Income Volatility and Portfolio Choices

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SNU Workshop
Jan 10, 2020

Labor Market Risk & Financial Decisions

- "Background" risks are important for financial decisions
- Uncertainty in labor market: main risk
- Better understanding of interaction between labor and financial market risks is important for:
  - Consumption / Savings
  - Portfolio Choices
  - Policies (social security etc.)

Studies on Interaction between Portfolio Choices and Labor Market Risk

- Limited Empirical Analysis:
  - Lack of panel data for both financial and labor markets
  - Mostly cross-sectional variation (occupation, industry, etc.): Heaton and Lucas (2000, JF), Angerer and Lam (2009)
  - Exception: Fagereng, Guiso, and Pistaferri (2017)

- Quantitative Analysis:
  - Krusell and Smith (1997), Heaton and Lucas (2000, EJ), Cocco, Gomes and Maenhout (2005), Storesletten, Telmer, Yaron (2007), Benzoni et al. (2011), Huggett and Kaplan (2016), Chang, Hong, and Karabarbounis (2018), etc.

This Paper: New Empirical evidence

- Norwegian administration (tax records) data:
  long panel of detailed financial and labor market data

- Identify the interaction between income volatility and portfolio choices with *novel* features:
  1. Identify individual structural breaks in income volatility
  2. Worker-Firm Matched Data: firm-side information as IV

This Paper: New Empirical evidence

- Clear negative relationship between the income volatility and household's risky share
- We also find:
  1. Responses before volatility changes
  2. Gradual/persistent adjustment in risky shares
  3. Heterogeneity across demographics

This paper: Quantitative Analysis

- Standard Life-cycle model with portfolio choices
- What's new?
  - Volatility shocks in income process
  - Allowing for Perfect and/or Imperfect information about volatility regimes: Bayesian learning and updating
- Model is consistent with empirical facts along various dimensions

This paper: New Implications

- Importance of volatility shocks on households' portfolio choices:
    - Not studied previously
    - (Heaton and Lucas (2000 EJ), Cocco, Gomes and Maenhout (2005)
- Persistence of volatility matter (panel feature)
    - Dynamics of risky shares can be useful

Empirical Analysis

Wealth Registry Record

- All Norwegian residents required to report their wealth
  - Bank deposits
  - Bonds traded in the financial market
  - Shares in mutual funds
  - Shares in private companies
  - Cash value of life insurance policies
  - Other "Financial securities"

  - Debt
  - Value of home ownership and real estate
- Cross check with financial institutions.
- Relatively "Measurement-Error Free"

Merge with Other Data Sets

- Income Tax Registry: Detailed Incomes & Tax/Transfers
- Employer-Employee Register: Labor Market Status
- Central Population Register: Demographics
- National Educational Database: Education

Sample Selection

- Randomly selected 10% Norwegian males
- At least 25 years old as of 1993.
- More than 20 years panel for 1993-2014.
- At least 18 years of positive labor earnings
- At least 16 years of positive risky shares
- Total financial asset > 50K in 2005 NOK (10th percentile) $\approx \$ 6{,}000$

$\Longrightarrow$

- About 50,000 workers per year.

Risky vs. Safe Assets

Focus on *financial* portfolio choice b/w risky and safe assets

- **Risky Assets**:
  - Shares in mutual funds
  - Shares in private companies
  - Risky component of "financial securities" (mainly stocks and equity certificates)
- **Safe Assets**:
  - Bank deposits
  - Cash value of life insurance policies
  - Safe component of "financial securities" (mainly government bonds, corporate short-term and long-term bonds)
- $\textbf{Risky Share} = \frac{\textbf{Risky}}{\textbf{Risky + Safe}}$
- Robustness across alternative definitions

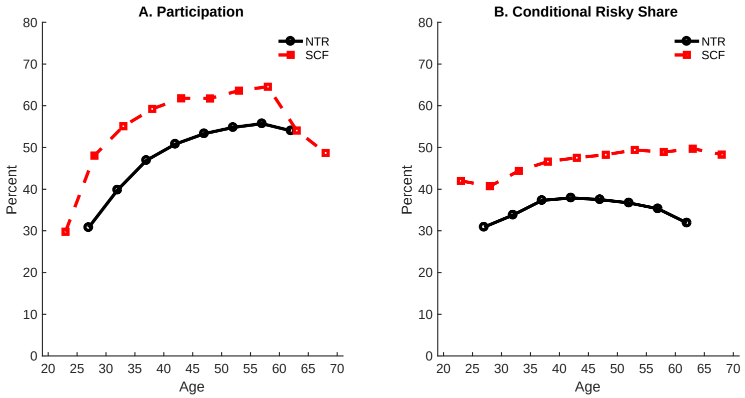
Risky Shares: NTR vs. SCF

Table: Conditional Risky Share and Participation Rate

	Participation		Conditional RS	
	NTR	SCF	NTR	SCF
All Sample	0.48	0.55	0.31	0.46
Renter	0.26	0.34	0.29	0.43
Homeowner	0.54	0.65	0.31	0.47
Less than College	0.44	0.57	0.30	0.44
College Degree	0.59	0.57	0.33	0.47
Single	0.34	0.45	0.35	0.46
Married	0.55	0.66	0.30	0.47

NTR: Norwegian Tax Registry
SCF: Survey of Consumer Finances

Life-Cycle Profile of Risky Share



Income Volatility

- y_{it}: log (real) annual labor earnings of worker i in year t
  - net of age and time effects
  - earnings vs. wages
  - less measurement error than wages (due to reported hours)
  - also taking care of possible multiple jobs

- $\Delta y_{it} \equiv y_{it} - y_{i,t-1}$: annual income growth

- $SD_i[\Delta y_{it}]$: SD of income growth for individual i

Change in Income Volatility

- $SD_i[\Delta y_{it}]$: SD of income growth for individual i
- For a given T, Volatility before T

$$SD_{i,T^-} \equiv SD_i[\Delta y_{it} | t < T]$$

- Volatility after T

$$SD_{i,T^+} \equiv SD_i[\Delta y_{it} | t \geq T]$$

- **Change** in income volatility before and after T:

$$\Delta SD_{i,T} \equiv SD_{i,T^+} - SD_{i,T^-}.$$

Identifying *individual* structural break

- Look for the **"largest"** change in income volatility $SD_{i,\tau}[\Delta y_{it}]$ over 20 years (1995-2014) for each worker.
  - Similar spirit as in Card, Mas and Rothstein (2008), Charles, Hurst and Notowidigdo (2018) for housing price changes/other time series

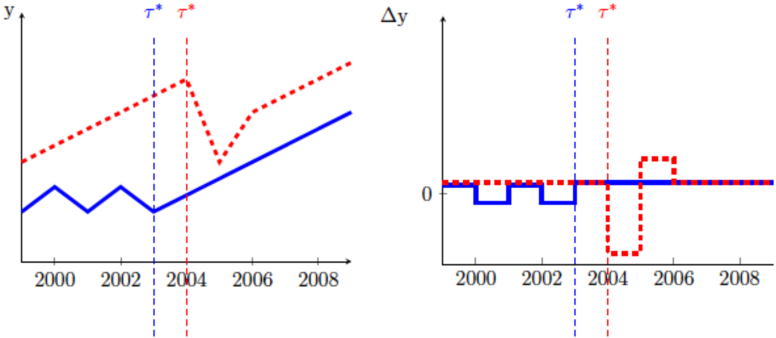
- For each worker i, find year τ^*

$$\tau^* \equiv argmax_{1999 \leq \tau \leq 2009} \{|\Delta SD_{i,\tau}|\}$$

  - At least 5 years in each sub-sample.

- $\Delta SD_{i,\tau^*}$: Our benchmark measure of change in income volatility in the labor market.

Illustration of Structural Break

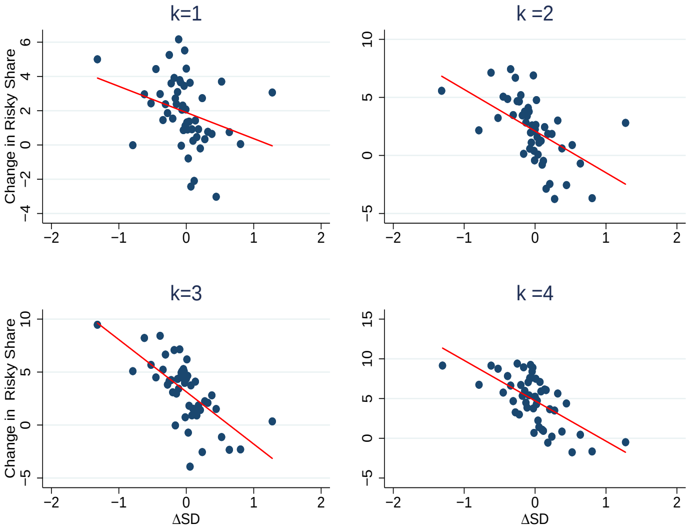


Income Volatility

	Mean	S.D.	Percentile						
			5%	10%	25%	50%	75%	90%	95%
$\Delta y_{i,t}$	-0.002	0.398	-0.499	-0.240	-0.065	0.004	0.069	0.230	0.476
$SD_i[\Delta y_{it}]$	0.319	0.260	0.056	0.075	0.136	0.247	0.419	0.659	0.831
$\Delta SD_{i,2005}[\cdot]$	-0.052	**0.389**	-0.675	**-0.454**	-0.203	-0.030	0.097	**0.332**	0.547
$\Delta SD_{i,\tau^*}[\cdot]$	-0.098	0.583	-1.031	-0.722	-0.352	-0.072	0.193	0.498	0.775

Empirical Results

Δ Risky Shares vs. Δ Volatility



Response of Risky Share to Volatility

Consider:

$$\mathrm{RS}_{i,\tau^*+k} - \mathrm{RS}_{i,\tau^*-k} = \beta \Delta SD_{i,\tau^*} + \ \alpha X_{i,\tau^*} + \delta D_t + \epsilon_{i,\tau^*}$$

X_{i,τ^*} include:

- Differences (b/w $\tau^*(i) + k$ and $\tau^*(i) - k$):
  - HH Income, HH Wealth
  - Marital status, Home ownership
  - Number of children, Number of young children.
- Levels (as of τ^*): Age, Age squared, Income, Wealth.

D_t: year dummy

Response of Risky Share (β)

Dependent Variable: $RS_{i,\tau^*+k} - RS_{i,\tau^*-k}$

$k=1$	$k=2$	$k=3$	$k=4$
-0.50	-1.94***	-1.54***	-1.76***
(0.42)	(0.51)	(0.55)	(0.55)

One SD increase in $\Delta SD_{i,\tau^*}$ (0.583), leads to a decrease in Risky Share about 1 percentage point

What's behind Structural Break?

What's associated with "Structural Break"?

- Inspecting events associated with τ^*'s

$$\text{I(Big Structural Change)}_{i,\tau^*} = \beta_E^k \times E_{i,\tau^*-k} + X_{i,\tau^*} + D_t + \epsilon_{i,\tau^*}.$$

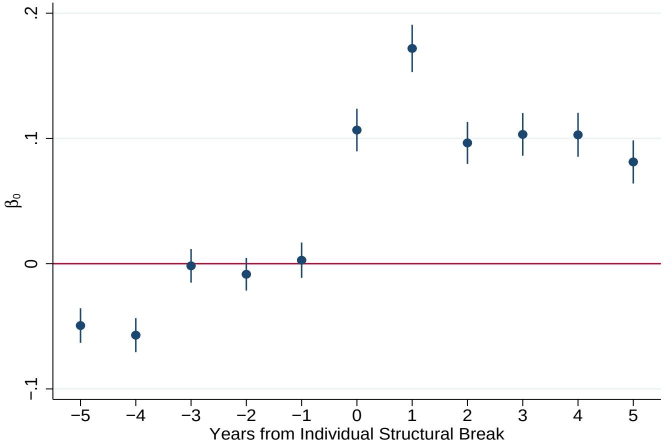
- E_{i,τ^*-k}, $(-5 \leq k \leq 5)$:
  Individual events such as **changes** in:
  - Employers
  - Industry/occupation/community
  - Marital status, Home ownership

Define Big Structural Breaks

- To highlight significant cases among τ^*'s
- Structural Break of Volatility **Increase**:
$\Delta SD_{i,\tau^*} > \overline{SD}$ (0.33, 90th percentile)
- Structural Break of Volatility **Decrease**:
$\Delta SD_{i,\tau^*} < \underline{SD}$ (-0.45 10th percentile)

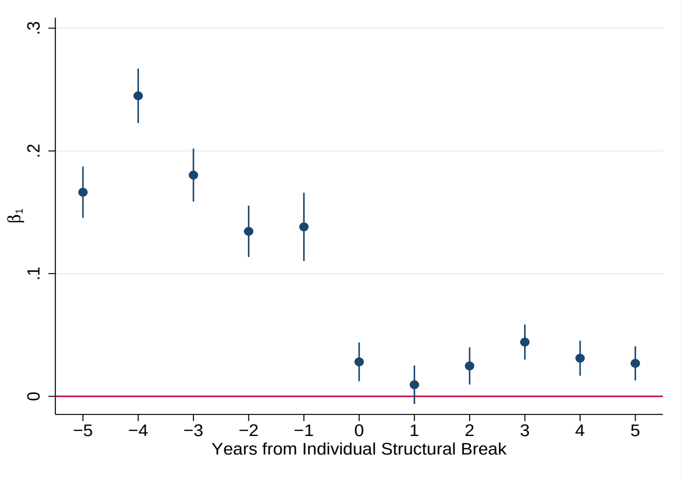
Changing Employers in year k

Prob {Structural break of Volatility **Increase**}



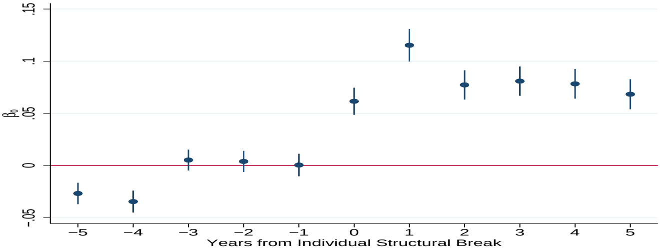
Changing Employers in year k

Prob {Structural break of Volatility **Decrease**}

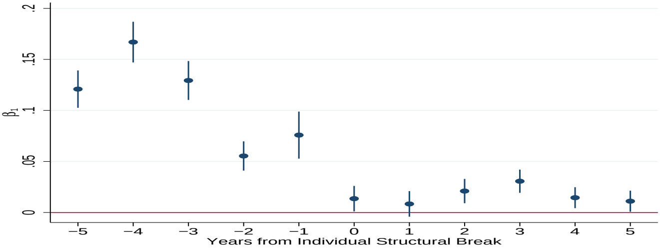


Changing Industry

Prob {Structural break of Volatility **Increase**}

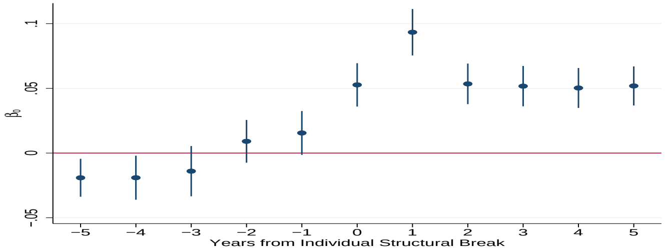


Prob {Structural break of Volatility **Decrease**}

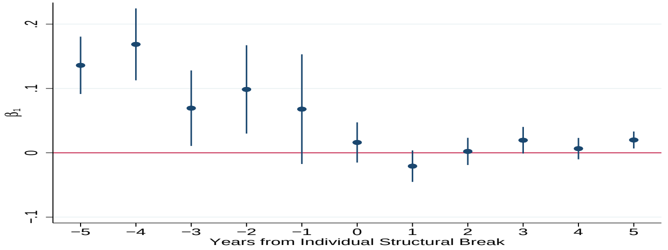


Changing Occupation

Prob {Structural break of Volatility **Increase**}

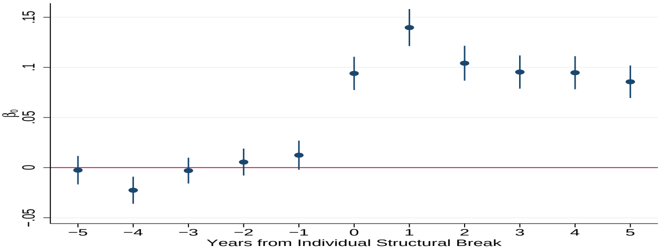


Prob {Structural break of Volatility **Decrease**}

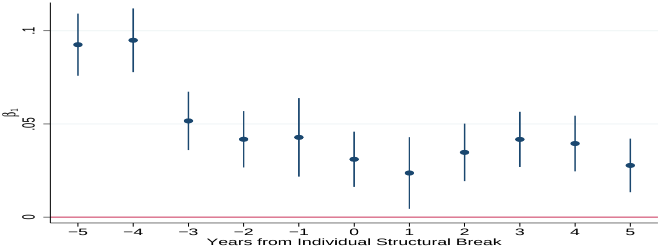


Changing Community; (Back)

Prob {Structural break of Volatility **Increase**}



Prob {Structural break of Volatility **Decrease**}



Potential Issues with $SD_{i,\tau*}$

- Huge measurement errors in SD of income growth
  – limited time series
  – attenuation bias
- Endogeneity
- Anticipated income risk (predictable and reflects individual choice rather than risk)
  – Primiceri and van Rens, 2009; Guvenen and Smith, 2014.

Firm-Side Information as IV

- Firm registry data on income statement and balance sheet statement (only for limited liability firms)
- Work i worked for Firm j in period t.
- $y_{j,t}$: value added and/or sales (relative to firm's assets) of firm j
- Compute $\Delta SD(\Delta y_{j,t})$; similarly
- Exclude outliers at top and bottom 1% of $\Delta y_{j,t}$
- $\Delta SD_{j,t}$ instrument for $\Delta SD_{i,t}$

Firm-Side Information as IV

$$\Delta SD_{i,t} = \gamma \Delta SD_{j,t} + X_{i,t} + \varepsilon_{i,t}.$$

- γ: "pass-through" of firm volatility to worker's volatility.
- $\widehat{\Delta SD}_{i,t}$, "exogenous" variation of earnings volatility.
- $X_{i,t}$: Household Characteristics
- Based on $\widehat{\Delta SD}_{i,t}$'s, identify structural break similarly.
- Year of "exogenous" structural break: $\hat{\tau}$
- The projected volatility change at that year as $\widehat{\Delta SD}_{i,\hat{\tau}}$.

$\Delta SD_{i,\tau^*}$ vs. $\widehat{\Delta SD}_{i,\hat{\tau}}$

	Obs.	Mean	S.D.	1^{st} decile	9^{th} decile
$\Delta SD_{i,\tau^*}$	16,041	-0.06	0.556	-0.628	0.493
$\widehat{\Delta SD}_{i,\hat{\tau}}$	8,049	-0.02	0.128	-0.166	0.164

OLS vs. IV

	$k=1$	$k=2$	$k=3$	$k=4$
		Large Sample		
$\Delta SD_{i,\tau^*}$ (OLS)	-0.50	-1.94***	-1.54***	-1.76***
	(0.42)	(0.51)	(0.55)	(0.55)
		Worker-Firm Matched Sample		
$\Delta SD_{i,\tau^*}$ (OLS)	-0.80	-2.94***	-2.35***	-2.91***
	(0.58)	(0.72)	(0.74)	(0.76)
$\widehat{\Delta SD}_{i,\hat{\tau}}$ (IV)	-8.20	-26.39***	-25.11***	-27.37***
	(6.26)	(7.14)	(7.81)	(8.09)
J test†	0.26	0.67	0.92	0.66

– One SD increase of $\Delta SD_{i,\hat{\tau}}$ (0.13) $\rightarrow$ Risky Share 3.5 pp $\uparrow$

Dynamics of Risky Shares

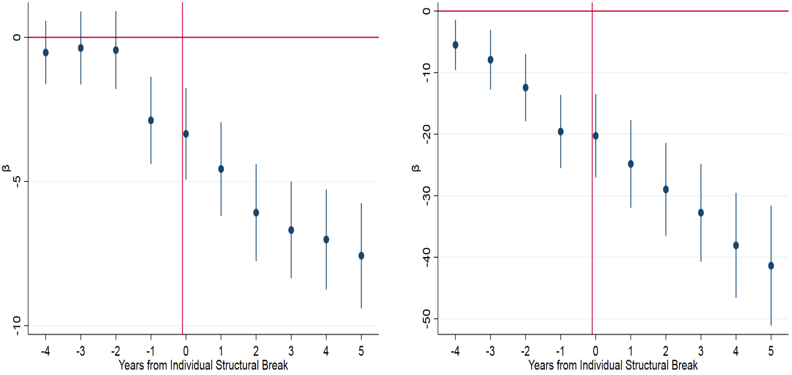
Consider

$$RS_{i,\tau+k} - RS_{i,\tau-\mathbf{4}} = \beta_k \Delta V_{i,\tau} + \alpha X_{i,\tau} + \delta D_t + \epsilon_{i,\tau}$$

where $\tau \in \{\tau^*, \hat{\tau}\}$ and $\Delta V_{i,\tau} \in \{\Delta SD_{i,\tau^*}, \widehat{\Delta SD}_{i,\hat{\tau}}\}$.

$RS_{i,\tau+k} - RS_{i,\tau-\mathbf{4}}$: *cumulative* change of RS since 4 years before the structural break.

Cumulative Change in Risky Share: OLS vs. IV



Robustness

- Different Controls in Regression (Go)
- Alternative Measures of Risky Share (Go)
- Household's Disposable Income (Go)
- Alternative Sample Selection Criteria (Go)
- Excluding the Very Rich (Go)
- Controlling for Housing and Mortgage Debt (Go)
- Controlling for Capital income (Go)
- Using common year for all ($\tau = 2005$) (Go)

Heterogeniety across Groups

- By Age (Go)
- By Wealth (Go)
- By Income Growth rate (Go)
- By Education (Go)
- By Financial Literacy (Go)
- By Marital Status (Go)

Quantitative Model

Description of Model

- Benchmark
  - Heterogeneous agent
  - Finite life cycle
  - Portfolio choices: Stock vs. Bond
  - Uninsurable Labor Income Shock
  - Time Varying Volatility of Income (Second Moment Shock)
  - Partial equilibrium.

- Extended Model
  - Imperfect information about volatility regime

Description of Model

- Life cycle: age $j = \{21, ..., 80\}$ with retirement $j = 65$.
  - **risk-free bond** b pays $(1 + r_b)$ with certainty
  - **risky stock** s pays $(1 + r_b + \mu + \eta)$ with $\eta \sim N(0, \sigma_\eta^2)$
  - Stochastic returns to stock with equity premium (μ)
- Stochastic labor income y with time-varying volatility
  - (Extended Model): worker forms **beliefs** about volatility regime.

Log Labor Income of Worker i at age j

$$Y_{ij} = \underbrace{z_j}_{\text{common age profile}} + y_{ij}$$

$$y_{ij} = \underbrace{a_i + \beta_i \times j}_{\text{individual specific (HIP)}} + \underbrace{x_{ij} + \varepsilon_{ij}}_{\text{idiosyncratic shocks}}$$

- a_i, β_i: individual specific age profile
- x_{ij}: idiosyncratic shocks to level:

$$x_{ij} = \rho_x x_{i\,j-1} + \nu_{ij} \;,\; \nu_{ij} \sim N(0, \sigma^2_{i,j+1})$$

- idiosyncratic shock to variance :

$$\log(\sigma^2_{i,j+1}) = (1 - \rho_\sigma)\log(\sigma^2_\nu) + \rho_\sigma \log(\sigma^2_{i,j}) + \zeta_{i,j+1},$$

$$\zeta_{i,j+1} \sim \text{ i.i.d. } N(0, \sigma^2_\zeta)$$

- $\varepsilon_{ij} \sim$ i.i.d. $N(0, \sigma^2_\varepsilon)$

Imperfect Information about Volatility

- Imperfect information about the variance (regime g).
- Workers enter with a prior probability
  $\boldsymbol{\pi}_{j|j-1} = \{\pi^g_{j|j-1}\}_{g=1}^N$ for each regime g.
- Form a posterior $\boldsymbol{\pi}_{j|j} = \{\pi^g_{j|j}\}_{g=1}^N$ using
  current income y_j and perceived expected income $\mathbf{H}'_j\mathbf{M}_{j|j-1}$,

Learning: Bayesian + True

Posterior probability of regime g:

$$\pi_{j|j}(\sigma_g^2 \mid y_j, \mathbf{H}_j'\mathbf{M}_{j|j-1})$$

$$= (1-\lambda^v)\frac{F(y_j \mid \mathbf{H}_j'\mathbf{M}_{j|j-1}, \sigma_g^2) \times \pi_{j|j-1}^g(\sigma_g^2)}{\sum_{h=1}^N F(y_j \mid \mathbf{H}_j'\mathbf{M}_{j|j-1}, \sigma_h^2) \times \pi_{j|j-1}^h(\sigma_h^2)} \; + \; \lambda^v \pi_{j|j-1}^g(\sigma_g^2)$$

- $\lambda^v = 1 \rightarrow$ Perfect Information: posterior = correct prior
- $\lambda^v = 0 \rightarrow$ Bayesian: prior updated based on y

Learning: Bayesian + True

Posterior probability of regime g:

$$\pi_{j|j}(\sigma_g^2 \mid y_j, \mathbf{H}_j'\mathbf{M}_{j|j-1})$$

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- $\lambda^v = 1 \rightarrow$ Perfect Information: posterior = correct prior
- $\lambda^v = 0 \rightarrow$ Bayesian: prior updated based on y

Next period probability of regime g depends on posterior and actual law of motion for variance:

$$\pi_{j+1}(\sigma_g^2) = \sum_{h=1}^N \Gamma(\sigma_g^2 \mid \sigma_h^2) \times \pi_{j|j}(\sigma_h^2)$$

Dynamic Program

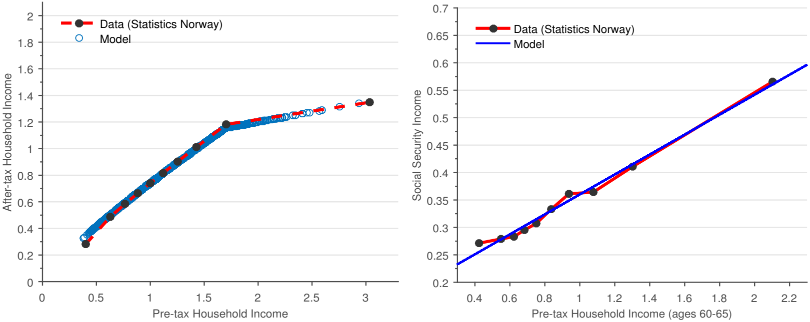
- State variables:
  - workers' wealth (W) and income (y)
  - prior for mean ($\mathbf{M}_{j|j-1}$) and variance ($\mathbf{V}_{j|j-1}$)
  - prior probability about the current variance regime, $\boldsymbol{\pi}_{j|j-1}$.

$$V_j(W, y, \mathbf{M}_{j-1}, \boldsymbol{\pi}_{j|j-1}) = \max_{c,s',b'} \left\{ \frac{c_j^{1-\gamma}}{1-\gamma} \right.$$

$$\left. + \ \delta s_j \sum_g \int_{\eta'} \int_{y'} \pi_{j+1}(\sigma_g^2) V_{j+1}(W', y', \mathbf{M}_j, \boldsymbol{\pi}_{j+1|j}) dF(y_{j+1}|y_j, \sigma_g^2) d\pi(\eta') \right\}$$

$$\begin{aligned} \text{s.t.} \quad & c + s' + b' \\ & = [(1-\tau_{ss}) \exp^{Y_j} - T(y_j)] \times \mathbf{1}_{\{j<j_R\}} + ss(y_{J_R-1}) \times \mathbf{1}_{\{j \geq j_R\}} + W \\ & F(y'|y, \sigma_g^2) = N(\mathbf{H}'_{j+1}\mathbf{M}_{j+1|j} \ , \ \mathbf{H}'_{j+1}\mathbf{V}_{j+1|j}(\sigma_g^2)\mathbf{H}_{j+1} + \sigma_{\varepsilon_j}^2) \\ & W' = b'(1+r_b) + s'(1+r(\eta')), b' \geq \underline{b}, \ s' \geq 0 \end{aligned}$$

Calibration



Tax function: $T(y) = y - \tau_1 y^{1-\tau_2} + \mathcal{I}_{\{y^* > y\}} \tau^* (y - y^*)$.

Calibrate $\tau_1 = 0.73, \tau_2 = 0.16, \tau^* = 0.85, y^* = 1.7$ to match before- and after-tax earnings.

Calibration

Parameter	Variable	Value	Target / Source
Life Cycle	J	80	–
Retirement Age	j_R	45	–
Risk-free Rate	R	1.43%	Klovland (2004)
Equity Premium	μ	4.57%	Dimson et al. (2008)
Stock-Return Volatility	σ_η	23.8%	Dimson et al. (2008)
Social Security Benefit	ss	–	Statistics Norway
Tax Parameter	τ_1	0.73	Statistics Norway
Tax Parameter	τ_2	0.16	Statistics Norway
Tax Parameter	τ^*	0.85	Statistics Norway
Tax Parameter	y^*	1.7	Statistics Norway
Credit Limit	$\underline{b}$	10.2%	Credit Card Debt/Income
Variance of i.i.d. ϵ	σ_ε^2	0.1%	Guvenen and Smith (2014)
Age-Earnings Profile	$\{z_j\}_{j=21}^{65}$	–	Norway from OECD

Targets for Simulated Methods of Moments

The estimator minimizes the loss function of 512 moments.

$$\min L_{\Theta} = [M^d(\Theta) - M^m(\Theta)]' W [M^d(\Theta) - M^m(\Theta)]. \tag{1}$$

1. Average assets-income ratio.
2. Average risky share.
3. Average debt-income ratio.
4. Variance-covariance matrix of log income by age (441 moments).
5. Dispersion IV'd Volatility Changes $\widehat{\Delta SD_{i,t}}$.
6. Response of risky share at $k = 4$.
7. Life-cycle profile of variance of log-consumption.
8. Life-cycle profile of kurtosis of income growth.

Estimation

Parameters to estimate: $\Theta = [\delta, \gamma, \sigma_a^2, \sigma_\beta^2, \rho_x, \rho_\sigma, \sigma_\nu^2, \sigma_\zeta^2, \lambda_V]$.

Estimation

Parameters to estimate: $\Theta = [\delta, \gamma, \sigma_a^2, \sigma_\beta^2, \rho_x, \rho_\sigma, \sigma_\nu^2, \sigma_\zeta^2, \lambda_V]$.

$$\left.\begin{array}{l}\bullet\ \text{variance-covariance matrix of income growth}\end{array}\right\} [\sigma_\nu^2, \rho_x, \sigma_\alpha^2, \sigma_\beta^2]$$

$$\left.\begin{array}{l}\bullet\ \text{dispersion of } \Delta SD \\ \bullet\ \text{age-profile of kurtosis of income change}\end{array}\right\} [\rho_\sigma, \sigma_\zeta^2]$$

$$\left.\begin{array}{l}\bullet\ \text{assets-income ratio} = 2.19 \\ \bullet\ \text{risky share} = 0.57\end{array}\right\} [\delta, \gamma]$$

$$\left.\begin{array}{l}\bullet\ \text{dispersion of consumption growth across age 25 - 55} \\ \bullet\ \text{Response of risky share at } k = 4\text{: } \beta_k\end{array}\right\} \lambda^V$$

Estimated Parameters

Income Process		Preferences		Information	
Parameter	Estimate	Parameter	Estimate	Parameter	Estimate
σ_a^2	0.022	δ	0.94	λ_V	0.82
	(0.0002)		(0.02)		(0.011)
$\sigma_\beta^2 \times 100$	0.072	γ	5.4		
	(0.002%)		(0.3)		
ρ	0.754				
	(0.007)				
σ_ν^2	0.029				
	(0.001)				
ρ_σ	0.932				
	(0.03)				
σ_ζ^2	0.08				
	(0.002)				

Model Simulated data

Figure: $k = 2$

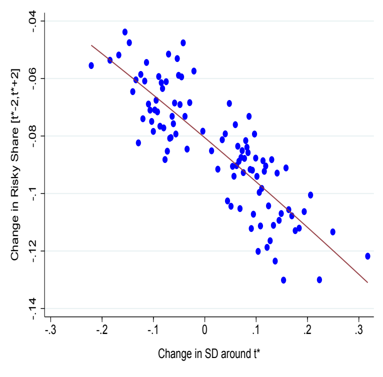
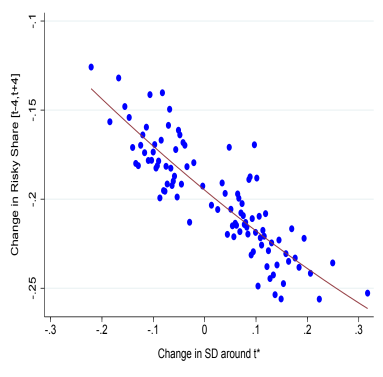


Figure: $k = 4$

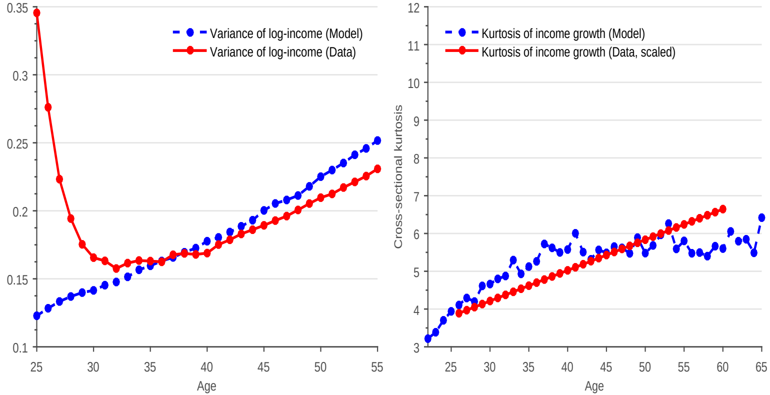


Net of age effects; Robust to income and/or wealth controls.

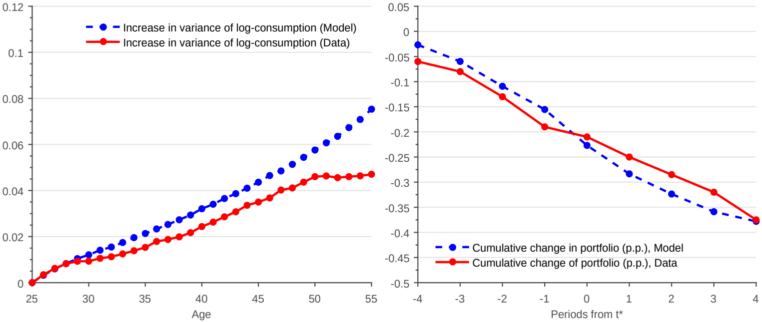
Model Fit

	Data (Target)	Model
Assets/ Income	2.19	2.19
Risky Share	0.57	0.57
Credit Card Debt/ Income	4.9%	4.8%
SD of ΔSD	0.12	0.12
Response of Risky Share	-0.37	-0.38
Difference between ages 55-30		
Variance of $\log y$	0.08	0.10
Variance of $\log c$	0.07	0.035
Kurtosis of $\Delta \log y$	2.2	1.7

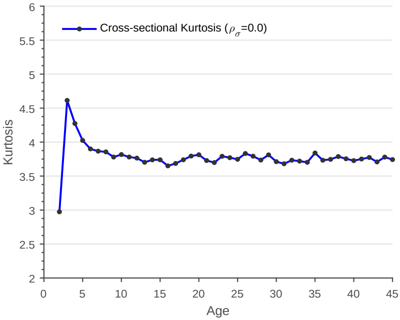
Results


0.35
0.3
0.25
0.2
0.15
0.1
Variance of log-income (Model)
Variance of log-income (Data)
25
30
35
40
45
50
55
Age
12
11
10
9
8
7
6
5
4
3
Cross-sectional kurtosis
Kurtosis of income growth (Model)
Kurtosis of income growth (Data, scaled)
25
30
35
40
45
50
55
60
65
Age

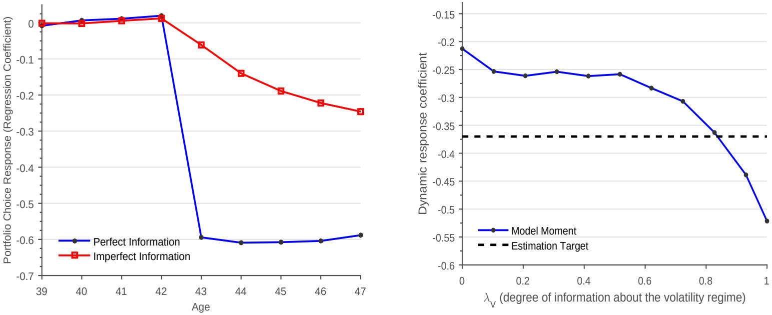
Results


Increase in variance of log-consumption (Model)
Increase in variance of log-consumption (Data)
0.12
0.1
0.08
0.06
0.04
0.02
0
25
30
35
40
45
50
55
Age
Cumulative change in portfolio (p.p.), Model
Cumulative change of portfolio (p.p.), Data
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
-0.35
-0.4
-0.45
-0.5
-4
-3
-2
-1
0
1
2
3
4
Periods from t*

Identification of ρ_σ



Identification of λ_V



- $\lambda_V = 0.82$
- Perfect information ($\lambda_V = 1$) falls within the 2 SE of data.

Other Models

4 Models for Conditional Variance

- ARCH (similar to Meghir and Pistaferri (2014))

$$\sigma^2_{i,j+1} = \underbrace{\sigma^2_\nu}_{\text{homogeneous comp.}} + \phi \underbrace{(x_{ij} - \rho_x x_{i,j-1})}_{\text{innovation in income level}}{}^2$$

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- GARCH

$$\sigma^2_{i,j+1} = a + \underbrace{\rho_\sigma \sigma^2_{i,j}}_{\text{individual comp.}} + \phi \underbrace{(x_{ij} - \rho_x x_{i,j-1})}_{\text{innovation in income level}}^2$$

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$$\log(\sigma^2_{ij}) = \zeta_{ij}, \qquad \zeta_{ij} \sim \text{ i.i.d. } N(0, \sigma^2_\zeta).$$

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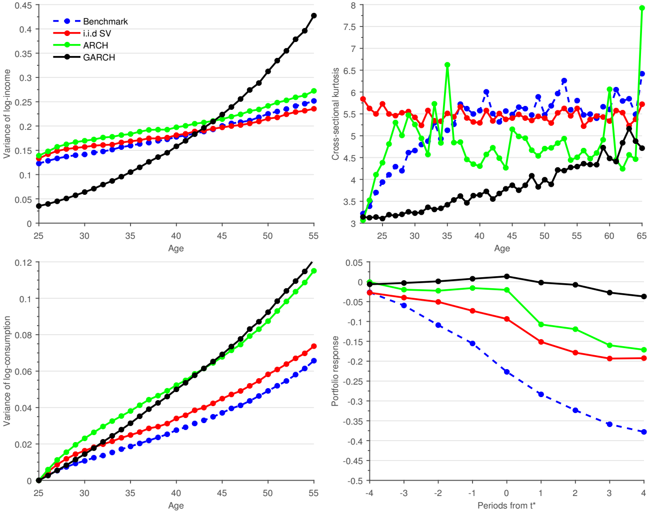
- Benchmark: Persistent Stochastic Volatility

$$\log(\sigma^2_{ij}) = (1-\rho_\sigma) \log(\sigma^2_\nu) + \rho_\sigma \log(\sigma^2_{i,j-1}) + \zeta_{ij}, \quad \zeta_{ij} \sim \text{ i.i.d. } N(0, \sigma^2_\zeta).$$

Life Cycle Profiles



Conclusion

- Empirical Analysis (Norwegian Administration Panel)
  - Clear negative relationship: Volatility $\Uparrow$ $\longrightarrow$ Risky shares $\Downarrow$
    - Strongly associated with job changes
    - Stronger results based on IV
    - Dynamic Adjustment
- Quantitative Analysis
  - A simple life-cycle model with time-varying income volatility can replicate the data well
  - Robust to various specifications
  - Policy Implications (coming soon)

Thank You!

Appendix

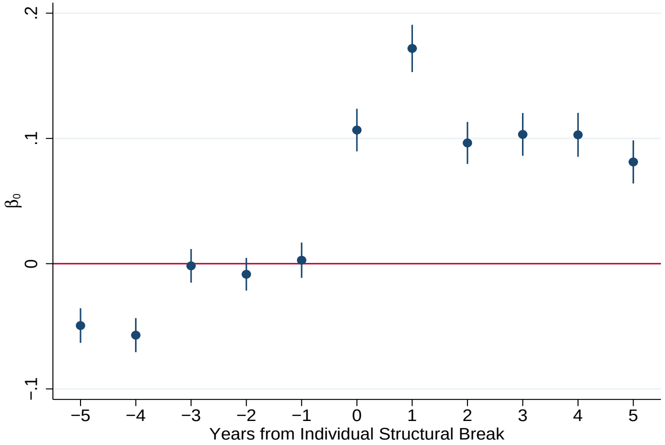
What is behind Structural Break?

What is associated with "Structural Break"?

- Intuitively inspecting events that are correlated with structural breaks:
- $$\text{I(Structural Change)}_{i,\tau^*} = \sum_k \beta_E^k \times E_{i,\tau^*-k} + X_{i,\tau^*} + D_t + \epsilon_{i,\tau^*}.$$
- $E_{i,\tau^\star(i)-k}$, $(-5 \leq k \leq 5)$:
  Individual events such as **changes** in:
  - Employers
  - Industry/occupation/community
  - Marital status, Home ownership

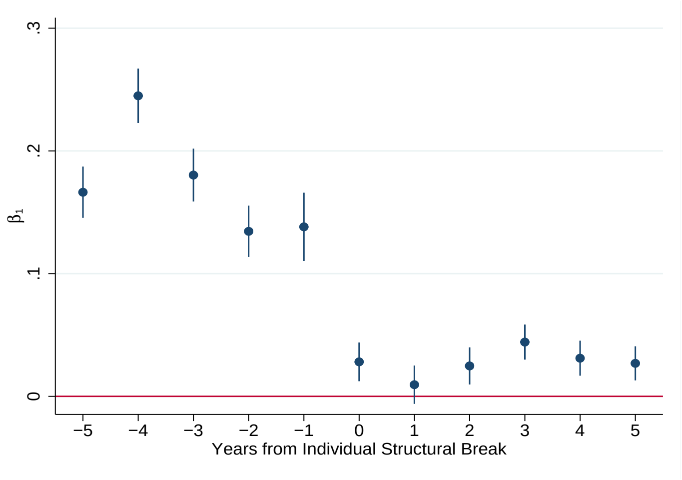
Changing Employers in year k

Prob {Structural break of Volatility **Increase**}



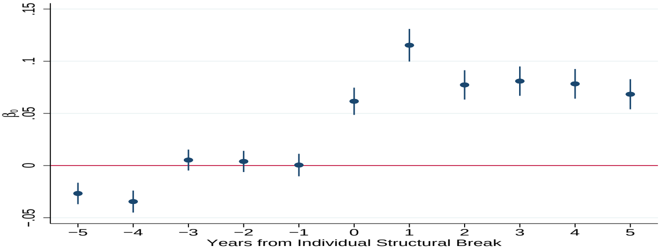
Changing Employers in year k

Prob {Structural break of Volatility **Decrease**}

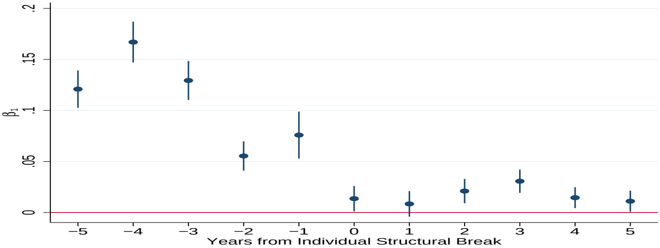


Changing Industry

Prob {Structural break of Volatility **Increase**}

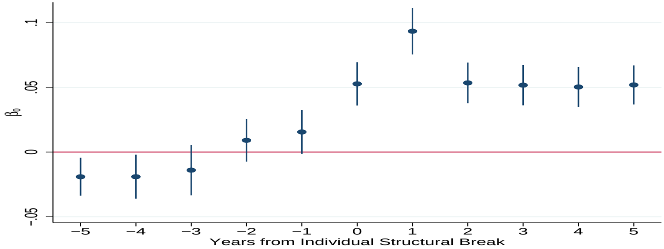


Prob {Structural break of Volatility **Decrease**}

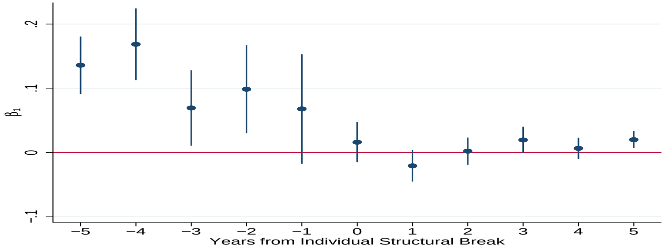


Changing Occupation

Prob {Structural break of Volatility **Increase**}

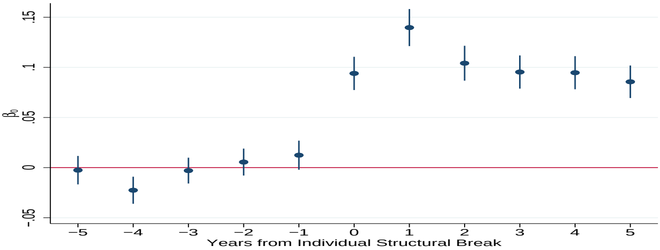


Prob {Structural break of Volatility **Decrease**}

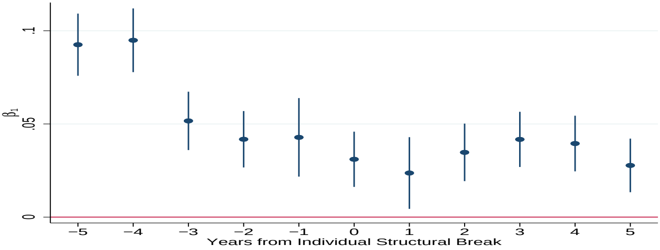


Changing Community; (Back)

Prob {Structural break of Volatility **Increase**}



Prob {Structural break of Volatility **Decrease**}



By Age (Back)

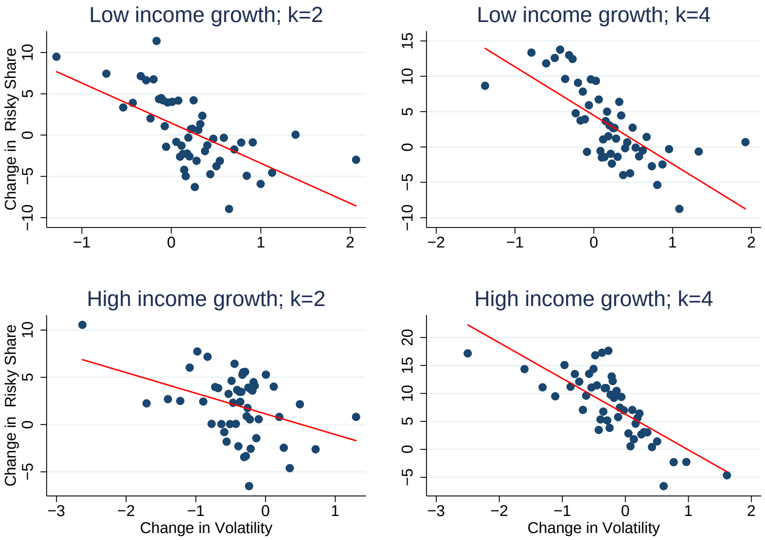
Dependent Variable: $RS_{i,\tau^\star(i)+k} - RS_{i,\tau^\star(i)-k}$

	$k=1$	$k=2$	$k=3$	$k=4$	$k=5$
Young (<40)	-0.395	-2.242*	-0.554	-0.908	-3.139*
Middle	-0.362	-1.409**	-1.041	-1.202	-1.588*
Old (>55)	-0.677	-2.726***	-3.378***	-3.484***	-2.386**

By Wealth (Back)

	$k=1$	$k=2$	$k=3$	$k=4$	$k=5$
Poor: Bottom 25%					
$\Delta SD_{i,\tau^\star(i)}$	0.106	-1.057	-0.725	-0.806	-1.870
	(0.842)	(0.961)	(1.059)	(1.095)	(1.349)
Middle					
$\Delta SD_{i,\tau^\star(i)}$	-0.524	-2.187***	-1.571*	-0.902	-2.281**
	(0.612)	(0.747)	(0.815)	(0.789)	(0.919)
Rich: Top 25%					
$\Delta SD_{i,\tau^\star(i)}$	-1.000	-2.295**	-1.883*	-3.816***	-1.157
	(0.808)	(1.026)	(1.031)	(1.109)	(1.294)

By Income growth (Back)



By Education (Back)

Dependent Variable: $RS_{i,\tau^\star(i)+k} - RS_{i,\tau^\star(i)-k}$

	$k=1$	$k=2$	$k=3$	$k=4$	$k=5$
College	-0.455	-2.288***	-2.055**	-1.310	-1.358
	(0.621)	(0.760)	(0.827)	(0.835)	(0.983)
High School	-0.577	-1.624**	-1.097	-2.267***	-2.690***
	(0.576)	(0.694)	(0.737)	(0.745)	(0.904)

Financial Literacy (Back)

Dependent Variable: $RS_{i,\tau^\star(i)+k} - RS_{i,\tau^\star(i)-k}$

	$k=1$	$k=2$	$k=3$	$k=4$	$k=5$
Econ Major	-0.393	-3.599*	-4.171**	-2.593	-3.168
Other Major	-0.497	-2.071**	-1.604*	-1.119	-0.901

By Marital Status (Back)

	$k = 1$	$k = 2$	$k = 3$	$k = 4$	$k = 5$
Married	-0.643	-2.171***	-1.654***	-1.810***	-1.563**
Singles	-0.0146	-1.037	-1.219	-1.815	-4.812***

With Different Controls (Back)

	$k=1$	$k=2$	$k=3$	$k=4$	$k=5$
Benchmark	-0.497	-1.944***	-1.543***	-1.757***	-2.027***
	(0.422)	(0.512)	(0.550)	(0.554)	(0.662)
No Control at all	-0.862**	-3.727***	-5.242***	-6.592***	-6.622***
	(0.356)	(0.414)	(0.460)	(0.494)	(0.589)
Δage^2 and Year Dummies	-0.366	-1.644***	-1.483***	-1.315**	-1.915***
	(0.404)	(0.469)	(0.514)	(0.537)	(0.636)
+ Δ income and wealth	-0.230	-1.611***	-1.323**	-1.330**	-1.992***
	(0.409)	(0.473)	(0.524)	(0.544)	(0.641)
Benchmark+ Ind dummies	-0.507	-2.048***	-1.523***	-1.718***	-1.985***
	(0.426)	(0.521)	(0.557)	(0.560)	(0.672)
Benchmark+ Ind/Occ dummies	-0.323	-2.343***	-2.250***	-1.770**	-2.483***
	(0.539)	(0.675)	(0.718)	(0.728)	(0.775)

Household's Disposable Income (Back)

Table: Response to Volatility of Household's Disposable Income

	$k=1$	$k=2$	$k=3$	$k=4$	$k=5$
$\Delta SD_{i,\tau*}[\Delta Y_{it}^{D}]$	-3.826***	-2.916***	-0.852	-0.831	2.141**
	(0.595)	(0.680)	(0.724)	(0.750)	(0.953)

Spouseal Income (Back)

Controlling for Spousal Income Volatility:

	$k=1$	$k=2$	$k=3$	$k=4$	$k=5$
$\mathbf{I}\{\Delta SD_{i,\tau^\star(i)} > \underline{SD}\}$	-0.436	-1.949***	-1.883***	-2.107***	-1.907**
	(0.561)	(0.660)	(0.721)	(0.743)	(0.804)
$\mathbf{I}\{\Delta SD_{i,\tau^\star(i)} < \overline{SD}\}$	0.470	0.837	0.160	0.527	0.648
	(0.654)	(0.783)	(0.844)	(0.879)	(1.188)
$\Delta SD_{i,\tau^\star(i)}$	-0.530	-2.141***	-1.534**	-1.619***	-1.383*
	(0.465)	(0.562)	(0.600)	(0.603)	(0.716)

Alternative Definitions of Risky Share: (Back)

Dependent Variable: $RS_{i,\tau^\star(i)+k} - RS_{i,\tau^\star(i)-k}$

	$k=1$	$k=2$	$k=3$	$k=4$	$k=5$
28% safe	-0.450	-2.074***	-1.579***	-2.017***	-2.021***
0% safe	-0.541	-2.049***	-1.634***	-1.838***	-2.060***
Excl. life insurance	-0.573	-2.122***	-1.666***	-1.672***	-2.053***

Benchmark: **18%** of "financial securities" $\rightarrow$ **safe** assets.

Alternative Measures of Volatility (Back)

Dependent Variable: $RS_{i,\tau^\star(i)+k} - RS_{i,\tau^\star(i)-k}$

	$k=1$	$k=2$	$k=3$	$k=4$	$k=5$
$\Delta SD^1_{i,\tau^\star(i)}$	-1.872**	-2.835***	-2.071**	-3.463***	-2.840**
$\Delta SD^2_{i,\tau^\star(i)}$	-0.124	-0.176*	-0.346***	-0.294**	-0.344**
$\Delta SD^3_{i,\tau^\star(i)}$	-0.0267	-0.0755*	-0.0818**	-0.0965**	-0.236***

Alternative Sample Selection Criterion (Back)

Dependent Variable: $RS_{i,\tau^\star(i)+k} - RS_{i,\tau^\star(i)-k}$

	$k=1$	$k=2$	$k=3$	$k=4$	$k=5$
non-zero $RS \geq$ **18 yrs**	-0.469	-1.881***	-1.488***	-1.707***	-2.006***
non-zero $RS \geq$ **14 yrs**	-0.512	-1.979***	-1.574***	-1.784***	-2.038***
Age in 2014 ≤ 70	-2.198***	-2.738***	-1.921*	-2.896***	-2.539*

Controlling for housing/mortgage debt (Back)

Dependent Variable: $RS_{i,\tau^\star(i)+k} - RS_{i,\tau^\star(i)-k}$

$k=1$	$k=2$	$k=3$	$k=4$	$k=5$
-0.184	-1.935***	-1.465**	-1.192**	-1.882***

Controlling for Capital Income (Back)

Dependent Variable: $RS_{i,\tau^\star(i)+k} - RS_{i,\tau^\star(i)-k}$

$k=1$	$k=2$	$k=3$	$k=4$	$k=5$
-0.442	-1.818***	-1.697***	-1.736***	-2.041***

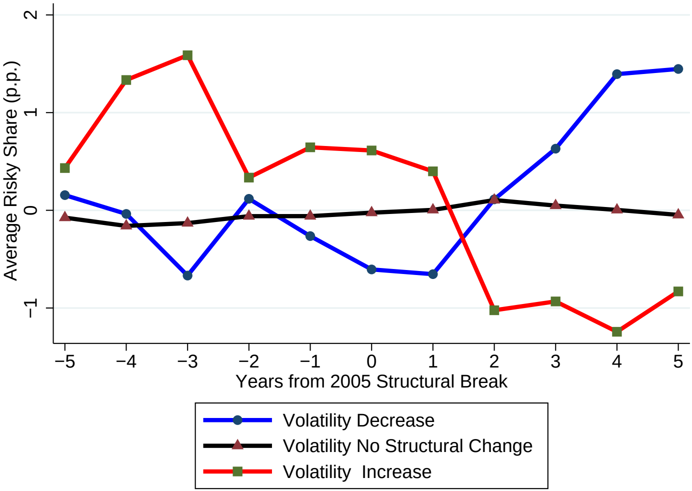
Also, include polynomials of (log) household capital income.

Excluding the Rich (Back)

Dependent Variable: $RS_{i,\tau^\star(i)+k} - RS_{i,\tau^\star(i)-k}$

Excluding:	$k=1$	$k=2$	$k=3$	$k=4$	$k=5$
Top 0.1%	-0.529	-1.951***	-1.501***	-1.728***	-1.926***
Top 1%	-0.471	-1.930***	-1.422**	-1.597***	-2.037***
Top 10%	-0.182	-1.597***	-0.850	-1.200*	-2.256***

Using $T = 2005$ for All (Back)



ARCH-based Income Volatility $\sigma^2_{i,t}$

- Denote the growth rate for residual income as $g_{i,t} \equiv y_{i,t} - y_{i,t-1}$
- Assume $g_{i,t}$ follows a quite simple ARCH process:

$$\left\{ \begin{array}{c} g_{i,t} = \phi_i + \rho g_{i,t-1} + \varepsilon_{i,t}, \\ \sigma^2_{i,t} \equiv E_{t-1}\varepsilon^2_{i,t} = \eta_i + \gamma \varepsilon^2_{i,t-1}, \\ \varepsilon_{i,t} \sim N(0, \sigma^2_{i,t} | I_{i,t-1}) \end{array} \right\} \tag{2}$$

- still very general: allowing individual heterogeneity both in the levels and in the volatility of growth rates
- MLE estimation