\rightarrow$ higher MPC

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  3. $\uparrow$ extrapolation: lower income/unemployment $\rightarrow$ higher PR $\rightarrow$ intensified precautionary motive

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  4. $\uparrow$ counter-cyclical risks: amplified business cycle fluctuations Bayer et al. (2019)

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- On wealth inequality
  - ↑ Direct effect: heterogeneous PR → heterogeneity in saving/wealth
  - ↑ Indirect effect: lower PR → lower self-insurance → higher ex-post wealth inequality

# Model overview

- Overlapping generation
- General equilibrium
- Uninsured idiosyncratic income risks
  - Permanent+ transitory productivity shock
  - Persistent unemployment spells
- No aggregate risk a la Krusell and Smith (1998)
- A blend of Huggett (1996) and Carroll (1997)
- Single one risk-free asset
- Allowing for subjective risk perceptions
  - Individuals swing between low/high risk perceptions

# Benchmark model (objective risk perceptions)

$$\max \quad \mathbb{E}\left[\sum_{\tau=0}^{\tau=L-1}(1-D)^{\tau}\beta^{\tau}u(c_{i,\tau})\right]$$

$$\underbrace{a_{i,\tau}}_{\text{Savings}} = \underbrace{m_{i,\tau}}_{\text{Cash in hand}} - c_{i,\tau}$$

$$b_{i,\tau+1} = a_{i,\tau}R$$

$$m_{i,\tau+1} = b_{i,\tau+1} + (1 - \underbrace{\lambda}_{\text{Income tax}})y_{i,\tau+1}$$

$$a_{i,\tau} \geq 0$$

- CRRA: $u(c) = \frac{c^{1-\rho}}{1-\rho}$
- Work age: $\tau = 1, 2..., T$ (since entering job market)
- Life length: $\tau = 1, 2..., L$ (since entering job market)
- Survival probability: 1-D

# Income process over the life-cycle

- income

$$y_{i,\tau} = n_{i,\tau} W$$
$$n_{i,\tau} = p_{i,\tau}\xi_{i,\tau}$$

- permanent component

$$p_{i,\tau} = G_\tau p_{i,\tau-1}\psi_{i,\tau}, \quad log(\psi_{i,\tau}) \sim N(-\sigma^2_\psi/2, \sigma^2_\psi) \quad \forall \tau \leq T$$

- persistent/transitory component

$$\xi_{i,\tau} = \begin{cases} \theta_{i,\tau} \quad \text{if} \quad \nu_{i,\tau} = e \quad \& \quad \tau \leq T, \quad log(\theta_{i,\tau}) \sim N(-\frac{\sigma^2_\theta}{2}, \sigma^2_\theta) \\ \zeta \quad \text{if} \quad \nu_{i,\tau} = u \quad \& \quad \tau \leq T \\ \mathbb{S} \quad \text{if} \quad \tau > T \end{cases}$$

- transition probability between $\nu = u$ and $\nu = e$

$$\pi(\nu_{\tau+1}|\nu_\tau) = \begin{bmatrix} \mho & 1-\mho \\ 1-E & E \end{bmatrix}$$

# Objective versus subjective profile

- objective: agents perceive $\underbrace{\Gamma = \{\sigma^2_\psi, \sigma^2_\theta, \mho, E\}}_{\text{income risk parameters}}$
- subjective with state-dependence: each agent $i$ swings between two subjective risk state $\tilde{\Gamma}_{i,\tau} = \tilde{\Gamma}_l$ and $\tilde{\Gamma}_{i,\tau} = \tilde{\Gamma}_h$, with transition matrix $\Omega$.
  - heterogeneity in risk perceptions
- subjective model with extrapolation: $\tilde{\Gamma}_{i,\tau}$ depends on employment status $\nu_{i,\tau}$, i.e. $\tilde{\Gamma}_{i,\tau}(\nu_{i,\tau} = 0) = \tilde{\Gamma}_l$ and $\tilde{\Gamma}_{i,\tau}(\nu_{i,\tau} = 1) = \tilde{\Gamma}_h$

# Why subjective risk perceptions?

- I don't take a stance on if agents perceptions are correct or wrong
  - unobserved information to economists
  - or agents under-perceive the true risks
- The subjective risk profile is disciplined by the survey data
- Risk parameters are exogenous to the model, therefore, does not contradict with rational expectation.

# Economic environment

- Technology

$$Y = ZK^{\alpha}N^{1-\alpha}$$

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$$\lambda \left[1 - \Pi^{\mho} + \zeta\Pi^{\mho}\right] = \zeta\Pi^{\mho} \tag{1}$$

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- Demographics
  - Stable age distribution $\{\mu_{\tau}\}_{\mu=1,2,..L}$

$$\mu_{\tau+1} = (1-D)\mu_{\tau}$$

$$\sum_{\tau=1}^{L}\mu_{\tau} = 1$$

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$$\sum_{\tau=1}^{L}\mu_{\tau}=1$$

- Accidental bequests
  - Newborn starts with a bank-balance equal to $0-1$ fraction of the lump-sum of the accidental deceased's wealth

# Value functions under different profiles

- objective:

$$V_\tau(\underbrace{\nu_{i,\tau}, m_{i,\tau}, p_{i,\tau}}_{x_{i,\tau}}) = \max_{\{c_{i,\tau}, a_{i,\tau}\}} \quad u(c_{i,\tau})$$

$$+ (1-D)\beta\mathbb{E}_\tau\left[V_{\tau+1}((\nu_{i,\tau}, m_{i,\tau+1}, p_{i,\tau+1})\right]$$

- subjective:

$$\tilde{V}_\tau(\underbrace{\tilde{\Gamma}_\tau, \nu_\tau, m_\tau, p_\tau}_{\tilde{x}_{i,\tau}}) = \max_{\{c_\tau\}} \quad u(c_\tau)$$

$$+ (1-D)\beta\mathbb{E}_\tau\left[\tilde{V}_{\tau+1}(\tilde{\Gamma}_{\tau+1}, \nu_\tau, m_{\tau+1}, p_{\tau+1})\right]$$

# Evolution of the distribution over state variables

- objective:

$$\psi_\tau(B) = \int_{x \in X} \underbrace{P(x, \tau-1, B)}_{\text{transition funcs}} \mathrm{d}\psi_{\tau-1} \quad \text{for all} \quad B \in B(X)$$

  - $B(X)$: distribution measure on state space $X$
  - $\psi_\tau$: distribution over state variables $x$ for agents in age $\tau$
  - $\psi_1$ depends on initial draws of income shocks

- subjective:

$$\tilde{\psi}_\tau(\tilde{B}) = \int_{\tilde{x} \in \tilde{X}} \tilde{P}(\tilde{x}, \tau-1, \tilde{B}) \mathrm{d}\tilde{\psi}_{\tau-1} \quad \text{for all} \quad \tilde{B} \in \tilde{B}(X)$$

# Stationary equilibrium (StE)

- Optimal consumption and saving policies given $W$, $R$, $\lambda$
- Distribution evolution consistent with optimal $c$ and $a$ policies and exogenous probabilities of income/beliefs
- The factor markets are clearing.

$$\sum_{\tau} \mu_\tau \int_X a(x,\tau)\mathrm{d}\psi_\tau = K$$

$$\sum_{\tau=0}^{T-1} \mu_\tau \Pi_\tau^E = N$$

- Firm optimization under competitive factor markets.

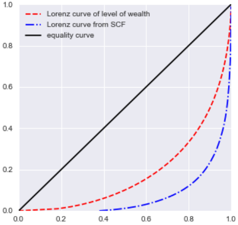
$$W = Z(1-\alpha)(K/N)^\alpha$$

$$R = 1 + Z\alpha(K/N)^{\alpha-1} - \delta$$

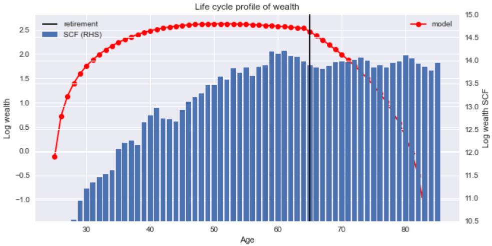
- Newborn's bank balance equal to accidental bequests
- Balanced government budget

# StE Distribution of the objective model (preliminary)

(a) Wealth inequality




(b) Life-cycle wealth distribution




Calibration Partial equilibrium

# Estimation of subjective risk profile

$$\underbrace{\tilde{\Gamma}^s_{i,t}}_{\text{reported PR}} = \underbrace{\tilde{\Gamma}_l + \mathbb{1}(\overbrace{J_{i,t}}^{\text{Hidden state}} = 1)(\tilde{\Gamma}_h - \tilde{\Gamma}_l)}_{\tilde{\Gamma}_{i,t}} + \xi_t + \eta_i + \epsilon_{i,t}$$

$$\text{Prob}(J_{i,t+1}|J_{i,t}) = \Omega$$

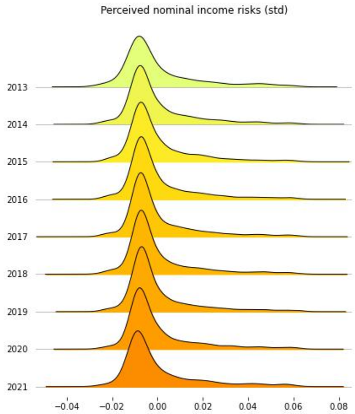
- $J_{i,t} = 0$ for low and $= 1$ for high PR state
- a short time series of $\tilde{\Gamma}_{i,t}$ for many $i$s observed in the survey
- $\{\tilde{\Gamma}_l \, \tilde{\Gamma}_h, \Omega\}$ can be estimated by $MLE$
- a modified Hamilton (1989) 2-regime-switching model
- $J_{i.t}$ can be also dependent upon business cycles

More details

# Summary

- Survey data can inform incomplete-market macro models
  - Direct evidence for heterogeneity in perceptions that *matter*
  - Closer to agents' information set that truly affects their decisions
  - No need to make stringent assumptions on expectation formation
- More work needed on
  - heterogeneous beliefs in HM models
  - understanding risk perception formation

# Within-group dispersion in nominal PR




- residuals controlling for observables /time fixed effects
- average PR: 2.1% in std; 10/90 IQR: 3.2% in std

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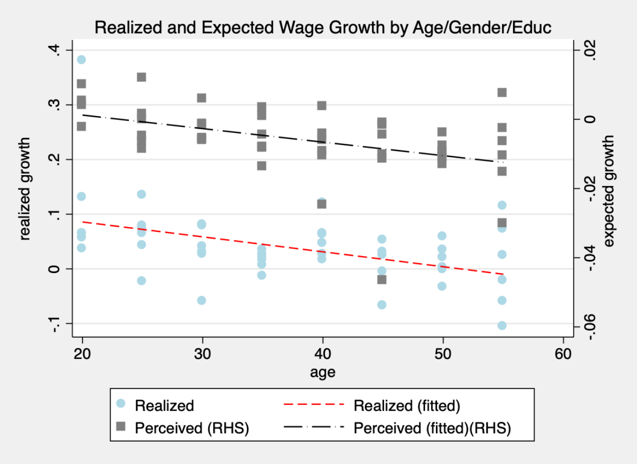
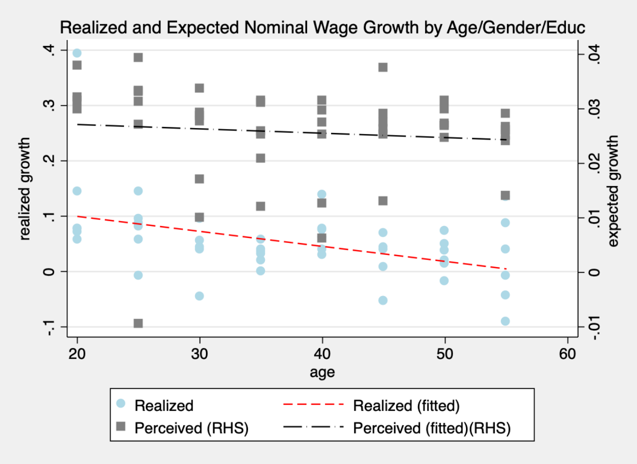
# Appendix: expected growth by age




- e.g. a male high school graduate aged 30

# Appendix: expected **nominal** growth by age

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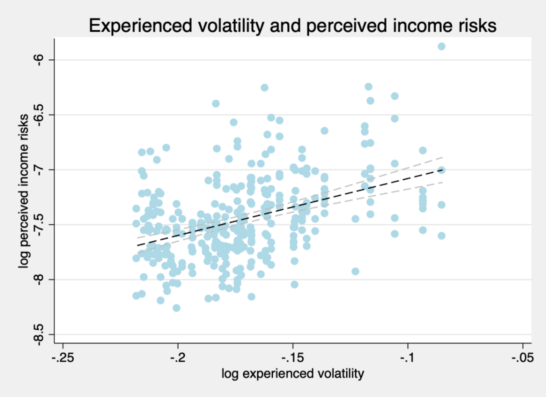
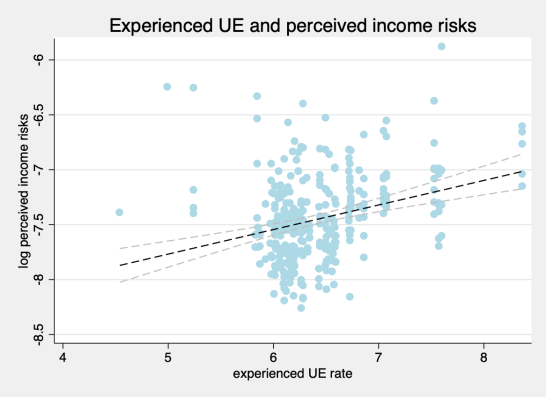
# Appendix: Experienced volatility and PR




- income volatility conditional on macroeconomic history Storesletten et al. (2004)
- e.g. the experience by a 25-year old till 2015 is between 1990-2015

# Experienced labor market and perceived risks




- e.g. experienced UE by a 25-year old in 2015 is between UE over 1990-2015

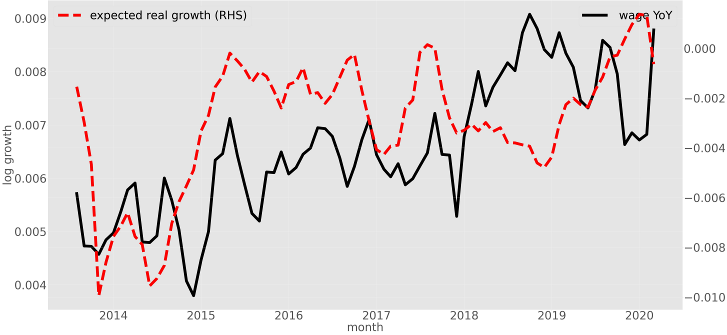
# Appendix: Extrapolation from individual experiences

- higher experienced volatility → higher PR
- recent unemployment experience → higher PR

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| income shock squared | 0.0225*** | 0.0222*** | 0.0217*** | 0.0207*** | 0.000773 | 0.00205*** | 0.000566 | 0.00183*** | 0.000614 | 0.00184*** |
| | (0.00562) | (0.00570) | (0.00562) | (0.00564) | (0.000743) | (0.000516) | (0.000744) | (0.000515) | (0.000745) | (0.000516) |
| recently unemployed | | | | 0.511* | 0.228*** | 0.0895*** | | | | |
| | | | | (0.260) | (0.0330) | (0.0200) | | | | |
| unemployed since m-8 | | | | | | | 0.161*** | 0.0783*** | | |
| | | | | | | | (0.0207) | (0.0121) | | |
| unemployed since y-1 | | | | | | | | | 0.138*** | 0.0701*** |
| | | | | | | | | | (0.0193) | (0.0113) |
| Observations | 3662 | 3662 | 3662 | 3662 | 3701 | 1871 | 3701 | 1871 | 3701 | 1871 |
| R-squared | 0.004 | 0.013 | 0.016 | 0.017 | 0.015 | 0.030 | 0.019 | 0.041 | 0.016 | 0.039 |

# Appendix: expected income growth and recent (past) wage growth

- $\overline{\exp_t}$: average expected growth across individuals
- quarterly growth in average hourly wage

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# Appendix: PR and current labor market condition

$$\underbrace{\overline{\text{risk}_t}}_{\text{average perceived risk}} = \alpha + \beta \underbrace{\left(log(\text{wage}_{t-k/12}) - log(\text{wage}_{t-(k-3)/12})\right)}_{\text{wage growth}} + \epsilon_{i,t}$$

$$\forall k = 0...4$$

| | mean:var | mean:iqr | mean:rvar | mean:skew |
|---|---|---|---|---|
| 0 | -0.28** | -0.42*** | -0.48*** | -0.02 |
| 1 | -0.42*** | -0.53*** | -0.51*** | 0.12 |
| 2 | -0.43*** | -0.48*** | -0.44*** | -0.01 |
| 3 | -0.43*** | -0.48*** | -0.42*** | -0.1 |
| 4 | -0.31*** | -0.41*** | -0.32*** | -0.21* |

- Counter-cyclical income risks: Storesletten et al. (2004), Guvenen et al. (2014), Bayer et al. (2019)

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# Appendix: PR and current labor market condition

$$\underbrace{\overline{\text{risk}_{s,t}}}_{\text{median perceived risk in state } s} = r + {\color{red}\psi} \underbrace{LM_{s,t}}_{\text{state labor market condition}} + \eta_{s,t}$$

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | log(var) | log(risk) | log(iqr) | log(iqr) |
| wage growth | -0.05*** | | -0.03*** | |
| | (0.01) | | (0.01) | |
| unemp rate | | 0.04* | | 0.04*** |
| | | (0.02) | | (0.01) |
| Observations | 3529 | 3529 | 3546 | 3546 |
| R-squared | 0.023 | 0.020 | 0.025 | 0.028 |

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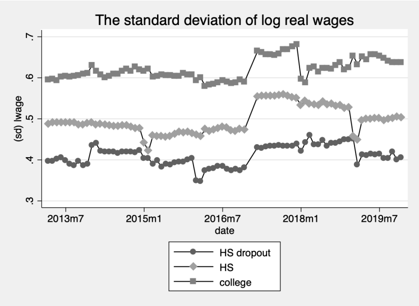
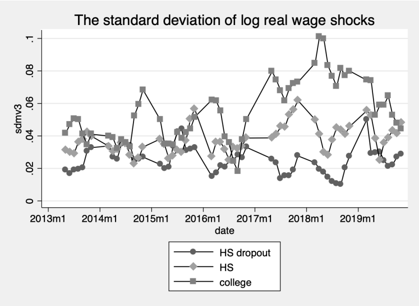
# Appendix: monthly earning inequality and volatility

(a) Inequality




(b) Volatility

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# Appendix: estimation of subjective risk profile

$$\log(\tilde{\text{var}}_{i,t}) = (12 + \frac{1}{12\kappa^2})\tilde{\sigma}^2_{i,t,\psi} + \xi_t + \eta_i + \epsilon_{i,t}$$

- $\kappa$: externally assumed ratio of permanent and transitory risks $\frac{\tilde{\sigma}_{i,t,\psi}}{\tilde{\sigma}_{i,t,\theta}}$

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# Appendix: calibration of the objective model

Table: Model parameters

| block | parameter name | values | source |
|---|---|---|---|
| risk | $\sigma_\psi$ | 0.15 | Median estimates from the literature |
| risk | $\sigma_\theta$ | 0.1 | Median estimates from the literature |
| risk | $U2U$ | 0.18 | Median estimates from the literature |
| risk | $E2E$ | 0.96 | Median estimates from the literature |
| initial condition | $\sigma_\psi^{\text{init}}$ | 0.629 | Estimated for age 25 in the 2016 SCF |
| initial condition | bequest ratio | 0 | assumption |
| life cycle | $T$ | 40 | standard assumption |
| life cycle | $L$ | 60 | standard assumption |
| life cycle | $1-D$ | 0.994 | standard assumption |
| preference | $\rho$ | 1 | standard assumption |
| preference | $\beta$ | 0.98 | standard assumption |
| policy | $\mathbb{S}$ | 0.65 | U.S. average |
| policy | $\lambda$ | 0 | endogenously determined |
| policy | $\lambda_{SS}$ | 0 | endogenously determined |
| policy | $\mu$ | 0.15 | U.S. average |
| production | $W$ | 1 | target values in steady state |
| production | K2Y ratio | 3 | target values in steady state |
| production | $\alpha$ | 0.33 | standard assumption |
| production | $\delta$ | 0.025 | standard assumption |

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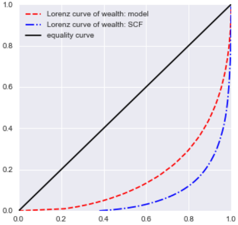
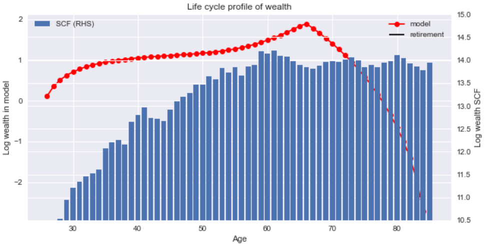
# Appendix: distribution in the partial equilibrium

(a) Wealth inequality




(b) Life-cycle wealth distribution

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# Extensions: additional heterogeneity in $MPC$

- Heterogeneous time preferences
  - Ex-ante differences in $\beta$, a la Krusell and Smith (1998); Carroll et al. (2017); Krueger et al. (2016).
- Costly adjustments

$$V_{i,\tau}(c_{i,\tau-1}, x_{i,\tau}) = \max \quad \{V^A_\tau(x_{i,\tau}) - \chi, V^N_\tau(c_{i,\tau-1}, x_{i,\tau})\}$$

$$V^A_\tau(x_{i,\tau}) = \max_{\{c_{i,\tau}\}} \quad u(c_{i,\tau}) + (1-D)\beta\mathbb{E}_\tau\left[V_{\tau+1}(x_{i,\tau+1})\right]$$

$$V^N_\tau(c_{i,\tau-1}, x_{i,\tau}) = u(c_{i,\tau-1}) + (1-D)\beta\mathbb{E}_\tau\left[V_{\tau+1}(c_{i,\tau}, x_{i,\tau+1})\right]$$

  - Utility cost from adjusting consumption in each period
  - To introduce extensive margin of consumption change and match high $MPC$ from data

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