Imperfect Risk-Sharing and the Business Cycle

David Berger — NU and NBER

Luigi Bocola — Stanford and NBER

Alessandro Dovis — Penn and NBER

EIEF

June 2019

Imperfect risk-sharing and business cycles

- Does households' heterogeneity matter for business cycles?

- Recent literature (incomplete markets + New Keynesian models): answer is "yes"
  - Emphasizes importance of time-varying labor income risk and occasionally binding financial constraints for households' saving behavior
  - Time-varying precautionary motives affect aggregate demand

- Challenging to quantify these channels. Answer depends on modeling of risk-sharing mechanisms available to households and the risk they face
  - Ex: Bond vs. two assets (liquid vs illiquid) economy behave very differently
  - Ex: Cyclicality of firms' profits/timing of fiscal transfers matter for quantification

- We develop a framework robust to these considerations
  1. Measure degree of imperfect risk-sharing implicit in households' choices
  2. Provide framework to assess its macroeconomic implications

Our approach in a nutshell

We start with a *class* of New Kenesian models with idiosyncratic income risk, incomplete financial markets and isoelastic preferences

- Assets, financial constraints and nature of idiosyncratic risk mostly unrestricted

We will work with an equivalent representation (Nakajima, 2005; Werning, 2015): that of a representative-agent economy with state-dependent preferences

- Discount factor (captures time-varying precautionary motives in HA economy)
- Disutility of labor (captures changes in labor composition in HA economy)

Our main observation: these “preference shocks” are functions of households' consumption choices and individual productivities (wages)

Our approach:

1. Use the CEX to measure the “preference shocks”
2. Use the equivalent RA economy to measure the aggregate implications of imperfect risk-sharing

What we find

Imperfect risk-sharing $\rightarrow$ explains 20% of drop in output during Great Recession

- Due to an increase in the measured discount rate
- In a New Keynesian model, this shock reduces aggregate demand and inflation. At the zero lower bound, aggregate effect can be sizable

What in the micro data suggests higher propensity to save during Great Recession?

- Increase in dispersion of changes in consumption shares for the "savers" (high income/high net worth households)
- Due to increase in the sensitivity of consumption to labor income changes rather than an increase in cross-sectional dispersion of labor income changes

Literature

1 Aggregation results for models with incomplete markets

- Nakajima (2005), Krueger and Lustig (2010), Werning (2015)

2 New Keynesian models with incomplete markets

- Monetary policy: Auclert (2016), Kaplan, Moll and Violante (2017), McKay, Nakamura and Steinsson (2016), Auclert et al. (2018), Bhandari, Evans, Golosov and Sargent (2018), ...
- Business cycles: Guerrieri and Lorenzoni (2017), Heathcote and Perri (2018), Ravn and Sterk (2017), Bayer et al. (2019), ...

3 Asset pricing with incomplete markets

- Vissing-Jorgensen (2002), Kocherlakota and Pistaferri (2009), Krueger, Lustig and Perri (2008), ...

Outline

Overview

We consider a *class* of New Keynesian models with heterogeneous agents

- "Macro block": Standard "three-equations" NK model
  - Rotemberg (1982) price-adjustment costs
  - Aggregate shocks: preference, technology and monetary policy
- "Micro block": Consumption/saving problem under idiosyncratic income risk
  - Allow for many assets (nest the complete markets case)
  - Introduce *transaction costs* and *trading restrictions*

Main results

- Aggregate variables as in RA economy with preference "shocks"
- Mapping between preference shocks and micro allocation

Preferences and technology

- z_t and v_t are aggregate and idiosyncratic states. Let $z^t = (z_0, \ldots, z_t)$, $v^t = (v_0, \ldots, v_t)$, $s^t = (z^t, v^t)$, with $\Pr(s^t | s^{t-1}) = \Pr(v^t | z^t, v^{t-1}) \Pr(z^t | z^{t-1})$
- Households' preferences

$$u(c, l) = \tilde{\theta}(z_t) \left[\frac{c^{1-\sigma}}{1-\sigma} - \chi \frac{l^{1+\psi}}{1+\psi} \right]$$

- Competitive final good firms use intermediates to produce final good

$$Y(z^t) = \left(\int_0^1 y_i(z^t)^{1/\mu} di \right)^{\mu}$$

- Monopolistic competitive firms use labor to produce intermediate goods

$$y_i(z^t) = A(z_t) n_i(z^t)$$

where $n_i(z^t)$ is labor in efficiency units. Quadratic price-adjustment costs

The problem of the households

Households choose labor, consumption and savings

$$\max_{c,l,b,\{a_k\}_{k\in\mathcal{K}}} \sum_t \sum_{s^t} \beta^t \Pr\left(s^t|s_0\right) \exp\{\tilde{\theta}(z_t)\} \left[\frac{c\left(s^t\right)^{1-\sigma}}{1-\sigma} - \chi \frac{l(s^t)^{1+\nu}}{1+\nu}\right]$$

subject to

$$\begin{aligned} P\left(z^t\right) c\left(s^t\right) \quad &+ \quad \sum_{k\in\mathcal{K}} a_k\left(s^t\right) + \mathcal{T}\left(\left\{a_k\left(s^{t-1}\right)\right\}, \left\{a_k\left(s^t\right)\right\}, s^t\right) + \frac{b\left(s^t\right)}{i\left(z^t\right)} \\ &\leq \quad W\left(z^t\right) e(v_t) l\left(s^t\right) + b\left(s^{t-1}\right) + \sum_{k\in\mathcal{K}} R_k\left(s^{t-1}, s_t\right) a_k\left(s^{t-1}\right) \\ \mathcal{H}\left(b(s^t), \{a_j(s^t)\}_{k\in\mathcal{K}}, s^t\right) \quad &\geq \quad 0 \qquad \mathcal{H}_b(.) \geq 0 \end{aligned}$$

Remark 1: $\mathcal{T}(.)$ represents transaction costs, $\mathcal{H}(.)$ trading restrictions. Nests large class of models with incomplete markets

Remark 2: $\mathcal{H}_b(.) \geq 0$ imply that agents with highest marginal valuation for b are on their Euler equation

Closing the model

- New-Keynesian Phillips curve

$$\tilde{\pi}\left(z^t\right) = \frac{1}{\kappa\left(\mu - 1\right)} Y(z^t)\left[\mu \frac{w(z^t)}{A\left(z_t\right)} - 1\right] + \sum_{z^{t+1}} Q(z^{t+1}|z^t)\tilde{\pi}\left(z^{t+1}\right)$$

  where we define $\tilde{\pi}\left(z^t\right) = \left[(\pi(z^t) - \bar{\pi})/(1+\bar{\pi})\right] \times \left[(\pi(z^t)+1)/(1+\bar{\pi})\right]$

- Monetary policy follows standard Taylor rule

$$i(z^t) = \max\left\{[i(z^{t-1})]^{\rho_i}\left[\bar{i}\left(\frac{1+\pi(z^t)}{1+\bar{\pi}}\right)^{\gamma_\pi}\left(\frac{Y(z^t)}{Y^{\text{pot}}(z^t)}\right)^{\gamma_y}\right]^{1-\rho_i} \exp\{\varepsilon_m(z_t)\}, 1\right\}$$

- In equilibrium, labor, goods and financial markets clear
  - Labor market clearing requires $\int n_i(z^t)di = \sum_{v^t} \Pr(v^t|z^t)e(v^t)l(v^t, s^t)$
  - Nominal bonds in zero net supply. The assets $\{a_{k\in\mathcal{K}}(s^{t-1})\}$ satisfy

$$\sum \Pr(v^t|z^t) \sum_{k\in\mathcal{K}} R_k\left(s^{t-1}, s_t\right) a_k\left(s^{t-1}\right) = P(z^t)V(P(z^{t-1}), z^t)$$

Outline

1. A class of New Keynesian models with heterogeneous agents
2. The equivalent representative agent economy with preference "shocks"
3. Measuring the preference shocks
4. An application to the US Great Recession

Heterogeneity and the Euler equation

Euler equation holds for household(s) with highest marginal valuation

$$\frac{1}{i(z^t)} = \beta \max_{v^t} \sum_{s_{t+1}} \Pr\left(s^{t+1}|s^t\right) \left\{ \frac{\theta(z^{t+1})}{1+\pi\left(z^{t+1}\right)} \left(\frac{c\left(s^t, s_{t+1}\right)}{c\left(s^t\right)}\right)^{-\sigma} \right\}$$

Heterogeneity and the Euler equation

Divide and multiply by $[C(z^{t+1})/C(z^t)]^{-\sigma}$

$$\frac{1}{i(z^t)} = \beta \max_{v^t} \sum_{s_{t+1}} \Pr\left(s^{t+1}|s^t\right) \left\{ \frac{\theta(z^{t+1})}{1+\pi\left(z^{t+1}\right)} \left(\frac{c(s^t)/C(z^t)}{c(s^{t+1})/C(z^{t+1})}\right)^{-\sigma} \left(\frac{C\left(z^{t+1}\right)}{C\left(z^t\right)}\right)^{-\sigma} \right\}$$

Heterogeneity and the Euler equation

Aggregate C, π and i satisfy the Euler equation

$$\frac{1}{i(z^t)} = \beta \max_{v^t} \sum_{s_{t+1}} \Pr\left(s^{t+1}|s^t\right) \left\{ \frac{\theta(z^{t+1})\beta(v^t, z^t)}{1+\pi\left(z^{t+1}\right)} \left(\frac{C\left(z^{t+1}\right)}{C\left(z^t\right)}\right)^{-\sigma} \right\}$$

where

$$\beta(v^t, z^{t+1}) = \sum_{v_{t+1}} \Pr(v_{t+1}|z^{t+1}, v^t) \left(\frac{c(v^t, z^t)/C(z^t)}{c(v^{t+1}, z^{t+1})/C(z^{t+1})}\right)^{-\sigma}$$

Same FOC of RA agent economy with state-dependent discount factor $\beta(v^t, z^{t+1})$

- With complete markets, constant consumption shares. Euler equation as in RA economy, $\beta(v^t, z^{t+1}) = 1$
- With incomplete markets, consumption shares varies. Then $\beta(v^t, z^{t+1})$ varies (and typically > 1)

Remark : Conditional on allocation, $\beta(v^t, z^{t+1})$ does not depend on $\{\mathcal{K}, \mathcal{T}, \mathcal{H}\}$

Heterogeneity and labor supply

Optimal labor supply

$$\chi l(s^t)^{\psi} = w(z^t)e(v_t)c(s^t)^{-\sigma}$$

Heterogeneity and labor supply

Multiply both sides by $e(v_t)C(z^t)^{\frac{\sigma}{\psi}}$ and aggregate across households

$$\chi^{\frac{1}{\psi}} \underbrace{\left[\sum_{v^t} \Pr(v^t|z^t)e(v_t)l(s^t)\right]}_{L_e(z^t)} C(z^t)^{\frac{\sigma}{\psi}} = w(z^t)^{\frac{1}{\psi}} \left\{ \sum_{v^t} \Pr(v^t|z^t)e(v_t)^{\frac{1+\psi}{\psi}} \left[\frac{c(s^t)}{C(z^t)}\right]^{-\frac{\sigma}{\psi}} \right\}$$

Heterogeneity and labor supply

So, in the aggregate we must have

$$\omega(z^t)\chi L_e(z^t)^{\psi} = \frac{w(z^t)}{C(z^t)^{\sigma}}$$

where

$$\omega(z^t) = \left\{ \sum_{v^t} \Pr(v^t|z^t) \left[\frac{c(s^t)}{C(z^t)} \right]^{-\frac{\sigma}{\psi}} e(v_t)^{\frac{1+\psi}{\psi}} \right\}^{-\psi}$$

Same FOC of RA agent economy with state-dependent disutility of labor

- With complete markets, constant consumption shares. Labor supply as in RA economy with state-dependent disutility of labor (substitution effects)
- With incomplete markets, consumption shares varies. Additional wealth effects

Remark : Conditional on allocation, $\omega(z^t)$ does not depend on $\{\mathcal{K}, \mathcal{T}, \mathcal{H}\}$

An equivalent representative-agent economy

Suppose that C, Y, π, i are part of an equilibrium. Then they satisfy

$$
\begin{aligned}
\tilde{\pi}(z^t) &= \frac{Y(z^t)}{\kappa(\mu - 1)} \left[\mu\chi \frac{Y(z^t)^{\psi} C(z^t)^{\sigma} \omega(z^t)}{A(z_t)^{1+\psi}} - 1 \right] + \sum_{\mathbf{s}'} Q(z^{t+1}|z^t)\tilde{\pi}(z^{t+1}) \\
\frac{1}{i(z^t)} &= \beta \max_{v^t} \sum_{z^{t+1}} \Pr\left(z^{t+1}|z^t\right) \left\{ \frac{\theta(z^{t+1})\beta\left(v^t, z^{t+1}\right)}{1 + \pi\left(z^{t+1}\right)} \left(\frac{C\left(z^{t+1}\right)}{C\left(z^t\right)} \right)^{-\sigma} \right\} \\
i(z^t) &= \max\left\{ [i(z^{t-1})]^{\rho_i} \left[\bar{i} \left(\frac{1 + \pi(z^t)}{1 + \bar{\pi}} \right)^{\gamma_\pi} \left(\frac{Y(z^t)}{Y^{\text{pot}}(z^t)} \right)^{\gamma_y} \right]^{1-\rho_i} \exp\{\varepsilon_m(z_t)\}, 1 \right\} \\
Y\left(z^t\right) &= C\left(z^t\right) + \frac{\kappa}{2} \left[\frac{\pi(z^t) - \bar{\pi}}{1 + \bar{\pi}} \right]^2
\end{aligned}
$$

Key observation: Knowledge of $\{\beta(v^t, z^{t+1}), \omega(z^t)\}$ is all we need from the "micro block" to characterize law of motion for aggregate variables

As $\{\beta(v^t, z^{t+1}), \omega(z^t)\}$ varies, the aggregate allocation varies with them

Some examples

"β" shocks important to explain Great Recession in representative-agent economies

- $\beta \uparrow \rightarrow$ representative household wants to save more
- Aggregate demand and inflation fall. Large effects if ZLB binds

HA economies endogenously induce time-variation in β. What mechanisms?

1. Time-varying idiosyncratic risk (Heathcote and Perri, 2018, ...) ▸ Example
   - Increase in idiosyncratic income risk + incomplete markets $\rightarrow$ more precautionary savings $\rightarrow$ *as if* $\beta \uparrow$
2. Tightening of borrowing constraints
   - Borrowers cannot borrow $\rightarrow$ Savers cannot save $\rightarrow$ *as if* $\beta \uparrow$ (Eggertson and Krugman, 2012)
   - Expectation of tightening in the future $\rightarrow$ more precautionary savings $\rightarrow$ *as if* $\beta \uparrow$ (Guerrieri and Lorenzoni, 2018)

Counterfactuals at a conceptual level

We can use equivalent representation to assess macroeconomic effects of imperfect risk-sharing without modeling explicitly $\{\mathcal{K}, \mathcal{T}, \mathcal{H}\}$

- Suppose we know

$$x = \{\theta(z_t), A(z_t), \epsilon_m(z_t), \beta(v^t, z^{t+1}), \omega(z^t)\}$$

- Use equivalent representative-agent economy and x to solve for

$$y = \{Y(z^t), \pi(z^t), i(z^t)\}$$

- Use $x^{\text{cm}} = \{\theta(z_t), A(z_t), \epsilon_m(z_t), \beta^{\text{cm}}(v^t, z^{t+1}), \omega^{\text{cm}}(z^t)\}$ to solve for the "complete markets" counterfactual

$$y^{\text{cm}} = \{Y^{\text{cm}}(z^t), \pi^{\text{cm}}(z^t), i^{\text{cm}}(z^t)\}$$

Contribution of imperfect risk-sharing to macroeconomic aggregates

$$y - y^{\text{cm}}$$

Outline

1. A class of New Keynesian models with heterogeneous agents
2. The equivalent representative agent economy with preference "shocks"
3. Measuring the preference shocks
4. An application to the US Great Recession

Taking stock

- To perform the counterfactual we need to measure $\{\beta(v^t, z^{t+1}), \omega_t\}$
- These are functions of consumption shares and individual productivities (relative wages)
- We use the Consumption Expenditure Survey (CEX) to measure these objects and construct empirical counterpart to $\{\beta(v^t, z^{t+1}), \omega_t\}$
- Main findings
  - $\beta(v^t, z^{t+1})$ of "savers" increases substantially in Great Recession
  - ω_t and ω_t^{cm} close to each other

Data

- We use the CEX (1996-2012). Head of household between 22 and 64 years old
- Data definitions
  - Consumption: Dollar spending in non-durables and services
  - Earnings: Labor + business income
  - Hours: Total hours worked per year
  - Net worth: Total assets (checking/savings accounts, bonds, stocks, house, car) minus total liabilities (mortgage and car loans)
- Mapping between model and data
  - Measure at household level and adjust for number of members
  - Control for characteristics that are not in the model: education, age, sex, race and state of residence
- Set $\sigma = 1$ and $\psi = 1$

Comparison to NIPA | Households' characteristics | Measurement errors

Constructing $\beta(v^t, z^{t+1})$

$$\beta(v^t, z^{t+1}) = \sum_{v_{t+1}} \Pr(v_{t+1}|z^{t+1}, v^t) \left[\frac{c(z^t, v^t)/C(z^t)}{c(z^{t+1}, v^t, v_{t+1})/C(z^{t+1})} \right]$$

Want

- Measure change in consumption shares for an individual with history v^t in every state v_{t+1}

Problem

- For each individual, v^t, we observe only one realization of v_{t+1}

Constructing $\beta(v^t, z^{t+1})$

$$\beta(v^t, z^{t+1}) = \sum_{v_{t+1}} \Pr(v_{t+1}|z^{t+1}, v^t) \left[\frac{c(z^t, v^t)/C(z^t)}{c(z^{t+1}, v^t, v_{t+1})/C(z^{t+1})} \right]$$

What we do

- Group individuals with same history v^t
- Compute realized cross-sectional mean of change in consumption shares between z^t and z^{t+1} for individuals in the group
- By law of large numbers, it equals $\beta(v^t, z^{t+1})$

Constructing $\beta(v^t, z^{t+1})$

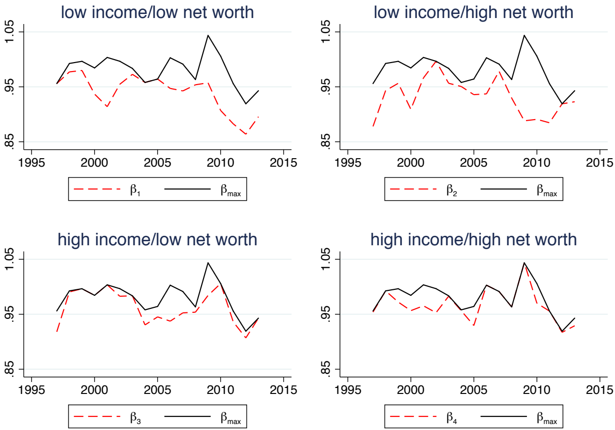
$$\beta(v^t, z^{t+1}) = \sum_{v_{t+1}} \Pr(v_{t+1}|z^{t+1}, v^t) \left[\frac{c(z^t, v^t)/C(z^t)}{c(z^{t+1}, v^t, v_{t+1})/C(z^{t+1})} \right]$$

In particular

- Group individuals by income and net worth
  - Logic: Sufficient statistic for v^t in baseline incomplete markets economies
- Within each group i, compute

$$\beta_{it+1} = \frac{1}{N_i} \sum_{j=1}^{N_i} \frac{c_{jt}/C_t}{c_{jt+1}/C_{t+1}}$$

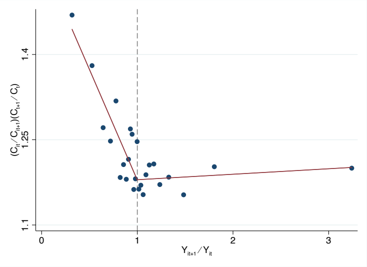
Path for β_{it+1} for each group



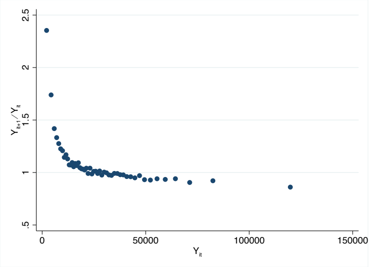
Two patterns

1. High income households have higher β_{it+1} (more incentives to save)
2. β_{it+1} increases during great recession

Why high income households have higher β_{it+1}?



(a) $\frac{c_{it}/C_t}{c_{it+1}/C_{t+1}}$ vs $\frac{y_{it+1}}{y_{it}}$



(b) $\frac{y_{it+1}}{y_{it}}$ vs y_{it}

- Consumption shares falls when income falls (consumption sensitive to income)
- High income today predicts low income growth (mean reversion)

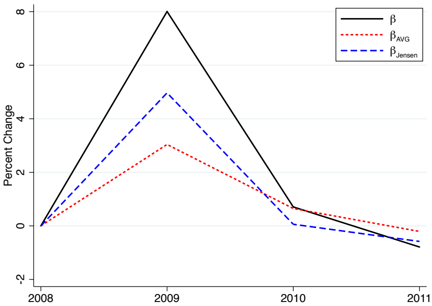
High income today predicts consumption shares to fall next period

Why β_{it+1} increases in Great Recession?

Mechanically, β_{it+1} can increase because of two forces

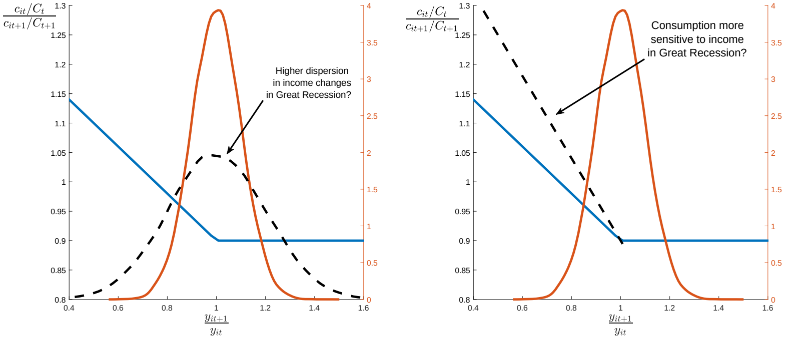
- The average consumption share of the group falls
- The dispersion in consumption share within the group increases

$$\beta_{it+1} = \underbrace{\left[\frac{C_{t+1}/C_t}{\frac{1}{N_i}\sum_{j=1}^{N_i} c_{jt+1}/c_{jt}}\right]}_{\beta_{AVG,it+1}} \times \underbrace{\sum_{j=1}^{N_i}\left[\frac{\sum_{j=1}^{N_i} c_{jt+1}/c_{jt}}{c_{jt+1}/c_{jt}}\right]}_{\beta_{JEN,it+1}}.$$



Why β_{it+1} increases in Great Recession?

Two (mutually non-exclusive) effects can increase dispersion



(c) Increase in income dispersion

(d) Increase in consumption sensitivity

Increase in β_{it+1} driven by increase in consumption sensitivity of high income/high net worth group ▸ income dispersion ▸ consumption sensitivity

Constructing $\omega(z^t)$

$$\omega(z^t) = \left\{ \sum_{v^t} \Pr(v^t|z^t) \left[\frac{c(s^t)}{C(z^t)} \right]^{-\frac{\sigma}{\psi}} e(v_t)^{\frac{1+\psi}{\psi}} \right\}^{-\psi}$$

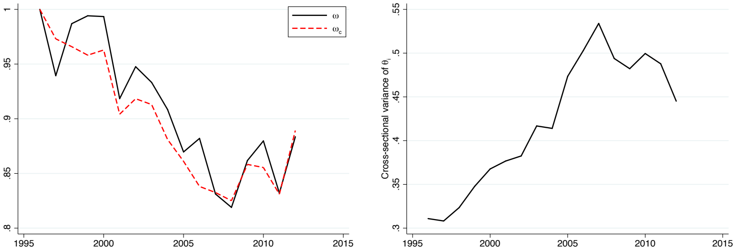
- For each household, compute $e_{it} = w_{it}/W_t$ and $\varphi_{it} = c_{it}/C_t$
- Compute cross-sectional average

$$\omega_t = \left[\frac{1}{N} \sum_{i=1}^{N} e_{it}^2 \times \varphi_{it}^{-1} \right]^{-1}$$

- For ω_t^{cm}, set distribution of consumption shares to 1996 value

$$\omega_t^{\text{cm}} = \left[\frac{1}{N} \sum_{i=1}^{N} e_{it}^2 \times \frac{1}{N} \sum_{i=1}^{N} \varphi_{i1996}^{-1} + \text{Cov}\left(e_{i1996}^2, \varphi_{i1996}^{-1} \right) \right]^{-\psi}$$

Path for $\omega(z^t)$ and $\omega^{cm}(z^t)$



(e) ω_t and ω_t^{cm} (f) Variance of θ_i

- ω_t mostly driven by increase in dispersion in relative wages (model infers from this that composition of labor force got better over time)
- Not much difference between ω_t and ω_t^{cm}

Outline

1. A class of New Keynesian models with heterogeneous agents

2. The equivalent representative agent economy with preference “shocks”

3. Measuring the preference shocks

4. An application to the US Great Recession

Counterfactuals in practice

We have detected an increase in β_{it+1} during the Great Recession. Is it big enough to induce sizable macroeconomic effects?

We use the equivalent representative-agent economy to answer this question

- Assume stochastic process for $\{\theta_t, A_t, \epsilon_{m,t}, \max_i \beta_{it}, \omega_t\}$
- Estimate structural parameters using data on $\{Y_t, \pi_t, i_t, \max_i \beta_{it+1}, \omega_t\}$
- Apply particle filter to estimate $\{\theta_t, A_t, \epsilon_{mt}\}$
- Solve equivalent RA economy under complete markets and compute counterfactual $y^{\text{cm}} = \{Y_t^{\text{cm}}, \pi_t^{\text{cm}}, i_t^{\text{cm}}\}$ by feeding $\{\theta_t, A_t, \varepsilon_{m,t}, \omega_t^{cm}\}$

Contribution of imperfect risk-sharing to macroeconomic aggregates

$$y - y^{\text{cm}}$$

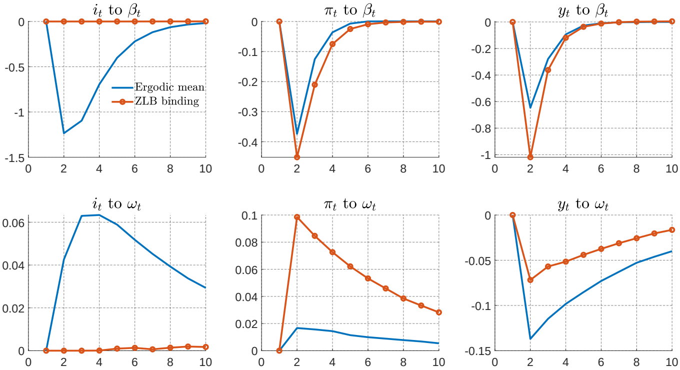
Estimation

- Restricted VAR(1) process for stochastic process
  - Structural shocks orthogonal
  - Do not allow for feedback of aggregate shocks on $\{\beta_{it+1}, \omega_t\}$ (imprecisely estimated given small sample)
- We set $\sigma = 1$, $\nu = 1$, $\mu = 1.2$, $\chi = 1/\mu$, $\bar{\pi} = 0.02$, $\beta = 0.99$
- Remaining parameters: $[\kappa, \rho_i, \gamma_\pi, \gamma_y]$ and those of stochastic process
- Evaluate likelihood function of equivalent representative-agent economy and estimate parameters using $\mathbf{Y}_t = \{Y_t, \pi_t, i_t, \max_i \beta_{it+1}, \omega_t\}$ as observables

Parameters Model fit

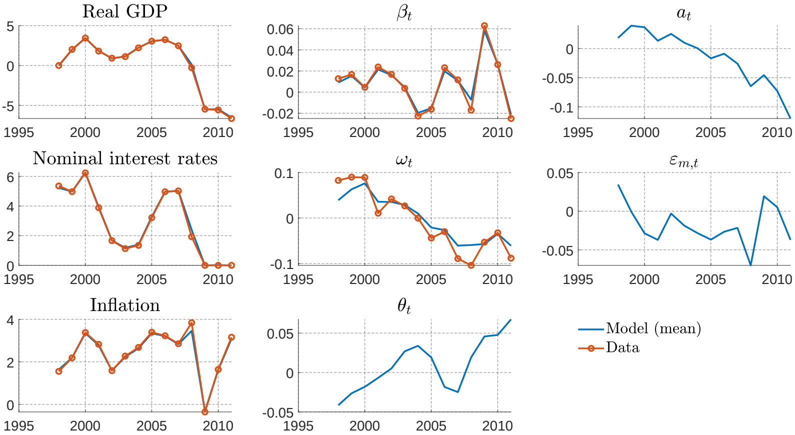
IRFs to β_t and ω_t in estimated model

2sd shocks to β_t and ω_t in estimated model



- $\uparrow \beta_t \rightarrow$ Lower aggregate demand, lower inflation $\rightarrow$ effects stronger if monetary authority constrained by ZLB
- $\uparrow \omega_t \rightarrow$ Higher marginal costs, higher inflation, lower output $\rightarrow$ Effects on output mitigated at the ZLB

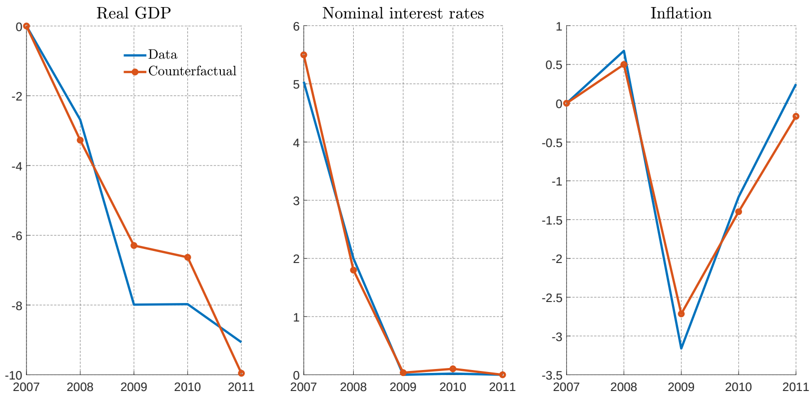
Estimate latent shocks via particle filter



Model needs positive shocks to θ_t to reach the ZLB

Counterfactual

Feed estimated $\{\theta_t, A_t, \varepsilon_{m,t}\}$ and ω_t^{cm} on model with $\beta_{it} = 1\ \forall t$



Milder recession ($\approx 20\%$) in 2009-2010 if households perfectly insured

Summing up

- What matters for propagation of shocks in incomplete market economy can be summarized by two statistics, $\{\beta_{it}, \omega_t\}$
- Our analysis doesn't establish what drives them. Still useful for structural models, as they should be consistent with their stochastic properties
- The finding that β_{it} increases during Great Recession consistent with studies that explain depressed aggregate demand via a disruption in risk-sharing
- The finding that β_{it} increases because of an increase in dispersion, and that this is driven by higher sensitivity of consumption helps discriminating across models
  - Two agents (TANK) models don't feature a Jensen term in β_{it}
  - Mechanisms that can explain increase in sensitivity
    - Tightening of collateral constraints for high income/high net worth households
    - Relative importance of permanent income shocks increases in Great Recession

Conclusion

- Novel approach to evaluate macro models with incomplete markets
- Measure preference "shocks" of equivalent representative-agent economy using the CEX
- Document increase in "discounting" around the Great Recession
  - Due to worsening of risk-sharing mechanisms rather than heightened income risk
  - Sizable aggregate effects when interpreted through the lens of standard New Keynesian models
- We are working on
  - Repeating the analysis with a more sophisticated "Macro block" (adding capital)

Additional Material

The problem of intermediate goods producers

- We assume that the firm discounts future profits using the real state price

$$Q\left(z^{t+1}\right) = \beta \max_{v^t} \left\{ \Pr\left(z^{t+1}|z^t\right)\theta(z^{t+1}) \sum_{v_{t+1}} \Pr\left(v^{t+1}|z^{t+1}, v^t\right) \left[\frac{c\left(z^{t+1}, v^{t+1}\right)}{c\left(z^t, v^t\right)}\right]^{-\sigma} \right\}$$

- The firm's problem can be written recursively as

$$\begin{aligned} V\left(P_j, z^t\right) &= \max_{p_j, y_j, n_j} \frac{y_j}{P\left(z^t\right)} - w(z^t)n_j(z^t) - \frac{\kappa}{2}\left[\frac{p_j}{P_j(1+\bar{\pi})} - 1\right]^2 \\ &+ \sum_{z^{t+1}} Q(z^{t+1}|z^t)V\left(p_j, z^{t+1}\right) \end{aligned}$$

- New-Keynesian Phillips curve

$$\tilde{\pi}\left(z^t\right) = \frac{1}{\kappa\left(\mu - 1\right)} Y(z^t)\left[\mu \frac{w(z^t)}{A\left(z_t\right)} - 1\right] + \sum_{z^{t+1}} Q(z^{t+1}|z^t)\tilde{\pi}\left(z^{t+1}\right)$$

where we define $\tilde{\pi}\left(z^t\right) = [(\pi(z^t) - \bar{\pi})/(1+\bar{\pi})] \times [(\pi(z^t)+1)/(1+\bar{\pi})]$

A simple example

- Assume $\sigma = 1$
- Law of motion for idiosyncratic efficiency

$$\Delta \log[e(v_t)] = -\frac{\sigma(z_t)}{2} + \sigma(z_t)\varepsilon_{v,t}$$

- Asset market structure
  - Households can only trade a risk-free bond
  - Face a tight borrowing limit: $b(s^t) \geq 0$

In equilibrium financial autarky: every agent is hand-to-mouth

- Labor supply is the same for all households ($\sigma = 1$)
- Individual consumption: $c(s^t) = e(v_t)C(z^t)$

Idiosyncratic risk and aggregate demand

We can compute the "micro block"

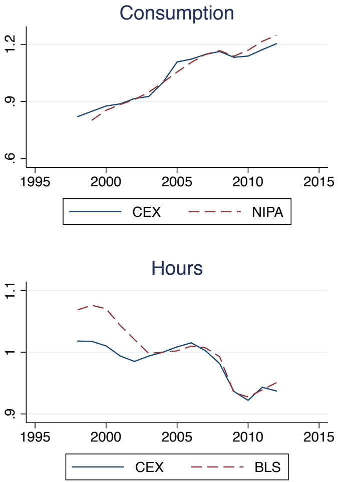
$$\begin{aligned} \beta(v^t, z^{t+1}) &= \sum_{v^{t+1}} \Pr(v^{t+1} | v^t, z^{t+1}) \exp\left\{-\Delta \log[e(v_{t+1})]\right\} \\ &= \exp\{\sigma(z^{t+1})\} \\ \omega(z^t) &= 1 \end{aligned}$$

Mechanism: high expected $\sigma(z_{t+1})$ increases precautionary motives. Higher desired savings manifests itself in the aggregate as increase in β

In benchmark NK models, these shocks lead to a fall in aggregate demand

Return

Comparison with NIPA Aggregates



Return

Households' characteristics in 2006

	CEX
Age of head	44.10
Household size	2.71
Head with college (%)	34.25
Consumption expenditures per person	10330.98
Labor income per person	26456.95
Disposable income per person	26492.00
Hours worked per person	1301.17
Wage per hour	21.69
Household's net worth	142174.40
Liquid assets	14296.21

Notes: *The sample size is 2328 households. All statistics are computed using sample weights. All monetary variables are expressed in 2000 U.S. dollars.*

Return

Measurement errors

A concern is that time-series variation in $\{\beta_{it}, \omega_t\}$ are due to measurement errors.

- One form of measurement errors is recording errors that create extreme outliers. We remove top and bottom 1% for all variables used in the analysis

- We follow Vissing-Jorgensen (2002) and compute semi-annual changes in consumption to minimize both time aggregation and category switching concerns

$$\frac{c_m + c_{m+1} + c_{m+2} + c_{m+3} + c_{m+4} + c_{m+5}}{c_{m+6} + c_{m+7} + c_{m+8} + c_{m+9} + c_{m+10} + c_{m+11}}$$

- We measure $\{\beta_{it}, \omega_t\}$ as cross-sectional averages across individuals. Reduce problems induced by classical multiplicative measurement errors

- We introduce Gaussian measurement errors on $\{\beta_{it}, \omega_t\}$ (10% of their sample variance) when estimating the model and performing counterfactuals

Return

Distribution of income changes

Distribution of Income changes									
Y_H Households	p1	p5	p10	p25	p50	p75	p90	p95	p99
2006-2007	0.25	0.44	0.69	0.80	0.94	1.06	1.23	1.41	2.00
2008-2009	0.21	0.45	0.69	0.81	0.95	1.07	1.23	1.38	1.89
Y_H, NW_H Households									
2006-2007	0.25	0.44	0.61	0.80	0.94	1.05	1.23	1.45	2.06
2008-2009	0.23	0.44	0.58	0.79	0.95	1.06	1.24	1.43	1.93

- For high income households, distribution of income changes very similar before and during Great Recession

Return

Sensitivity of consumption shares to income

We estimate the following relation, conditioning of $y_{it}/y_{it-1} < 1$

$$\frac{c_{it-1}/C_{t-1}}{c_{it}/C_t} = \alpha + \beta \frac{y_{it}}{y_{it-1}} + \delta \text{rec}_t + \gamma \frac{y_{it}}{y_{it-1}} \times \text{rec}_t + e_{it},$$

Consumption Response to Income Changes in 2006-2009

	All Groups	Separate Groups			
		(Y_L, NW_L)	(Y_L, NW_H)	(Y_H, NW_L)	(Y_H, NW_H)
α	1.468***	1.726***	1.472***	1.438***	1.318***
	(17.49)	(7.95)	(11.77)	(7.66)	(10.22)
β	-0.247**	-0.579**	-0.213	-0.203	-0.0909
	(-2.47)	(-2.28)	(-1.39)	(-0.90)	(-0.59)
δ	0.287	-0.240	-0.0274	0.179	1.078**
	(1.59)	(-0.88)	(-0.16)	(0.73)	(1.96)
γ	-0.369*	0.220	-0.0584	-0.198	-1.272**
	(-1.74)	(0.69)	(-0.28)	(-0.68)	(-1.96)
N	9016	2032	2166	2305	2513

- For high income/high net worth households, consumption shares more sensitive to income changes in Great Recession

Return

Bayesian estimation

Estimate the first-order approximation of the model with Bayesian methods

		Prior		Posterior	
Parameter	Distribution	Mean	St. dev.	Mean	90% Interval
$4 \times \kappa$	Gamma	85.00	15.00	73.71	[52.17, 93.81]
ρ_i	Beta	0.50	0.25	0.57	[0.34, 0.80]
γ_π	Normal	1.50	2.00	3.72	[1.91, 5.41]
γ_y	Normal	1.00	2.00	0.18	[0.00, 0.42]
ρ_θ	Beta	0.50	0.28	0.69	[0.49, 0.90]
ρ_a	Beta	0.50	0.28	0.91	[0.83, 0.99]
$\Phi_{\beta,\beta}$	Beta	0.50	0.25	0.33	[0.06, 0.55]
$\Phi_{\omega,\omega}$	Beta	0.50	0.25	0.86	[0.74, 0.99]
$100 \times \sigma_\theta$	InvGamma	1.00	5.00	2.48	[1.02, 4.02]
$100 \times \sigma_a$	InvGamma	1.00	5.00	2.18	[0.73, 2.89]
$100 \times \sigma_m$	InvGamma	1.00	5.00	1.94	[1.15, 2.69]
$100 \times \sigma_\beta$	InvGamma	1.00	5.00	2.24	[1.51, 2.96]
$100 \times \sigma_\omega$	InvGamma	1.00	5.00	2.28	[1.29, 3.25]

Return

Model Fit

	Data	Model (linear)	Model (non-linear)
Mean(π_t)	2.69	2.00	1.87
Mean(i_t)	3.87	3.00	3.57
Stdev(Y_t)	4.15	3.42	5.85
Stdev(π_t)	1.23	1.59	1.50
Stdev(i_t)	3.02	2.68	3.16
Corr(Y_t, Y_{t-1})	0.93	0.85	0.81
Corr(i_t, i_{t-1})	0.90	0.72	0.42
Corr(π_t, π_{t-1})	0.51	0.14	0.17
Corr(Y_t, i_t)	0.11	-0.08	0.04
Corr(Y_t, π_t)	0.14	0.12	0.14
Corr(i_t, π_t)	0.71	0.52	0.68

Return