Information and Wealth Heterogeneity in the Macroeconomy

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Dynamic Equilibrium Models

Motivation

I. Inequality matters for macro, and vice versa

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II. Evidence that FIRE-benchmark is restrictive

- Limited information
- Heterogeneous expectations

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  - *... interacts with other dimensions of household heterogeneity?*
  - *... affecst the propagation of aggregate shocks?*
  - *... changes the efficacy of policy?*

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This Paper:

A (rational) framework to answer these questions

This Paper

1. **Evidence**

   Systematic heterogeneity in macro expectations of US housholds

2. **Theoretical Framework**

   Dynamic information choice in neoclassical HA model (KS 98)

   - Consistent with micro-data

3. **Quantitative results**

   - Information-wealth nexus important for GE
   - Limited information increases macro volatility and inequality
   - Endogenous-information channel alters effects of policies

Previous Work

- Systematic differences in expectations
  Vissing-Jorgensen (2003), Malmendier and Nagel (2011), D'Acunto et al (2019), Coibion et al (2019a,b,...), Das et al (2019)
- Optimal information choice and implications
  Grossman and Stiglitz (1980), Barlevy and Veronesi (2000), Sims (2003), Hellwig and Veldkamp (2009), Mackowiak and Wiederholt (2009), Veldkamp (2010), Mackowiak et al. (2018), Vives (2010)
- HA models with exogenous limited information
  Auclert et al. (2020), Carroll et al. (2020)

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Our contribution:

- Optimal, dynamic, heterogeneous information choice in GE
- Implications for inequality, macro dynamics, policy

Overview

1) **Motivating Evidence**
   Heterogeneity in expectations in the SCE

2) **Model**
   a) General setup
   b) Recursive formulation and equilibrium

3) **Analytical results** (companion paper)
   a) Heterogeneous benefits of information
   b) Existence of homogeneous-information equilibria

4) **Quantitative results**
   a) Household information acquisition decision
   b) Saving choices and information
   c) Accuracy of expectations
   d) Aggregate implications: dynamics and inequality
   e) Effect on efficacy of policies

MOTIVATING EVIDENCE

NY Fed Survey of Consumer Expectations (SCE)

- Monthly survey, June 2013 until present
- Rotating (12m) nationally representative panel with 1300 household heads
- Advantages:
  - Probabilistic question format
  - Detailed information on household finances; housing; labor market

- Prices
  1. 12-month “inflation”
  2. percent increase in “average home price nationwide”

  → probabilistic question format: point forecasts and distributions
  → errors: point-forecast compared to first-release outcome

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- Unemployment
  - *“percent chance that 12 months from now the unemployment rate in the U.S. will be higher”*
  - Forecast errors relative to SPF benchmark:

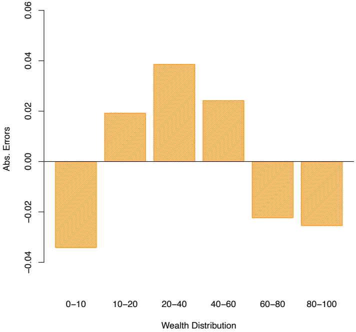
$$\nu_{it} = \frac{P_i(u_{t+12} > u_t|t) - P_{SPF}(u_{t+12} > u_t|t)}{P_{SPF}(u_{t+12} > u_t|t)}$$

Stylized Facts

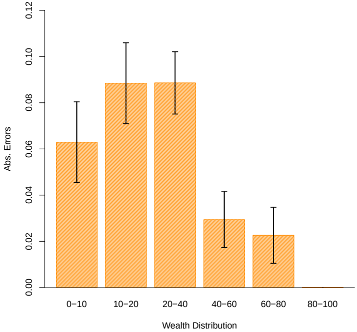
1. Relative to professional forecasts, household expectations are
   - ... less accurate
   - ... more uncertain
   - ... and more heterogeneous
2. Variation in accuracy and uncertainty across wealth distribution
   - Wealthy households: more accurate, less uncertain expectations
   - Evidence of inverse-U shape in wealth

Expectations and Wealth

Unemployment Forecasts: Absolute Errors



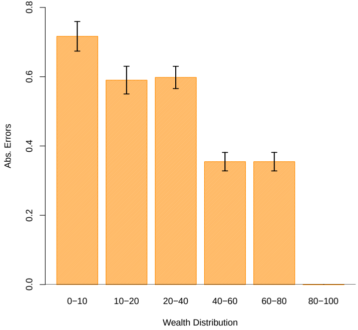
a) $\overline{|v_{it}|}_q - \overline{|v_{it}|}$



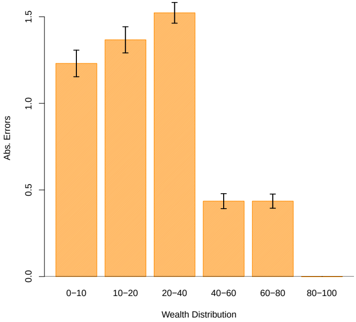
b) $|v_{it}| = \beta \times (\text{wealth-percentile}) + \delta X_{it} + \eta_t + \epsilon_{it}$

Expectations and Wealth

Inflation Forecasts: Accuracy and Uncertainty



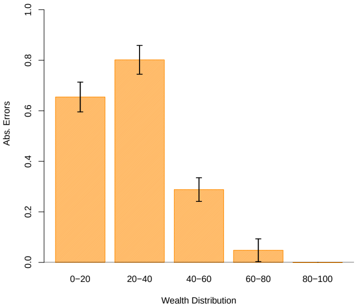
a) Accuracy



b) Perceived Uncertainty

Expectations and Wealth

House Price Inflation Forecasts: Accuracy and Uncertainty



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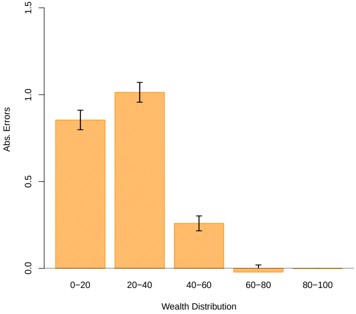

b) Perceived Uncertainty

Stylized Facts

... Give Rise to Two Questions

1. Relative to professional forecasts, household expectations are less accurate, more uncertain and more heterogeneous.

2. Variation in accuracy and uncertainty across wealth distribution
   - Wealthy households: more accurate, less uncertain expectations
   - Evidence of inverse-U shape in wealth

Two questions:

1. Can a standard HA model with info choice capture these facts?
2. Does this matter for macro dynamics, inequality, or policy?

MODEL

Model

General Framework

- Closely follows Krusell and Smith (1998)
- But with modified information structure:
  - Optimally decide which information to acquire
  - Two-dimensional heterogeneity: wealth and information

- Continuum of households
- Maximize utility choosing $\{c_t, k_{t+1} \quad\}_{t=0}^{\infty}$

$$\mathcal{U} = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{c_t^{1-\gamma} - 1}{1-\gamma} \qquad \right]$$

- Subject to budget constraint

$$c_t + k_{t+1} \qquad = \underbrace{r_t k_t + (1-\tau_t)\epsilon_t w_t + \mu(1-\epsilon_t) w_t + (1-\delta) k_t}_{y_t\text{: cash-at-hand}}$$

- Idiosyncratic employment shocks ($\epsilon_t \in \{0, 1\}$)
- Follow joint Markov process with aggregate productivity

Model

Households

- Continuum of households
- Maximize utility by choosing $\{c_t, k_{t+1}, \mathcal{I}_t\}_{t=0}^{\infty}$

$$\mathcal{U} = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{c_t^{1-\gamma} - 1}{1-\gamma} - \kappa_t(\mathcal{I}_t) \right]$$

- Subject to budget constraint

$$c_t + k_{t+1} + \nu_t(\mathcal{I}_t) = \underbrace{r_t k_t + (1-\tau_t)\epsilon_t w_t + \mu(1-\epsilon_t) w_t + (1-\delta) k_t}_{y_t\text{: cash-on-hand}}$$

- Information costs: Utility cost $\kappa_t(\mathcal{I}_t)$, Monetary cost $\nu_t(\mathcal{I}_t)$

Firms and Markets:

- Cobb-Douglas technology

$$Y_t = z_t K_t^{\alpha} (L_t)^{1-\alpha}$$

- Productivity follows first-order Markov process: $z_t \in \{Z_l, Z_h\}$
- Firm rents capital and labor in perfectly competitive markets:

$$w_t = z_t (1-\alpha) \left(\frac{K_t}{L_t}\right)^{\alpha}, \quad r_t = z_t \alpha \left(\frac{K_t}{L_t}\right)^{\alpha-1}$$

Model

Firms and Markets, Government

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Government:

- Runs balanced budget: $\tau_t = \dfrac{\mu u_t}{L_t}$

Model

Timeline Each Period

1. Shocks $(\epsilon_t, \kappa_t)_i$ and z_t realize, z_t unobserved
2. Households buy signals about state of the economy: $\mathcal{I}_t \in \mathcal{I}_t^{max}$, household's information set accumulates: $\Omega_t = \{\Omega_{t-1}, \mathcal{I}_t\}$
3. Firms rent K and L, production takes place, factors are paid
4. Households make consumption and savings choices (conditional on information choice)

Model

Recursive Formulation of Household Problem

State Variables

- $S = (\Gamma, z)$
  - Γ: cross-sectional dist. of capital and employment status

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- $S = (\Gamma, z)$
  - Γ: cross-sectional dist. of capital and employment status
- Individual (higher-order) beliefs p, and their distribution $\mathcal{P}$

Detail

$\Rightarrow$ Aggregate state variables: $\Sigma = (S, \mathcal{P})$

Individual state variables: $\sigma = (y, \epsilon, p)$

Two-Stage Household Problem:

- Stage 1: choose information $\mathcal{I}_t \in \mathcal{I}_t^{max}$:

$$V(y, \epsilon, p_{-1}, \Sigma_{-1}) = \max_{\mathcal{I}} \mathbb{E}\left[W\left(y - \nu\left(\mathcal{I}\right), \epsilon, p, \Sigma\right) - \kappa(\mathcal{I}) \mid \Omega_{-1}\right]$$

- Stage 2: choose consumption c and savings k':

$$W(y, \epsilon, p, \Sigma) = \max_{c, k' \geq 0} u(c) + \beta \mathbb{E}\left[V(y', \epsilon', p, \Sigma) \mid \Omega\right]$$

$$\text{subj. to}$$

$$c + k' = y$$

$$y' = r(\Sigma')k' + w(\Sigma')L'\epsilon + (1 - \delta)k'$$

Recursive Imperfect-Information Competitive Equilibrium (RIICE)

- Law of motion H for aggregate state
- Pair of individual value functions V and W
- Policy functions $\mathcal{I} = \iota(\sigma)$ and $k' = g(\sigma, \Sigma)$
- Pricing functions $r(\Sigma)$ and $w(\Sigma)$

such that

1. (V, W, ι, g) solves the household's two-stage problem
2. r and w satisfy firm maximization
3. H is generated by policy functions ι and g, the Markov processes Π and Π^z, and Bayes' rule, using the information contained in $\mathcal{I}$ and current beliefs in $\mathcal{P}$

ANALYTICAL RESULTS

Two-Period Model

Illustrate the economic forces at work

1. Exogenous distribution of initial cash-on-hand $y \in \mathbb{Y}$
2. Future reduced to one period: $c' = w + k \cdot R$
3. Optimal savings k depend on w, R
4. Information choice of households at beginning of period 1:
   - Prior over $\{w, R\} \in \Theta = [\underline{w}, \overline{w}]x[\underline{R}, \overline{R}]$
   - Utility cost κ to reveal w and R (dichotomous choice)

Information Choice Across Cash-on-Hand y

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1. Low y: no information acquisition for any $\kappa > 0$.

Intuition: Information useless if no saving for any (w, R).

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   Intuition: Information about w, R strictly improves interior savings choices.

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3. **High y ($y \longrightarrow \infty$)**

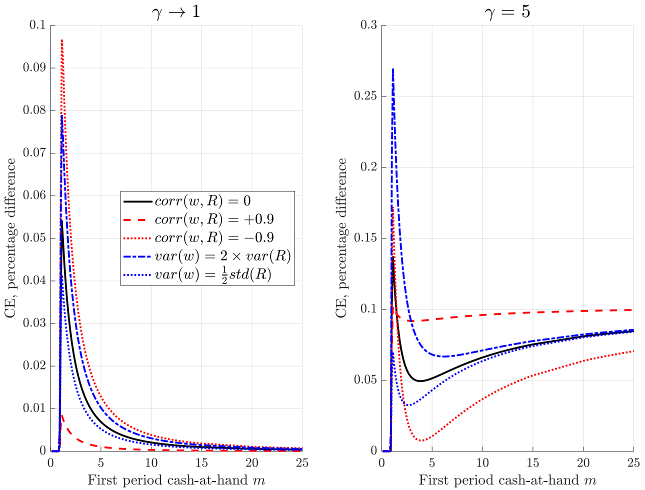
   - $\gamma = 1$: No information acquisition for any $\kappa > 0$.

     Intuition: Income and substitution effects cancel for saving of the rich.

   - $\gamma \neq 1$: Acquire information for some $\kappa > 0$.

     Intuition: Optimal savings depend on R: strict gains from information.

Utility Benefit of Information



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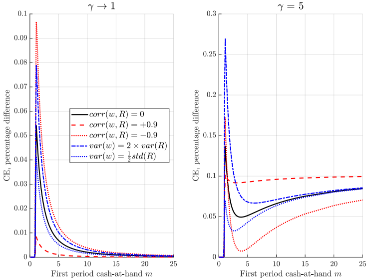

Key determinants of information choice:

- Preferences / risk-aversion
- Financial wealth
- Equilibrium (co-) variance of wages and interest rates

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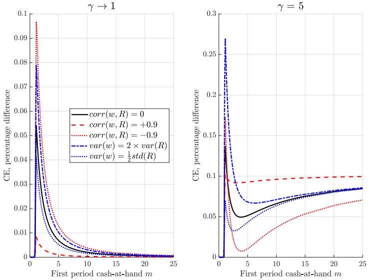

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$\Rightarrow$ Need GE analysis: endogenous comovement, wealth distribution

Information choice in GE - two periods

- Informed savings decisions are “countercyclial”: households save much (little) when capital expected to be low (high)
- K, R, w less dispersed when many are informed
- Lower dispersion reduces benefits of information
- So information choices are strategic substitutes
- Companion paper: For ranges of κ, non-existence of...
  1. ... pure-strategy equilibrium with simple, discrete y distribution
  2. ... representative-agent equilibrium
  3. .. homog-information (“KS”-) equilibria in quantitative HA model

Analytical results

Summary

- Heterogeneous benefits of information across the wealth distribution
- GE (co-)movement important
- Possibly non-existence of homogeneous-info equilibria

Need:

- Quantitative GE analysis
- With heterogeneous, dynamic information acquisition

QUANTITATIVE ANALYSIS

- **Problem**: $\mathcal{P}$ intractable, embodies "*infinite regress of expectations*" (Townsend 1983)

Infinite-horizon Model

Simplified Information Choice

- **Problem**: $\mathcal{P}$ intractable, embodies "*infinite regress of expectations*" (Townsend 1983)
- **Solution**: exploit two features of neoclassical HA economies:
  1. Information on $\bar{k}_t$ and z_t allows accurate forecasts (KS 98)
  2. Sequence $\{z_s\}_{s=0}^{t-1}$ accurately predicts $\bar{k}_t$ (den Haan 10)

$\Rightarrow$ $\mathcal{I}_t^{max} = z_t$: choose, or not, to learn current productivity

Infinite-horizon Model

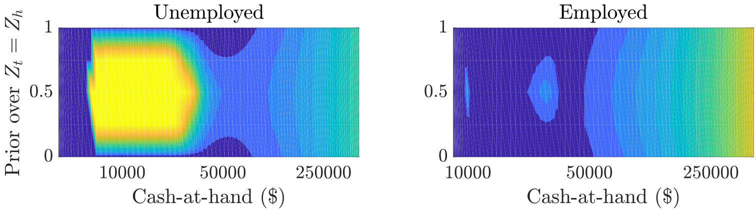
Parameter Choice

- Business cycle parameters: match key U.S. BC statistics
  $\rightarrow$ Unemployment risk lower in booms ($z_t = Z_h$)
- Relative risk aversion ($\gamma = 5$): information benefits at high wealth
- Discount factor ($\beta = 0.99$): quarterly $\frac{K}{Y}$ of 10 (Carroll et al. 17)
- Info costs: match mean and st dev of unemployment forecasts
  - Utility cost κ: mean-0 type-I EV shock, shape parameter $\alpha^{\kappa} = 1/3e^{-8}$
  - $\nu = 0.0012$

parameters

Benchmark Results

Household Information Acquisition Probability



Benchmark Results

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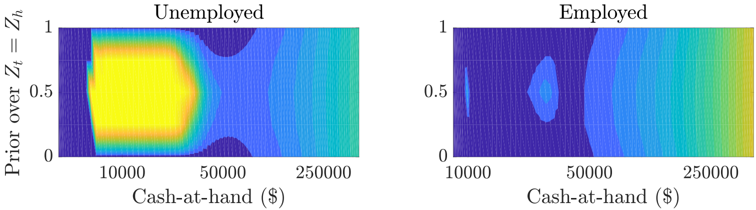
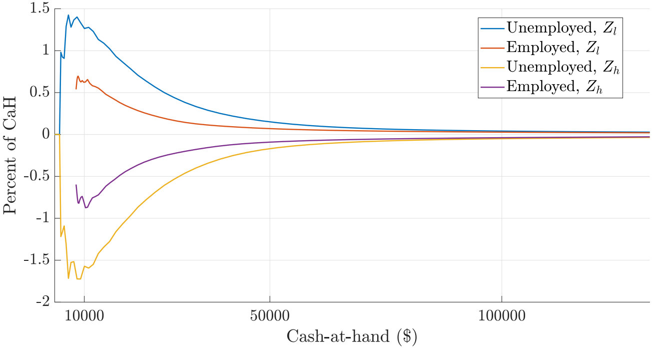


Strong heterogeneity in information acquisition

- No info acquisition at low wealth
- High incentives at moderate wealth and for super-wealthy
- Unemployed anticipate info acquisition upon job finding

Benchmark Results

Saving Choices - informed minus uninformed



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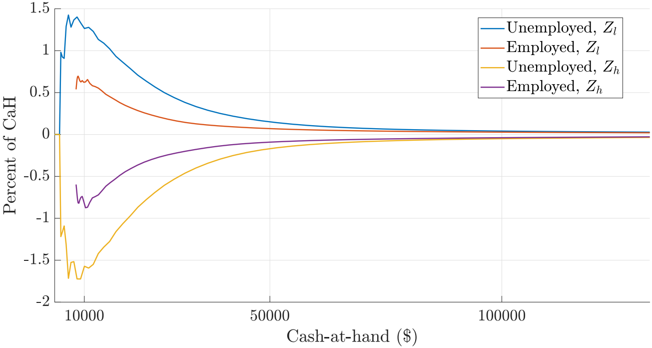
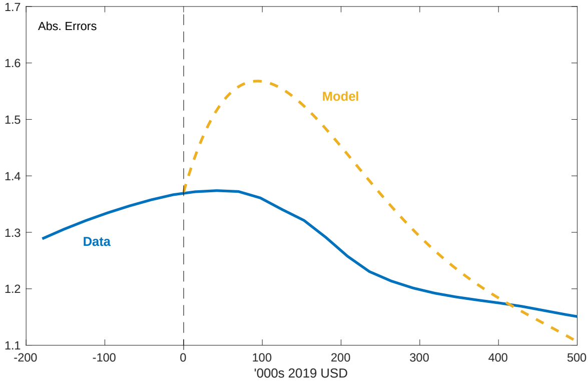


Information affects savings rate mainly at moderate wealth

Benchmark Results

Accuracy of Unemployment Expectations



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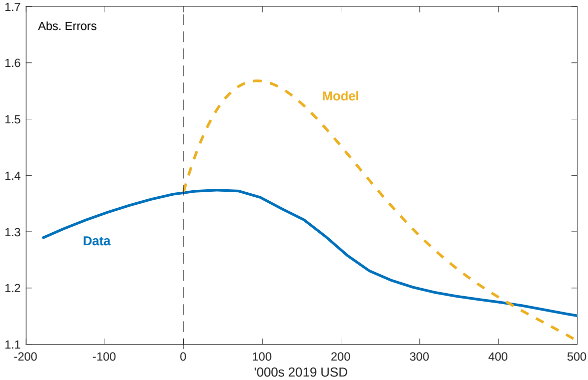
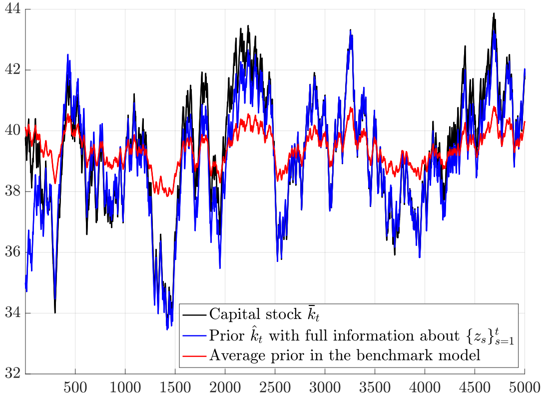


Accuracy of expectations inverse-U shaped, similar to data

Benchmark Results

$\{K_t\}$ and $\{E[K_t]|\Omega_t\}$



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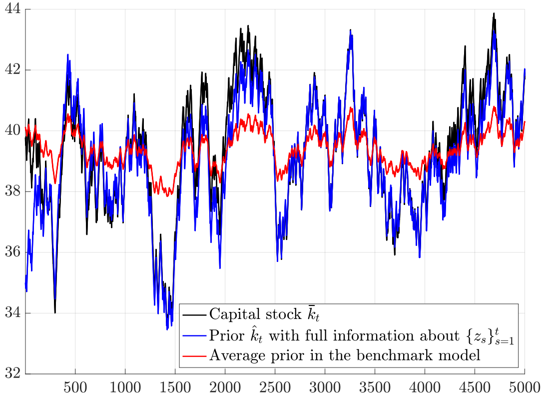

Predictions of K_{t+1} potentially accurate, on average slow-moving

Benchmark Results

Impact of Information on Aggregate Dynamics

	stdev K	stdev Y	stdev I	stdev C	info unemp	info emp
Full information	3.61	3.16	7.11	2.92	1.00	1.00
Differences w.r.t. FI (%):						
Benchmark	41.92	9.23	11.70	3.50	-84.13	-86.31
Exo. info	40.44	8.86	10.80	3.00	-85.00	-85.00

Benchmark Results

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Limited information amplifies aggregate fluctuations

- Booms: uninformed overpredict unemp risk, underpredict returns, oversave
- Busts: opposite, uninformed undersave

Benchmark Results

Impact of Information on Wealth Inequality

	Full Info.	Benchmark	Exo. Info.	Diff. (pct.)	Diff. (pct.)
Gini	0.35	0.40	0.32	14.29	-20.00

Heterogenous information increases wealth inequality

- ... dampens correlation between returns and savings rates
- ... generates Pareto tail ($\approx$ Piketty & Saez 03, but endogeneous)

Policy Effects

Policy Example: Effect of linear Wealth Tax

	Mean $\bar{k}_t$	SD $\bar{k}_t$	SD Y_t	90/10	99/1	Info acqu.
Benchmark, 1 %	-10.0	8.0	2.8	2.0	2.0	-30.4
Full information, 1 %	-10.2	1.3	0.5	-4.3	-7.3	0.0
Exo. information, 1 %	-9.2	-1.2	-0.5	-8.5	-2.2	0.0

Information channel of policy:

1. Change wealth distribution, and information acquisition policies
2. Here: mainly by moving wealth distribution to the left
3. Inequality: information channel dampens the direct effect

Conclusion

This paper:

- Heterogeneous, endogenous info choice in standard HA framework
- Matches key features of US data
- Predicts increased volatility and inequality, and information channel of policy
- Endogeneity of information matters

Implications:

- Standard macro models:
  - Lucas-type critique as policies may alter info choice
- Previous models of information choice:
  - Linear policy rules miss two-way feedback between heterogeneity in expectations and wealth

EXTRA SLIDES

Stylized Facts

Regression:

$$y_{it} \;=\; \delta_W{}'\mathbb{Q}_i^W + \beta' X_{it} + \eta_t + \epsilon_{it}$$

where $\mathbb{Q}_i^W$: wealth quintiles (highest omitted)
X_{it}: controls (gender, college degree, in labor force, constant)

Details about Stylized Facts

	(1) UE, Abs error	(2) Inflation, Abs Error	(3) Inflation, IQR	(4) HP Inflation, Abs Error	(5) HP Inflation, IQR
Male	0.0466	-0.354***	-0.776***	-0.292***	-0.182
	(1.01)	(-2.79)	(-3.68)	(-2.78)	(-0.92)
College Degree	-0.132**	-0.506***	-0.741***	-0.386***	-0.252
	(-2.53)	(-3.36)	(-3.04)	(-3.08)	(-1.10)
Participation	0.128***	0.243	-0.435	0.153	-0.390
	(2.67)	(1.56)	(-1.57)	(1.31)	(-1.45)
Fin Wealth, 1st quintile	0.0872	1.102***	0.915**	0.252	0.402
	(1.15)	(5.55)	(2.47)	(1.37)	(1.15)
Fin Wealth, 2nd quintile	0.226***	0.914***	1.471***	0.639***	0.783**
	(2.94)	(4.60)	(4.90)	(4.13)	(2.53)
Fin Wealth, 3rd quintile	0.0804	0.400**	0.412	0.218	-0.0630
	(1.18)	(2.17)	(1.60)	(1.47)	(-0.26)
Fin Wealth, 4th quintile	0.0314	0.0823	-0.0459	0.0163	-0.160
	(0.47)	(0.50)	(-0.23)	(0.11)	(-0.80)
Constant	0.973	1.766	8.081**	1.887	10.74***
	(1.60)	(1.05)	(2.10)	(1.21)	(3.13)
r2	0.0419	0.0954	0.0765	0.0280	0.0358
N	9139	8618	8618	7537	7537

t statistics in parentheses
* $p < .1$, ** $p < .05$, *** $p < .01$

back

Parameterization

Parameter	Value
Externally calibrated parameters	
Capital share (α)	0.36
Depreciation rate (δ)	0.025
Persistence of booms	0.88
Persistence of busts	0.82
Ratio of productivity between booms and bust (z_h/z_l)	1.027
Unemployment rate in booms	0.06
Unemployment rate in busts	0.10
Monthly job-finding rate in booms	0.55
Monthly job-finding rate in busts	0.45
Unemployment insurance replacement rate(μ)	0.40
Internally calibrated parameters	
Discount factor (β)	0.99
Relative risk aversion (γ)	5
Monetary cost of information (ν)	0.0012
Scale parameter of utility cost of information (α^{κ})	$1/3e^{-8}$

back

Model

Recursive Formulation of Household Problem

State Variables:

- Let $S = (\Gamma, z)$, where Γ: cross-sectional distribution of capital and productivity status
- Individual (Higher-order) beliefs p, and their distribution $\mathcal{P}$
  - first-order belief: $\mathcal{P}_i(S)$; second-order belief: $\mathcal{P}_{ij}(S)$, and so on ad infinitum
  - individual household's belief summarized by: $p = \left\{\mathcal{P}_i, (\mathcal{P}_{ij})_{j\in[0,1]}, ..., (\mathcal{P}_{ij...k})_{j,...,k\in[0,1]^{n-1}}, \cdots\right\}$
  - set of all such beliefs: $\mathcal{P} = \left\{(\mathcal{P}_i)_{i\in[0,1]}, (\mathcal{P}_{ij})_{i,j\in[0,1]^2}, ..., (\mathcal{P}_{ij...k})_{i,j,...,k\in[0,1]^n}, \cdots\right\}$

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