A Quantitative Analysis of Countercyclical Capital Buffers

Miguel Faria-e-Castro
Federal Reserve Bank of St. Louis

PEJ Évora, July 2019

The Countercyclical Capital Buffer

- **Basel II**: pre-2008 bank regulation

$$\text{Bank Capital}_t \geq \kappa \times \text{Bank Assets}_t$$
$$\text{Bank Reserves}_t \geq \phi \times \text{Bank Deposits}_t$$

- **Basel III**: introduces Countercyclical Capital Buffer (CCyB)

$$\text{Bank Capital}_t \geq \kappa(\mathbb{S}_t) \times \text{Bank Assets}_t$$

where $\mathbb{S}_t$ is the state of the economy

  - BIS: raise κ during periods of "excess aggregate credit growth"
  - Active in Hong Kong, Sweden, UK, Norway as of June 2019

This paper:

1. What are the quantitative effects of the CCyB?
2. Can CCyB-like policies prevent a 2008-like crisis?

The Countercyclical Capital Buffer

- **Basel II**: pre-2008 bank regulation

$$\text{Bank Capital}_t \geq \kappa \times \text{Bank Assets}_t$$

$$\text{Bank Reserves}_t \geq \phi \times \text{Bank Deposits}_t$$

- **Basel III**: introduces Countercyclical Capital Buffer (CCyB)

$$\text{Bank Capital}_t \geq \kappa(\mathbb{S}_t) \times \text{Bank Assets}_t$$

where $\mathbb{S}_t$ is the state of the economy

- BIS: raise κ during periods of “excess aggregate credit growth”
- Active in Hong Kong, Sweden, UK, Norway as of June 2019

This paper:

1. What are the quantitative effects of the CCyB?
2. Can CCyB-like policies prevent a 2008-like crisis?

The Countercyclical Capital Buffer

- **Basel II**: pre-2008 bank regulation

$$\text{Bank Capital}_t \geq \kappa \times \text{Bank Assets}_t$$
$$\text{Bank Reserves}_t \geq \phi \times \text{Bank Deposits}_t$$

- **Basel III**: introduces Countercyclical Capital Buffer (CCyB)

$$\text{Bank Capital}_t \geq \kappa(\mathbb{S}_t) \times \text{Bank Assets}_t$$

where $\mathbb{S}_t$ is the state of the economy

  - BIS: raise κ during periods of "excess aggregate credit growth"
  - Active in Hong Kong, Sweden, UK, Norway as of June 2019

This paper:

1. What are the quantitative effects of the CCyB?
2. Can CCyB-like policies prevent a 2008-like crisis?

The Countercyclical Capital Buffer

- **Basel II**: pre-2008 bank regulation

$$\text{Bank Capital}_t \geq \kappa \times \text{Bank Assets}_t$$

$$\text{Bank Reserves}_t \geq \phi \times \text{Bank Deposits}_t$$

- **Basel III**: introduces Countercyclical Capital Buffer (CCyB)

$$\text{Bank Capital}_t \geq \kappa(\mathbb{S}_t) \times \text{Bank Assets}_t$$

where $\mathbb{S}_t$ is the state of the economy

  - BIS: raise κ during periods of "excess aggregate credit growth"
  - Active in Hong Kong, Sweden, UK, Norway as of June 2019

This paper:

1. What are the quantitative effects of the CCyB?
2. Can CCyB-like policies prevent a 2008-like crisis?

Approach and Results

1. Structural model of (endogenous) financial crises
   - Economy endogenously enters and exits crisis regions
   - Crises trigger "aggregate demand" recessions
   - Scope for macroprudential regulation
2. Quantitative exercise
   - Calibrated Model + Data $\Rightarrow$ estimate shocks under Basel II
   - Counterfactual: Crisis and Great Recession under Basel III
3. Results

   3.1 What are the quantitative effects of the CCyB?

   (a) **Ex-ante**: crises become 3 times less frequent

   (b) **Ex-post**: reduce drop in GDP by 50%

   3.2 Can CCyB-like policies prevent a 2008-like crisis?

   (a) Could prevent financial panic in 2008

   (b) ...but not the subsequent Great Recession

Approach and Results

1. Structural model of (endogenous) financial crises
   - Economy endogenously enters and exits crisis regions
   - Crises trigger "aggregate demand" recessions
   - Scope for macroprudential regulation
2. Quantitative exercise
   - Calibrated Model + Data $\Rightarrow$ estimate shocks under Basel II
   - Counterfactual: Crisis and Great Recession under Basel III
3. Results

   3.1 What are the quantitative effects of the CCyB?

   (a) **Ex-ante**: crises become 3 times less frequent

   (b) **Ex-post**: reduce drop in GDP by 50%

   3.2 Can CCyB-like policies prevent a 2008-like crisis?

   (a) Could prevent financial panic in 2008

   (b) ...but not the subsequent Great Recession

Approach and Results

1. Structural model of (endogenous) financial crises
    - Economy endogenously enters and exits crisis regions
    - Crises trigger "aggregate demand" recessions
    - Scope for macroprudential regulation
2. Quantitative exercise
    - Calibrated Model + Data $\Rightarrow$ estimate shocks under Basel II
    - Counterfactual: Crisis and Great Recession under Basel III
3. Results

   3.1 What are the quantitative effects of the CCyB?

      (a) **Ex-ante**: crises become 3 times less frequent

      (b) **Ex-post**: reduce drop in GDP by 50%

   3.2 Can CCyB-like policies prevent a 2008-like crisis?

      (a) Could prevent financial panic in 2008

      (b) ...but not the subsequent Great Recession

Approach and Results

1. Structural model of (endogenous) financial crises
    - Economy endogenously enters and exits crisis regions
    - Crises trigger "aggregate demand" recessions
    - Scope for macroprudential regulation
2. Quantitative exercise
    - Calibrated Model + Data ⇒ estimate shocks under Basel II
    - Counterfactual: Crisis and Great Recession under Basel III
3. Results

   3.1 What are the quantitative effects of the CCyB?

      (a) **Ex-ante**: crises become 3 times less frequent

      (b) **Ex-post**: reduce drop in GDP by 50%

   3.2 Can CCyB-like policies prevent a 2008-like crisis?

      (a) Could prevent financial panic in 2008

      (b) ...but not the subsequent Great Recession

Approach and Results

1. Structural model of (endogenous) financial crises
   - Economy endogenously enters and exits crisis regions
   - Crises trigger "aggregate demand" recessions
   - Scope for macroprudential regulation
2. Quantitative exercise
   - Calibrated Model + Data $\Rightarrow$ estimate shocks under Basel II
   - Counterfactual: Crisis and Great Recession under Basel III
3. Results

   3.1 What are the quantitative effects of the CCyB?

   (a) **Ex-ante**: crises become 3 times less frequent

   (b) **Ex-post**: reduce drop in GDP by 50%

   3.2 Can CCyB-like policies prevent a 2008-like crisis?

   (a) Could prevent financial panic in 2008

   (b) ...but not the subsequent Great Recession

Approach and Results

1. Structural model of (endogenous) financial crises
    - Economy endogenously enters and exits crisis regions
    - Crises trigger "aggregate demand" recessions
    - Scope for macroprudential regulation
2. Quantitative exercise
    - Calibrated Model + Data $\Rightarrow$ estimate shocks under Basel II
    - Counterfactual: Crisis and Great Recession under Basel III
3. Results

    3.1 What are the quantitative effects of the CCyB?

    (a) **Ex-ante**: crises become 3 times less frequent

    (b) **Ex-post**: reduce drop in GDP by 50%

    3.2 Can CCyB-like policies prevent a 2008-like crisis?

    (a) Could prevent financial panic in 2008

    (b) ...but not the subsequent Great Recession

Approach and Results

1. Structural model of (endogenous) financial crises
    - Economy endogenously enters and exits crisis regions
    - Crises trigger "aggregate demand" recessions
    - Scope for macroprudential regulation
2. Quantitative exercise
    - Calibrated Model + Data $\Rightarrow$ estimate shocks under Basel II
    - Counterfactual: Crisis and Great Recession under Basel III
3. Results

    3.1 What are the quantitative effects of the CCyB?

    (a) **Ex-ante**: crises become 3 times less frequent

    (b) **Ex-post**: reduce drop in GDP by 50%

    3.2 Can CCyB-like policies prevent a 2008-like crisis?

    (a) Could prevent financial panic in 2008

    (b) ...but not the subsequent Great Recession

Literature

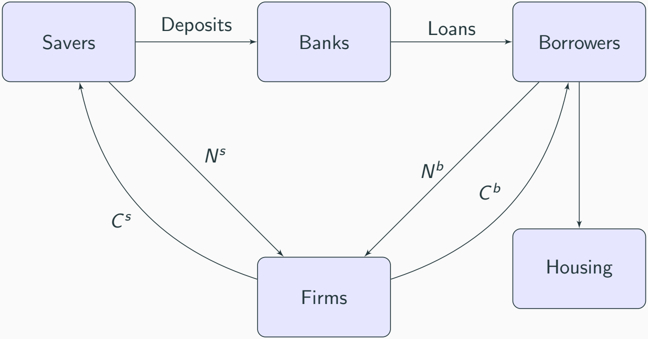
1. **Basel II**: What is the optimal level of capital requirements?
   Van den Heuvel (2008), Nguyen (2014), Martinez-Miera and Suarez (2014), Begenau (2015), Landvoigt and Begenau (2016)
2. **Basel III**: How should capital requirements change with the state of the economy?
   Karmakar (2016), Davidyuk (2017), Elenev, Landvoigt, and Van Nieuwerburgh (2018), Mendicino, Nikolov, Suarez, and Supera (2018)

This paper: Quantitative (positive) analysis of current CCyB framework.

Combines

- Gertler, Kiyotaki, and Prestipino (2018): bank runs in a macro model
- Faria-e-Castro (2019): financial crises and demand-driven recessions

Model Structure



Borrowers, Debt, and Default

- Borrower family: members $i \in [0, 1]$ enter period with

$$\underbrace{h_{t-1}}_{\text{housing}}, \quad \underbrace{B^b_{t-1}}_{\text{long-term debt}}, \quad \underbrace{\nu_t(i)}_{\text{house quality shock, } \sim F^b}, \quad \underbrace{\zeta_t(i)}_{\text{moving shock, 1 w.p. } \mathrm{m}}$$

- Movers choose to prepay debt, or default and lose $\nu_t(i) p^h_t h_{t-1}$
- Family makes all decisions, new borrowing subject to

$$B^{b,\text{new}}_t \leq \theta^{\text{LTV}} p^h_t h^{\text{new}}_t$$

- Optimal default rule (full problem)

$$\text{household default}_t = f\left(\frac{B^b_{t-1}}{\Pi_t p^h_t h_{t-1}}\right)$$

- Lenders recover R^b_t, per unit of debt

$$R^b_t = \underbrace{(1-\mathrm{m})[(1-\gamma)Q^b_t + \gamma]}_{\text{non-movers}} + \mathrm{m}\left\{\underbrace{1 - F^b(\nu^*_t)}_{\text{repaid}} + \overbrace{(1-\lambda^b)}^{\text{Resource Cost}} \int_0^{\nu^*_t} \nu \frac{p_t h_{t-1}}{B^b_{t-1}/\Pi_t} \mathrm{d}F^b \right\}$$

Borrowers, Debt, and Default

- Borrower family: members $i \in [0,1]$ enter period with

$$\underbrace{h_{t-1}}_{\text{housing}}, \quad \underbrace{B^b_{t-1}}_{\text{long-term debt}}, \quad \underbrace{\nu_t(i)}_{\text{house quality shock, } \sim F^b}, \quad \underbrace{\zeta_t(i)}_{\text{moving shock, 1 w.p. } \mathrm{m}}$$

- Movers choose to prepay debt, or default and lose $\nu_t(i) p^h_t h_{t-1}$
- Family makes all decisions, new borrowing subject to

$$B^{b,\text{new}}_t \leq \theta^{\text{LTV}} p^h_t h^{\text{new}}_t$$

- Optimal default rule (▸ full problem)

$$\text{household default}_t = f\left(\frac{B^b_{t-1}}{\Pi_t p^h_t h_{t-1}}\right)$$

- Lenders recover R^b_t, per unit of debt

$$R^b_t = \underbrace{(1-\mathrm{m})[(1-\gamma)Q^b_t + \gamma]}_{\text{non movers}} + \mathrm{m}\left\{\underbrace{1 - F^b(\nu^*_t)}_{\text{repaid}} + \overbrace{(1-\lambda^b)}^{\text{Resource Cost}} \int_0^{\nu^*_t} \nu \frac{p_t h_{t-1}}{B^b_{t-1}/\Pi_t} \mathrm{d}F^b \right\}$$

Borrowers, Debt, and Default

- Borrower family: members $i \in [0,1]$ enter period with

$$\underbrace{h_{t-1}}_{\text{housing}}, \quad \underbrace{B^b_{t-1}}_{\text{long-term debt}}, \quad \underbrace{\nu_t(i)}_{\text{house quality shock, } \sim F^b}, \quad \underbrace{\zeta_t(i)}_{\text{moving shock, 1 w.p. } \mathrm{m}}$$

- Movers choose to prepay debt, or default and lose $\nu_t(i) p^h_t h_{t-1}$
- Family makes all decisions, new borrowing subject to

$$B^{b,\text{new}}_t \leq \theta^{\text{LTV}} p^h_t h^{\text{new}}_t$$

- Optimal default rule (full problem)

$$\text{household default}_t = f\left(\frac{B^b_{t-1}}{\Pi_t p^h_t h_{t-1}}\right)$$

- Lenders recover R^b_t, per unit of debt

$$R^b_t = \underbrace{(1-\mathrm{m})[(1-\gamma)Q^b_t + \gamma]}_{\text{non-movers}} + \mathrm{m}\left\{\underbrace{1 - F^b(\nu^*_t)}_{\text{repaid}} + \overbrace{(1-\lambda^b)}^{\text{Resource Cost}} \int_0^{\nu^*_t} \nu \frac{p_t h_{t-1}}{B^b_{t-1}/\Pi_t} \mathrm{d}F^b \right\}$$

Borrowers, Debt, and Default

- Borrower family: members $i \in [0,1]$ enter period with

$$\underbrace{h_{t-1}}_{\text{housing}}, \quad \underbrace{B^b_{t-1}}_{\text{long-term debt}}, \quad \underbrace{\nu_t(i)}_{\text{house quality shock, } \sim F^b}, \quad \underbrace{\zeta_t(i)}_{\text{moving shock, 1 w.p. } \mathrm{m}}$$

- Movers choose to prepay debt, or default and lose $\nu_t(i) p^h_t h_{t-1}$
- Family makes all decisions, new borrowing subject to

$$B^{b,\text{new}}_t \leq \theta^{\text{LTV}} p^h_t h^{\text{new}}_t$$

- Optimal default rule (▸ full problem)

$$\text{household default}_t = f\left(\frac{B^b_{t-1}}{\Pi_t p^h_t h_{t-1}}\right)$$

- Lenders recover R^b_t, per unit of debt

$$R^b_t = \underbrace{(1-\mathrm{m})[(1-\gamma)Q^b_t + \gamma]}_{\text{non-movers}} + \mathrm{m}\left\{\underbrace{1 - F^b(\nu^*_t)}_{\text{repaid}} + \overbrace{(1-\lambda^b)}^{\text{Resource Cost}} \int_0^{\nu^*_t} \nu \frac{p_t h_{t-1}}{B^b_{t-1}/\Pi_t} \mathrm{d}F^b \right\}$$

Borrowers, Debt, and Default

- Borrower family: members $i \in [0,1]$ enter period with

$$\underbrace{h_{t-1}}_{\text{housing}}, \quad \underbrace{B^b_{t-1}}_{\text{long-term debt}}, \quad \underbrace{\nu_t(i)}_{\text{house quality shock, } \sim F^b}, \quad \underbrace{\zeta_t(i)}_{\text{moving shock, 1 w.p. } \mathrm{m}}$$

- Movers choose to prepay debt, or default and lose $\nu_t(i) p^h_t h_{t-1}$
- Family makes all decisions, new borrowing subject to

$$B^{b,\text{new}}_t \leq \theta^{\text{LTV}} p^h_t h^{\text{new}}_t$$

- Optimal default rule (full problem)

$$\text{household default}_t = f\left(\frac{B^b_{t-1}}{\Pi_t p^h_t h_{t-1}}\right)$$

- Lenders recover R^b_t, per unit of debt

$$R^b_t = \underbrace{(1-\mathrm{m})[(1-\gamma)Q^b_t + \gamma]}_{\text{non-movers}} + \mathrm{m}\left\{\underbrace{1 - F^b(\nu^*_t)}_{\text{repaid}} + \overbrace{(1-\lambda^b)}^{\text{Resource Cost}} \int_0^{\nu^*_t} \nu \frac{p_t h_{t-1}}{B^b_{t-1}/\Pi_t} \mathrm{d}F^b \right\}$$

Banks

Problem for bank $j \in [0,1]$ w/ earnings $e_{j,t}$, conditional on no run

$$\underbrace{V_t^k(e_{j,t})}_{\text{current mkt value}} = \max_{b_{j,t},d_{j,t}} \left\{ \underbrace{(1-\theta)e_{j,t}}_{\text{dividend}} + \underbrace{\mathbb{E}_t \left[\frac{\Lambda^s_{t,t+1}}{\Pi_{t+1}} \max\left\{0, V^k_{t+1}(e_{j,t+1})\right\} \right]}_{\text{ex-dividend value, } = \Phi_{j,t} e_{j,t}} \right\}$$

subject to

$$\text{balance sheet}: Q_t^b b_{j,t} = \theta e_{j,t} + Q_t^d d_{j,t}$$

$$\text{capital req.}: \kappa_t Q_t^b b_{j,t} \leq \Phi_{j,t} e_{j,t}$$

$$\text{LoM earnings}: e_{j,t+1} = (R^b_{t+1} b_{j,t} - d_{j,t})/\Pi_{t+1}$$

Banks

Problem for bank $j \in [0,1]$ w/ earnings $e_{j,t}$, conditional on no run

$$\underbrace{V_t^k(e_{j,t})}_{\text{current mkt value}} = \max_{b_{j,t}, d_{j,t}} \left\{ \underbrace{(1-\theta)e_{j,t}}_{\text{dividend}} + \underbrace{\mathbb{E}_t \left[\frac{\Lambda^s_{t,t+1}}{\Pi_{t+1}} \max\left\{0, V^k_{t+1}(e_{j,t+1})\right\} \right]}_{\text{ex-dividend value, } = \Phi_{j,t} e_{j,t}} \right\}$$

subject to

$$\begin{aligned} \text{balance sheet} &: Q_t^b b_{j,t} = \theta e_{j,t} + Q_t^d d_{j,t} \\ \text{capital req.} &: \kappa_t Q_t^b b_{j,t} \leq \Phi_{j,t} e_{j,t} \\ \text{LoM earnings} &: e_{j,t+1} = (R^b_{t+1} b_{j,t} - d_{j,t})/\Pi_{t+1} \end{aligned}$$

Bank Runs and Aggregation

- Bank defaults if

$$e_{j,t} < 0 \Leftrightarrow R_t^b b_{j,t-1} - d_{j,t-1} < 0$$

- Failure: assets sold at liquidation cost λ^d, paid to depositors
- Run possible if bank solvent but illiquid

$$R_t^b b_{j,t-1} - d_{j,t-1} \geq 0$$
$$(1-\lambda^d) R_t^b b_{j,t-1} - d_{j,t-1} < 0$$

- Multiplicity resolved with sunspot, $\omega_t = 1$ w.p. p
- Run indicator: $x_t = 1$
- **Aggregation**: representative bank w/. capital equal to

$$E_t = (1-x_t)\theta \Pi_t^{-1} \left(R_t^b B_{t-1} - D_{t-1} \right) + \varpi Q_t^b \Pi_t^{-1} B_{t-1}$$

- Define

$$u_t^D \equiv \frac{D_{t-1}}{R_t^b B_{t-1}} < \frac{D_{t-1}}{(1-\lambda^d) R_t^b B_{t-1}} \equiv u_t^R$$

▸ bank optimality

Bank Runs and Aggregation

- Bank defaults if

$$e_{j,t} < 0 \Leftrightarrow R_t^b b_{j,t-1} - d_{j,t-1} < 0$$

- Failure: assets sold at liquidation cost λ^d, paid to depositors
- Run possible if bank solvent but illiquid

$$R_t^b b_{j,t-1} - d_{j,t-1} \geq 0$$
$$(1-\lambda^d) R_t^b b_{j,t-1} - d_{j,t-1} < 0$$

- Multiplicity resolved with sunspot, $\omega_t = 1$ w.p. p
- Run indicator: $x_t = 1$
- **Aggregation**: representative bank w/. capital equal to

$$E_t = (1 - x_t)\theta \Pi_t^{-1} \left(R_t^b B_{t-1} - D_{t-1} \right) + \varpi Q_t^b \Pi_t^{-1} B_{t-1}$$

- Define

$$u_t^D \equiv \frac{D_{t-1}}{R_t^b B_{t-1}} < \frac{D_{t-1}}{(1-\lambda^d) R_t^b B_{t-1}} \equiv u_t^R$$

▸ bank optimality

Bank Runs and Aggregation

- Bank defaults if

$$e_{j,t} < 0 \Leftrightarrow R_t^b b_{j,t-1} - d_{j,t-1} < 0$$

- Failure: assets sold at liquidation cost λ^d, paid to depositors
- Run possible if bank solvent but illiquid

$$R_t^b b_{j,t-1} - d_{j,t-1} \geq 0$$
$$(1-\lambda^d) R_t^b b_{j,t-1} - d_{j,t-1} < 0$$

- Multiplicity resolved with sunspot, $\omega_t = 1$ w.p. p
- Run indicator: $x_t = 1$
- **Aggregation**: representative bank w/. capital equal to

$$E_t = (1-x_t)\theta \Pi_t^{-1} \left(R_t^b B_{t-1} - D_{t-1} \right) + \varpi Q_t^b \Pi_t^{-1} B_{t-1}$$

- Define

$$u_t^D \equiv \frac{D_{t-1}}{R_t^b B_{t-1}} < \frac{D_{t-1}}{(1-\lambda^d) R_t^b B_{t-1}} \equiv u_t^R$$

▸ bank optimality

Bank Runs and Aggregation

- Bank defaults if

$$e_{j,t} < 0 \Leftrightarrow R^b_t b_{j,t-1} - d_{j,t-1} < 0$$

- Failure: assets sold at liquidation cost λ^d, paid to depositors
- Run possible if bank solvent but illiquid

$$R^b_t b_{j,t-1} - d_{j,t-1} \geq 0$$
$$(1-\lambda^d) R^b_t b_{j,t-1} - d_{j,t-1} < 0$$

- Multiplicity resolved with sunspot, $\omega_t = 1$ w.p. p
- Run indicator: $x_t = 1$
- **Aggregation**: representative bank w/. capital equal to

$$E_t = (1-x_t)\theta\Pi_t^{-1}\left(R^b_t B_{t-1} - D_{t-1}\right) + \varpi Q^b_t \Pi_t^{-1} B_{t-1}$$

- Define

$$u^D_t \equiv \frac{D_{t-1}}{R^b_t B_{t-1}} < \frac{D_{t-1}}{(1-\lambda^d)R^b_t B_{t-1}} \equiv u^R_t$$

▸ bank optimality

Bank Runs and Aggregation

- Bank defaults if

$$e_{j,t} < 0 \Leftrightarrow R_t^b b_{j,t-1} - d_{j,t-1} < 0$$

- Failure: assets sold at liquidation cost λ^d, paid to depositors
- Run possible if bank solvent but illiquid

$$R_t^b b_{j,t-1} - d_{j,t-1} \geq 0$$
$$(1-\lambda^d) R_t^b b_{j,t-1} - d_{j,t-1} < 0$$

- Multiplicity resolved with sunspot, $\omega_t = 1$ w.p. p
- Run indicator: $x_t = 1$
- **Aggregation**: representative bank w/. capital equal to

$$E_t = (1-x_t)\theta \Pi_t^{-1} \left(R_t^b B_{t-1} - D_{t-1} \right) + \varpi Q_t^b \Pi_t^{-1} B_{t-1}$$

- Define

$$u_t^D \equiv \frac{D_{t-1}}{R_t^b B_{t-1}} < \frac{D_{t-1}}{(1-\lambda^d) R_t^b B_{t-1}} \equiv u_t^R$$

▸ bank optimality

Bank Runs and Aggregation

- Bank defaults if

$$e_{j,t} < 0 \Leftrightarrow R_t^b b_{j,t-1} - d_{j,t-1} < 0$$

- Failure: assets sold at liquidation cost λ^d, paid to depositors
- Run possible if bank solvent but illiquid

$$R_t^b b_{j,t-1} - d_{j,t-1} \geq 0$$
$$(1-\lambda^d) R_t^b b_{j,t-1} - d_{j,t-1} < 0$$

- Multiplicity resolved with sunspot, $\omega_t = 1$ w.p. p
- Run indicator: $x_t = 1$
- **Aggregation**: representative bank w/. capital equal to

$$E_t = (1 - x_t)\theta \Pi_t^{-1} \left(R_t^b B_{t-1} - D_{t-1} \right) + \varpi Q_t^b \Pi_t^{-1} B_{t-1}$$

- Define

$$u_t^D \equiv \frac{D_{t-1}}{R_t^b B_{t-1}} < \frac{D_{t-1}}{(1-\lambda^d) R_t^b B_{t-1}} \equiv u_t^R$$

▸ bank optimality

Bank Runs and Aggregation

- Bank defaults if

$$e_{j,t} < 0 \Leftrightarrow R_t^b b_{j,t-1} - d_{j,t-1} < 0$$

- Failure: assets sold at liquidation cost λ^d, paid to depositors
- Run possible if bank solvent but illiquid

$$R_t^b b_{j,t-1} - d_{j,t-1} \geq 0$$
$$(1-\lambda^d) R_t^b b_{j,t-1} - d_{j,t-1} < 0$$

- Multiplicity resolved with sunspot, $\omega_t = 1$ w.p. p
- Run indicator: $x_t = 1$
- **Aggregation**: representative bank w/. capital equal to

$$E_t = (1-x_t)\theta \Pi_t^{-1} \left(R_t^b B_{t-1} - D_{t-1} \right) + \varpi Q_t^b \Pi_t^{-1} B_{t-1}$$

- Define

$$u_t^D \equiv \frac{D_{t-1}}{R_t^b B_{t-1}} < \frac{D_{t-1}}{(1-\lambda^d) R_t^b B_{t-1}} \equiv u_t^R$$

bank optimality

Closing the Model

Standard DSGE model w/ nominal rigidities

- Producers $\rightarrow$ Phillips Curve ▸ producers
- Savers $\rightarrow$ Euler Equation (IS) ▸ savers
- Housing in fixed supply,

$$h_t = 1$$

- Central Bank $\rightarrow$ Taylor Rule

$$\frac{1}{Q_t} = \frac{1}{\bar{Q}} \left[\frac{\Pi_t}{\Pi}\right]^{\phi_\pi} \left[\frac{Y_t}{Y}\right]^{\phi_y} \mu_t$$

- Aggregate resource constraint,

$$C_t + \bar{G} + \text{DWL Default}_t = \underbrace{A_t N_t}_{=Y_t} \underbrace{[1 - d(\Pi_t)]}_{\text{Menu Costs}}$$

Closing the Model

Standard DSGE model w/ nominal rigidities

- Producers → Phillips Curve ▸ producers
- Savers → Euler Equation (IS) ▸ savers
- Housing in fixed supply,

$$h_t = 1$$

- Central Bank → Taylor Rule

$$\frac{1}{Q_t} = \frac{1}{\bar{Q}} \left[\frac{\Pi_t}{\Pi}\right]^{\phi_\pi} \left[\frac{Y_t}{Y}\right]^{\phi_y} \mu_t$$

- Aggregate resource constraint,

$$C_t + \bar{G} + \text{DWL Default}_t = \underbrace{A_t N_t}_{=Y_t} \underbrace{[1 - d(\Pi_t)]}_{\text{Menu Costs}}$$

Closing the Model

Standard DSGE model w/ nominal rigidities

- Producers → Phillips Curve ▸ producers
- Savers → Euler Equation (IS) ▸ savers
- Housing in fixed supply,
$$h_t = 1$$
- Central Bank → Taylor Rule
$$\frac{1}{Q_t} = \frac{1}{\bar{Q}} \left[\frac{\Pi_t}{\Pi}\right]^{\phi_\pi} \left[\frac{Y_t}{Y}\right]^{\phi_y} \mu_t$$
- Aggregate resource constraint,
$$C_t + \bar{G} + \text{DWL Default}_t = \underbrace{A_t N_t}_{=Y_t} \underbrace{[1 - d(\Pi_t)]}_{\text{Menu Costs}}$$

Closing the Model

Standard DSGE model w/ nominal rigidities

- Producers $\rightarrow$ Phillips Curve ▸ producers
- Savers $\rightarrow$ Euler Equation (IS) ▸ savers
- Housing in fixed supply,
$$h_t = 1$$
- Central Bank $\rightarrow$ Taylor Rule
$$\frac{1}{Q_t} = \frac{1}{\bar{Q}} \left[\frac{\Pi_t}{\Pi}\right]^{\phi_\pi} \left[\frac{Y_t}{Y}\right]^{\phi_y} \mu_t$$
- Aggregate resource constraint,
$$C_t + \bar{G} + \text{DWL Default}_t = \underbrace{A_t N_t}_{=Y_t} \underbrace{[1 - d(\Pi_t)]}_{\text{Menu Costs}}$$

Closing the Model

Standard DSGE model w/ nominal rigidities

- Producers $\rightarrow$ Phillips Curve ▸ producers
- Savers $\rightarrow$ Euler Equation (IS) ▸ savers
- Housing in fixed supply,

$$h_t = 1$$

- Central Bank $\rightarrow$ Taylor Rule

$$\frac{1}{Q_t} = \frac{1}{\bar{Q}} \left[\frac{\Pi_t}{\Pi}\right]^{\phi_\pi} \left[\frac{Y_t}{Y}\right]^{\phi_y} \mu_t$$

- Aggregate resource constraint,

$$C_t + \bar{G} + \text{DWL Default}_t = \underbrace{A_t N_t}_{=Y_t} \underbrace{[1 - d(\Pi_t)]}_{\text{Menu Costs}}$$

Crises and Propagation

- **Amplification**: double financial accelerator + default
- Run triggers demand-driven recession (Eggertsson & Krugman, 2012; Mian & Sufi, 2012)
  1. Bank capital collapses: lending $\downarrow$, spreads $\uparrow$
  2. Borrower constraint starts binding, MPC $\uparrow$
  3. Lending $\downarrow$, spreads $\uparrow$ $\Rightarrow$ disposable income $\downarrow$ $\Rightarrow$consumption $\downarrow$
  4. consumption $\downarrow$ house prices $\downarrow$ (through SDF) $\Rightarrow$ defaults $\uparrow$
  5. Persistent defaults further hamper bank capital
- **Nominal rigidities**: borrower consumption $\downarrow$ $\Rightarrow$ GDP $\downarrow$

calibration

Crises and Propagation

- **Amplification**: double financial accelerator + default
- Run triggers demand-driven recession (Eggertsson & Krugman, 2012; Mian & Sufi, 2012)
  1. Bank capital collapses: lending $\downarrow$, spreads $\uparrow$
  2. Borrower constraint starts binding, MPC $\uparrow$
  3. Lending $\downarrow$, spreads $\uparrow$ $\Rightarrow$ disposable income $\downarrow$ $\Rightarrow$consumption $\downarrow$
  4. consumption $\downarrow$ house prices $\downarrow$ (through SDF) $\Rightarrow$ defaults $\uparrow$
  5. Persistent defaults further hamper bank capital
- **Nominal rigidities**: borrower consumption $\downarrow$ $\Rightarrow$ GDP $\downarrow$

calibration

Crises and Propagation

- **Amplification**: double financial accelerator + default
- Run triggers demand-driven recession (Eggertsson & Krugman, 2012; Mian & Sufi, 2012)
  1. Bank capital collapses: lending ↓, spreads ↑
  2. Borrower constraint starts binding, MPC ↑
  3. Lending ↓, spreads ↑ ⇒ disposable income ↓ ⇒consumption ↓
  4. consumption ↓ house prices ↓ (through SDF) ⇒ defaults ↑
  5. Persistent defaults further hamper bank capital
- **Nominal rigidities**: borrower consumption ↓ ⇒ GDP ↓

▸ calibration

Crises and Propagation

- **Amplification**: double financial accelerator + default
- Run triggers demand-driven recession (Eggertsson & Krugman, 2012; Mian & Sufi, 2012)
  1. Bank capital collapses: lending $\downarrow$, spreads $\uparrow$
  2. Borrower constraint starts binding, MPC $\uparrow$
  3. Lending $\downarrow$, spreads $\uparrow$ $\Rightarrow$ disposable income $\downarrow$ $\Rightarrow$consumption $\downarrow$
  4. consumption $\downarrow$ house prices $\downarrow$ (through SDF) $\Rightarrow$ defaults $\uparrow$
  5. Persistent defaults further hamper bank capital
- **Nominal rigidities**: borrower consumption $\downarrow$ $\Rightarrow$ GDP $\downarrow$

calibration

Crises and Propagation

- **Amplification**: double financial accelerator + default
- Run triggers demand-driven recession (Eggertsson & Krugman, 2012; Mian & Sufi, 2012)
  1. Bank capital collapses: lending $\downarrow$, spreads $\uparrow$
  2. Borrower constraint starts binding, MPC $\uparrow$
  3. Lending $\downarrow$, spreads $\uparrow$ $\Rightarrow$ disposable income $\downarrow$ $\Rightarrow$consumption $\downarrow$
  4. consumption $\downarrow$ house prices $\downarrow$ (through SDF) $\Rightarrow$ defaults $\uparrow$
  5. Persistent defaults further hamper bank capital
- **Nominal rigidities**: borrower consumption $\downarrow$ $\Rightarrow$ GDP $\downarrow$

calibration

Crises and Propagation

- **Amplification**: double financial accelerator + default
- Run triggers demand-driven recession (Eggertsson & Krugman, 2012; Mian & Sufi, 2012)
  1. Bank capital collapses: lending $\downarrow$, spreads $\uparrow$
  2. Borrower constraint starts binding, MPC $\uparrow$
  3. Lending $\downarrow$, spreads $\uparrow$ $\Rightarrow$ disposable income $\downarrow$ $\Rightarrow$consumption $\downarrow$
  4. consumption $\downarrow$ house prices $\downarrow$ (through SDF) $\Rightarrow$ defaults $\uparrow$
  5. Persistent defaults further hamper bank capital
- **Nominal rigidities**: borrower consumption $\downarrow$ $\Rightarrow$ GDP $\downarrow$

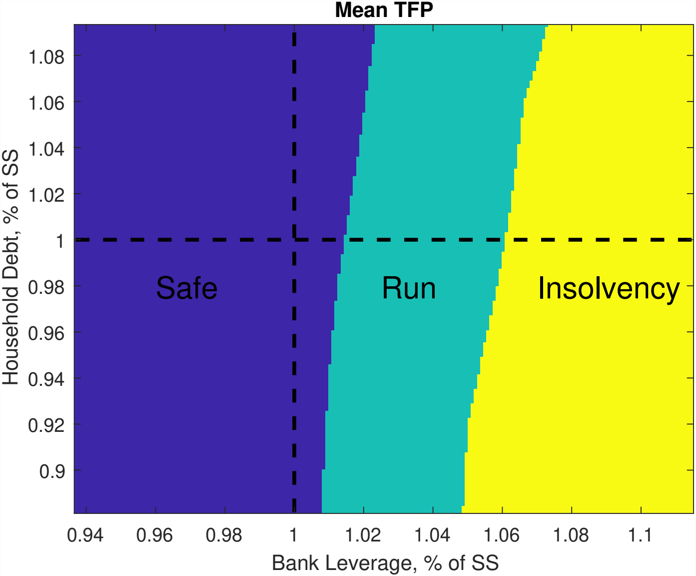
calibration

Crises and Propagation

- **Amplification**: double financial accelerator + default
- Run triggers demand-driven recession (Eggertsson & Krugman, 2012; Mian & Sufi, 2012)
    1. Bank capital collapses: lending $\downarrow$, spreads $\uparrow$
    2. Borrower constraint starts binding, MPC $\uparrow$
    3. Lending $\downarrow$, spreads $\uparrow$ $\Rightarrow$ disposable income $\downarrow$ $\Rightarrow$consumption $\downarrow$
    4. consumption $\downarrow$ house prices $\downarrow$ (through SDF) $\Rightarrow$ defaults $\uparrow$
    5. Persistent defaults further hamper bank capital
- **Nominal rigidities**: borrower consumption $\downarrow$ $\Rightarrow$ GDP $\downarrow$

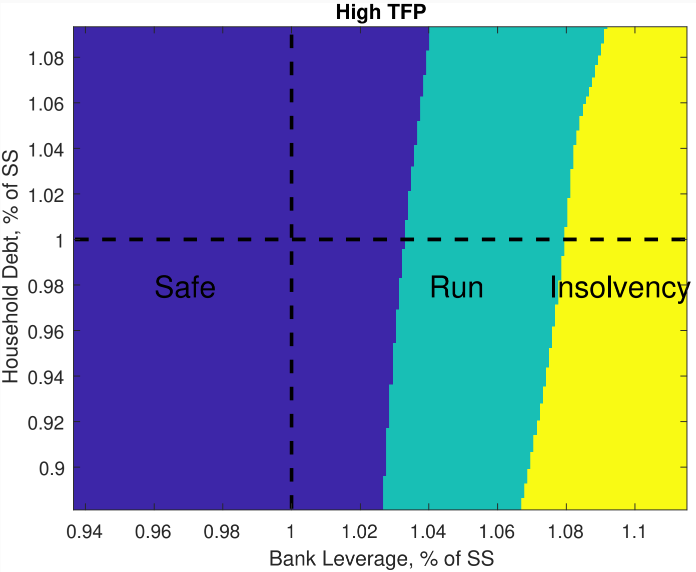
calibration

Run Regions: Average TFP



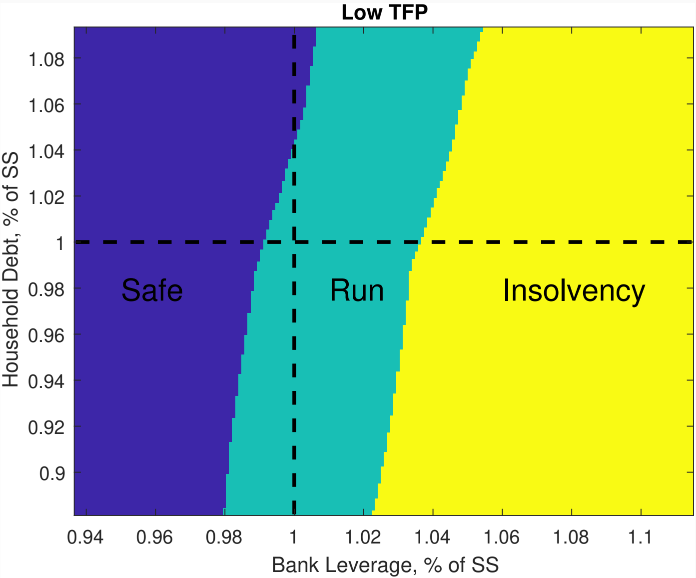
Safe, Run, and Insolvency regions

Run Regions: High TFP



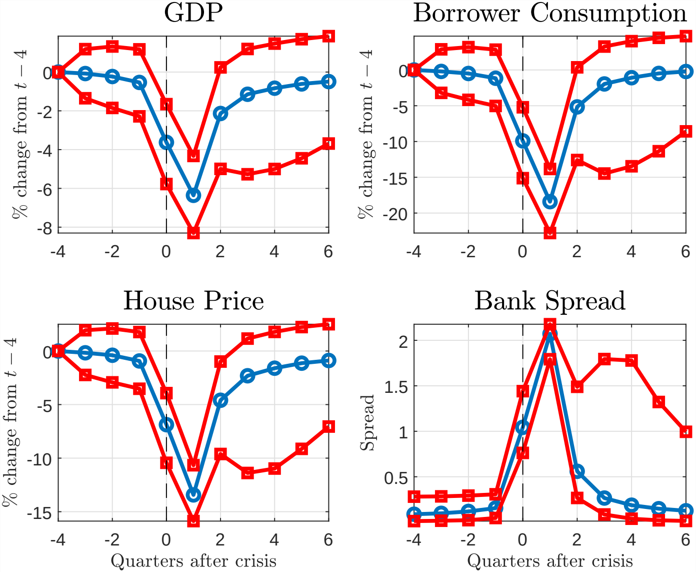
Safe, Run, and Insolvency regions

Run Regions: Low TFP



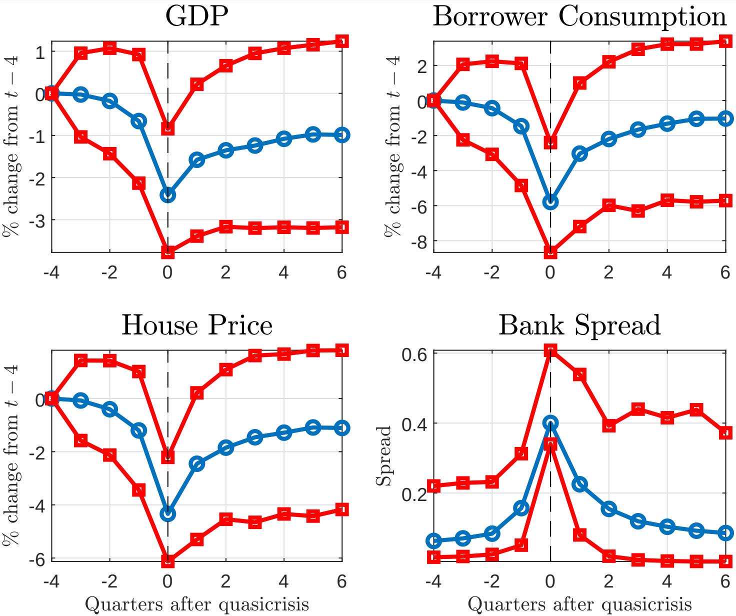
Safe, Run, and Insolvency regions

Typical Financial Crisis



▸ path to the crisis

Almost-Crisis



CCyB Implementation

- Benchmark capital requirement $\bar{\kappa} = 8.5\%$ (MCR + CCB)
- US CCyB implementation range: $[0, 2.5\%]$
- Allow regulator to:
  - Raise CRs if run is likely
  - Lower CRs if run is under way

$$\kappa_t = \begin{cases} \bar{\kappa} + 2.5\%, & \text{for } u_t^R \geq 1, \omega_t = 0 \\ \bar{\kappa}, & \text{for } u_t^R < 1 \\ \bar{\kappa} - 2.5\%, & \text{for } u_t^R \geq 1, \omega_t = 1 \end{cases}$$

Effects summarized in bank FOC:

$$\mathbb{E}_t \left[\underbrace{\Omega_{t+1}}_{\text{SDF: future const.}} \overbrace{(1 - x_{t+1})}^{\text{future runs}} \underbrace{\left(\frac{R_{t+1}^b}{Q_t^b} - \frac{1}{Q_t^d} \right)}_{\text{asset returns}} \right] = \kappa_t \mu_t$$

CCyB Implementation

- Benchmark capital requirement $\bar{\kappa} = 8.5\%$ (MCR + CCB)
- US CCyB implementation range: $[0, 2.5\%]$
- Allow regulator to:
  - Raise CRs if run is likely
  - Lower CRs if run is under way

$$\kappa_t = \begin{cases} \bar{\kappa} + 2.5\%, & \text{for } u_t^R \geq 1, \omega_t = 0 \\ \bar{\kappa}, & \text{for } u_t^R < 1 \\ \bar{\kappa} - 2.5\%, & \text{for } u_t^R \geq 1, \omega_t = 1 \end{cases}$$

Effects summarized in bank FOC:

$$\mathbb{E}_t \left[\underbrace{\Omega_{t+1}}_{\text{SDF: future const.}} \overbrace{(1 - x_{t+1})}^{\text{future runs}} \underbrace{\left(\frac{R_{t+1}^b}{Q_t^b} - \frac{1}{Q_t^d} \right)}_{\text{asset returns}} \right] = \kappa_t \mu_t$$

CCyB Implementation

- Benchmark capital requirement $\bar{\kappa} = 8.5\%$ (MCR + CCB)
- US CCyB implementation range: $[0, 2.5\%]$
- Allow regulator to:
  - Raise CRs if run is likely
  - Lower CRs if run is under way

$$\kappa_t = \begin{cases} \bar{\kappa} + 2.5\%, & \text{for } u_t^R \geq 1, \omega_t = 0 \\ \bar{\kappa}, & \text{for } u_t^R < 1 \\ \bar{\kappa} - 2.5\%, & \text{for } u_t^R \geq 1, \omega_t = 1 \end{cases}$$

Effects summarized in bank FOC:

$$\mathbb{E}_t \left[\underbrace{\Omega_{t+1}}_{\text{SDF: future const.}} \overbrace{(1 - x_{t+1})}^{\text{future runs}} \underbrace{\left(\frac{R_{t+1}^b}{Q_t^b} - \frac{1}{Q_t^d} \right)}_{\text{asset returns}} \right] = \kappa_t \mu_t$$

CCyB Implementation

- Benchmark capital requirement $\bar{\kappa} = 8.5\%$ (MCR + CCB)
- US CCyB implementation range: $[0, 2.5\%]$
- Allow regulator to:
  - Raise CRs if run is likely
  - Lower CRs if run is under way

$$\kappa_t = \begin{cases} \bar{\kappa} + 2.5\%, & \text{for } u_t^R \geq 1, \omega_t = 0 \\ \bar{\kappa}, & \text{for } u_t^R < 1 \\ \bar{\kappa} - 2.5\%, & \text{for } u_t^R \geq 1, \omega_t = 1 \end{cases}$$

Effects summarized in bank FOC:

$$\mathbb{E}_t \left[\underbrace{\Omega_{t+1}}_{\text{SDF: future const.}} \overbrace{(1 - x_{t+1})}^{\text{future runs}} \underbrace{\left(\frac{R_{t+1}^b}{Q_t^b} - \frac{1}{Q_t^d} \right)}_{\text{asset returns}} \right] = \kappa_t \mu_t$$

CCyB Implementation

- Benchmark capital requirement $\bar{\kappa} = 8.5\%$ (MCR + CCB)
- US CCyB implementation range: $[0, 2.5\%]$
- Allow regulator to:
    - Raise CRs if run is likely
    - Lower CRs if run is under way

$$\kappa_t = \begin{cases} \bar{\kappa} + 2.5\%, & \text{for } u_t^R \geq 1, \omega_t = 0 \\ \bar{\kappa}, & \text{for } u_t^R < 1 \\ \bar{\kappa} - 2.5\%, & \text{for } u_t^R \geq 1, \omega_t = 1 \end{cases}$$

Effects summarized in bank FOC:

$$\mathbb{E}_t \left[\underbrace{\Omega_{t+1}}_{\text{SDF: future const.}} \overbrace{(1 - x_{t+1})}^{\text{future runs}} \underbrace{\left(\frac{R_{t+1}^b}{Q_t^b} - \frac{1}{Q_t^d} \right)}_{\text{asset returns}} \right] = \kappa_t \mu_t$$

CCyB Implementation

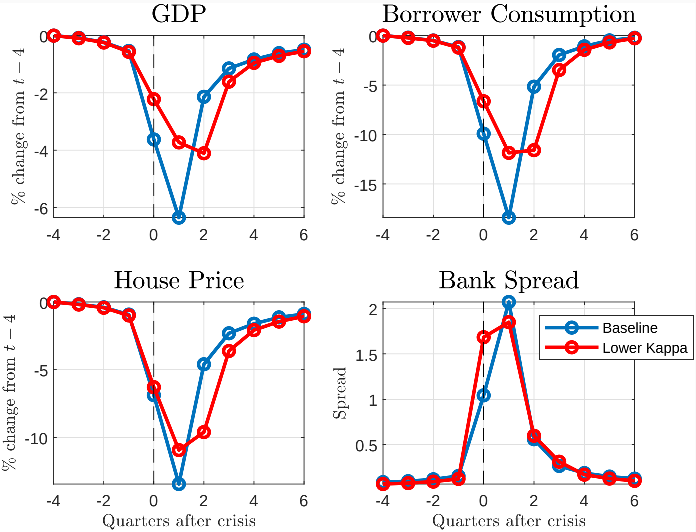
- Benchmark capital requirement $\bar{\kappa} = 8.5\%$ (MCR + CCB)
- US CCyB implementation range: $[0, 2.5\%]$
- Allow regulator to:
  - Raise CRs if run is likely
  - Lower CRs if run is under way

$$\kappa_t = \begin{cases} \bar{\kappa} + 2.5\%, & \text{for } u_t^R \geq 1, \omega_t = 0 \\ \bar{\kappa}, & \text{for } u_t^R < 1 \\ \bar{\kappa} - 2.5\%, & \text{for } u_t^R \geq 1, \omega_t = 1 \end{cases}$$

Effects summarized in bank FOC:

$$\mathbb{E}_t \left[\underbrace{\Omega_{t+1}}_{\text{SDF: future const.}} \overbrace{(1 - x_{t+1})}^{\text{future runs}} \underbrace{\left(\frac{R_{t+1}^b}{Q_t^b} - \frac{1}{Q_t^d} \right)}_{\text{asset returns}} \right] = \kappa_t \mu_t$$

Lowering CCyB (ex-post)



Raising CCyB (ex-ante)

Variable	No Policy	Ex-post Policy	Ex-ante Policy
$100 \times \Pr(x_t = 1)$	1.81	1.20	0.56
Bank Leverage	8.22	8.30	6.97
Lagrange Multiplier Borrower	0.12	0.13	0
Median % Δ GDP in Crisis	-5.82	-3.16	-4.99

Ex-ante policy:

- Amplifies precautionary motives for borrowers and banks
- Lower bank leverage $\Rightarrow$ lower run probability
- Lower leverage upon entering crisis $\Rightarrow$ less severe crisis

Could CCyB have helped in 2008?

1. Estimate structural shocks $\{A_t, \mu_t, \omega_t\}_{t=0}^{T}$

   - Make model match observables given $\kappa_t = \bar{\kappa}$
   - Sample: 2000Q1 - 2015Q4
   - Observables $\{\mathcal{Y}_t\}_{t=0}^{T} \equiv \{C_t, \text{TED spread}_t\}_{t=0}^{T}$ ▸ Macro Data
   - Use particle filter to estimate

   $$\{\hat{p}(A_t, \mu_t, \omega_t | \mathcal{Y}^T)\}_{t=0}^{T}$$

   (Fernández-Villaverde and Rubio-Ramírez, 2007) ▸ Particle Filter details

2. Use resulting estimates $\{\hat{A}_t, \hat{\mu}_t, \hat{\omega}_t\}_{t=0}^{T}$ to study counterfactuals

   - What if regulator could have adjusted κ_t?

▸ Filtered Shocks, ▸ Filtered Consumption ▸ Filtered Spread ▸ other variables

Could CCyB have helped in 2008?

1. Estimate structural shocks $\{A_t, \mu_t, \omega_t\}_{t=0}^T$
   - Make model match observables given $\kappa_t = \bar{\kappa}$
   - Sample: 2000Q1 - 2015Q4
   - Observables $\{\mathcal{Y}_t\}_{t=0}^T \equiv \{C_t, \text{TED spread}_t\}_{t=0}^T$ ▸ Macro Data
   - Use particle filter to estimate

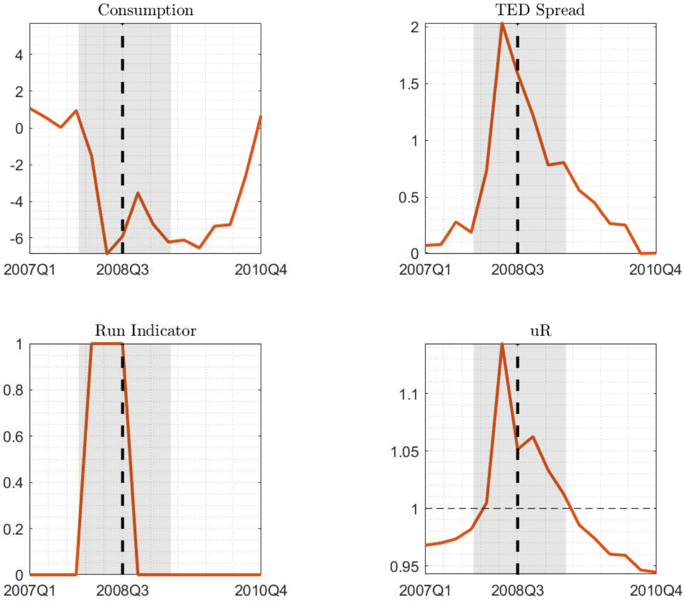
$$\{\hat{p}(A_t, \mu_t, \omega_t | \mathcal{Y}^T)\}_{t=0}^T$$

   (Fernández-Villaverde and Rubio-Ramírez, 2007) ▸ Particle Filter details

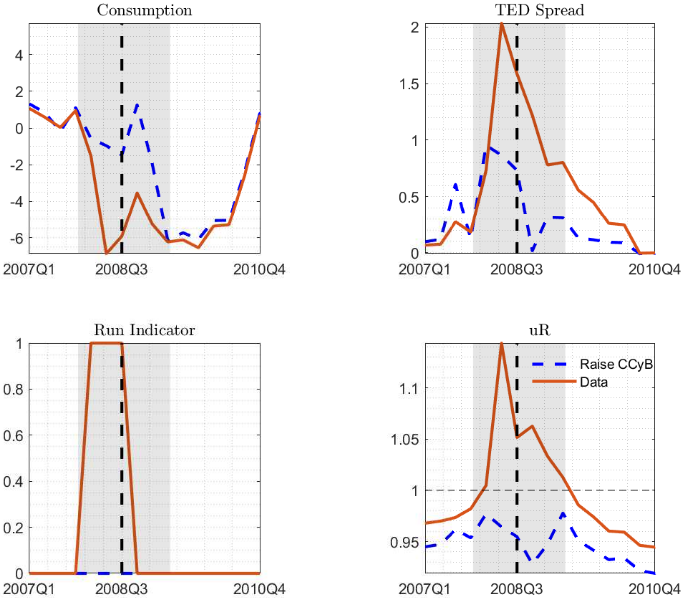
2. Use resulting estimates $\{\hat{A}_t, \hat{\mu}_t, \hat{\omega}_t\}_{t=0}^T$ to study counterfactuals
   - What if regulator could have adjusted κ_t?

▸ Filtered Shocks, ▸ Filtered Consumption ▸ Filtered Spread ▸ other variables

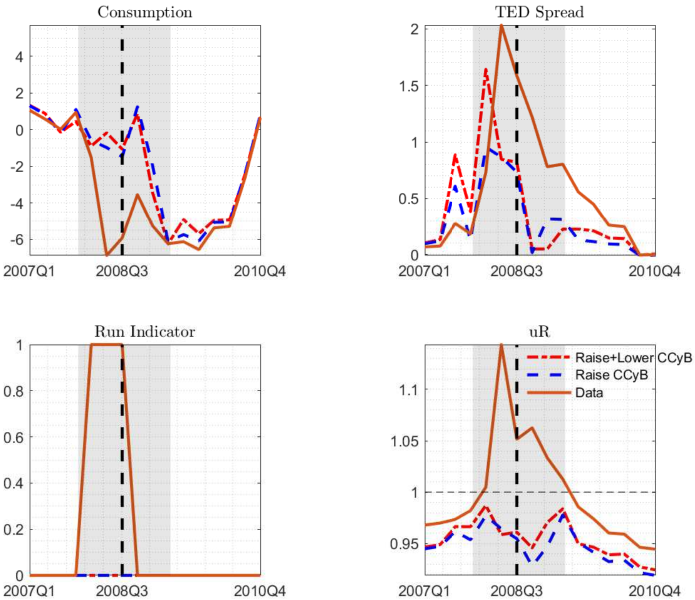
Crisis of 2007-2008, No Policy



Crisis of 2007-2008, Raising CCyB



Crisis of 2007-2008, Raising + Lowering CCyB



Summary of Results

- CCyB could have prevented bank run in 2007-08
  - but not Great Recession
  - GR mostly driven by TFP shocks
  - CCyB could have helped with "soft landing"
- **Quantifying Results**: define the consumption gap

$$\mathcal{G} = \sum_{t=2007Q1}^{T=2010Q4} \frac{C_t^{\text{CCyB}} - C_t^{\text{data}}}{C_{2007Q1}^{\text{data}}}$$

	$\mathcal{G}$	$\mathcal{G} \times C_{2007Q1}^{\text{data}}$
Raise CCyB	21.7%	\$ 2,294.4 bn
Raise+Lower CCyB	21.5%	\$ 2,271.4 bn

Summary of Results

- CCyB could have prevented bank run in 2007-08
  - but not Great Recession
  - GR mostly driven by TFP shocks
  - CCyB could have helped with "soft landing"
- **Quantifying Results**: define the consumption gap

$$\mathcal{G} = \sum_{t=2007Q1}^{T=2010Q4} \frac{C_t^{\text{CCyB}} - C_t^{\text{data}}}{C_{2007Q1}^{\text{data}}}$$

	$\mathcal{G}$	$\mathcal{G} \times C_{2007Q1}^{\text{data}}$
Raise CCyB	21.7%	\$ 2,294.4 bn
Raise+Lower CCyB	21.5%	\$ 2,271.4 bn

Summary of Results

- CCyB could have prevented bank run in 2007-08
  - but not Great Recession
  - GR mostly driven by TFP shocks
  - CCyB could have helped with "soft landing"
- **Quantifying Results**: define the consumption gap

$$\mathcal{G} = \sum_{t=2007Q1}^{T=2010Q4} \frac{C_t^{\text{CCyB}} - C_t^{\text{data}}}{C_{2007Q1}^{\text{data}}}$$

	$\mathcal{G}$	$\mathcal{G} \times C_{2007Q1}^{\text{data}}$
Raise CCyB	21.7%	\$ 2,294.4 bn
Raise+Lower CCyB	21.5%	\$ 2,271.4 bn

Summary of Results

- CCyB could have prevented bank run in 2007-08
  - but not Great Recession
  - GR mostly driven by TFP shocks
  - CCyB could have helped with "soft landing"
- **Quantifying Results**: define the consumption gap

$$\mathcal{G} = \sum_{t=2007Q1}^{T=2010Q4} \frac{C_t^{\text{CCyB}} - C_t^{\text{data}}}{C_{2007Q1}^{\text{data}}}$$

	$\mathcal{G}$	$\mathcal{G} \times C_{2007Q1}^{\text{data}}$
Raise CCyB	21.7%	\$ 2,294.4 bn
Raise+Lower CCyB	21.5%	\$ 2,271.4 bn

Conclusion

This Paper

- Quantitative analysis of CCyB in the 2008-09 financial crisis
- Structural Model + Data

CCyB

- Ex-ante benefits via off-equilibrium threat
- Could have mitigated financial panic in 2007-08
- Great Recession attributed to other (non-financial) shocks
- CCyB could have helped with "soft landing"

Conclusion

This Paper

- Quantitative analysis of CCyB in the 2008-09 financial crisis
- Structural Model + Data

CCyB

- Ex-ante benefits via off-equilibrium threat
- Could have mitigated financial panic in 2007-08
- Great Recession attributed to other (non-financial) shocks
- CCyB could have helped with “soft landing”

Full Borrower Family Problem

$$V_t^b(B_{t-1}^b, h_{t-1}) = \max_{c_t^b, n_t^b, h_t^{\text{new}}, B_t^{b,\text{new}}, \iota(\nu)} \left\{ u(c_t, n_t) + \xi^b \log(h_t) + \beta \mathbb{E}_t V_{t+1}^b(B_t^b, h_t) \right\}$$

subject to budget constraint

$$c_t^b + \underbrace{\frac{B_{t-1}^b}{\Pi_t}\left\{(1-\mathrm{m})\gamma + \mathrm{m}\int [1-\iota(\nu)]\mathrm{d}F^b(\nu)\right\}}_{\text{debt repayment}} + \underbrace{p_t h_t^{\text{new}}}_{\text{house purchase}} \leq$$

$$(1-\tau)w_t n_t^b + \underbrace{Q_t^b B_t^{b,\text{new}}}_{\text{new debt}} + \underbrace{\mathrm{m} p_t h_{t-1} \int \nu[1-\gamma\iota(\nu)]\mathrm{d}F^b(\nu)}_{\text{sale of non-forecl. houses}}$$

and borrowing constraint

$$B_t^{b,\text{new}} \leq \theta^{LTV} p_t h_t^{\text{new}}$$

back

Full Borrower Family Problem

$$V_t^b(B_{t-1}^b, h_{t-1}) = \max_{c_t^b, n_t^b, h_t^{\text{new}}, B_t^{b,\text{new}}, \iota(\nu)} \left\{ u(c_t, n_t) + \xi^b \log(h_t) + \beta \mathbb{E}_t V_{t+1}^b(B_t^b, h_t) \right\}$$

subject to budget constraint

$$c_t^b + \underbrace{\frac{B_{t-1}^b}{\Pi_t} \left\{ (1-\mathrm{m})\gamma + \mathrm{m} \int [1-\iota(\nu)] \mathrm{d}F^b(\nu) \right\}}_{\text{debt repayment}} + \underbrace{p_t h_t^{\text{new}}}_{\text{house purchase}} \leq$$

$$(1-\tau) w_t n_t^b + \underbrace{Q_t^b B_t^{b,\text{new}}}_{\text{new debt}} + \underbrace{\mathrm{m} p_t h_{t-1} \int \nu [1 - \gamma \iota(\nu)] \mathrm{d}F^b(\nu)}_{\text{sale of non-forecl. houses}}$$

and borrowing constraint

$$B_t^{b,\text{new}} \leq \theta^{LTV} p_t h_t^{\text{new}}$$

back

Full Borrower Family Problem

$$V_t^b(B_{t-1}^b, h_{t-1}) = \max_{c_t^b, n_t^b, h_t^{\text{new}}, B_t^{b,\text{new}}, \iota(\nu)} \left\{ u(c_t, n_t) + \xi^b \log(h_t) + \beta \mathbb{E}_t V_{t+1}^b(B_t^b, h_t) \right\}$$

subject to budget constraint

$$c_t^b + \underbrace{\frac{B_{t-1}^b}{\Pi_t} \left\{ (1-\mathrm{m})\gamma + \mathrm{m} \int [1-\iota(\nu)] \mathrm{d}F^b(\nu) \right\}}_{\text{debt repayment}} + \underbrace{p_t h_t^{\text{new}}}_{\text{house purchase}} \leq$$

$$(1-\tau) w_t n_t^b + \underbrace{Q_t^b B_t^{b,\text{new}}}_{\text{new debt}} + \underbrace{\mathrm{m} p_t h_{t-1} \int \nu [1 - \gamma \iota(\nu)] \mathrm{d}F^b(\nu)}_{\text{sale of non-forecl. houses}}$$

and borrowing constraint

$$B_t^{b,\text{new}} \leq \theta^{LTV} p_t h_t^{\text{new}}$$

back

Banks

- Asset prices:

$$\mathbb{E}_t\left[\frac{\Lambda_{t+1}}{\Pi_{t+1}}\underbrace{(1-x_{t+1})}_{\text{future runs}}\underbrace{(1-\theta+\theta\Phi_{t+1})}_{\text{future constraints}}\left(\frac{\overbrace{R^b_{t+1}}^{\text{credit risk}}}{Q^b_t}-\frac{1}{Q^d_t}\right)\right]=\underbrace{\kappa_t\mu_t}_{\text{current constraints}}$$

- Run risk also affects deposit rates

$$Q^d_t=\mathbb{E}_t\left[\frac{\Lambda_{t+1}}{\Pi_{t+1}}\left(1-x_{t+1}+x_{t+1}\frac{1}{u^R_{t+1}}\right)\right]$$

back

Banks

- Asset prices:

$$\mathbb{E}_t\left[\frac{\Lambda_{t+1}}{\Pi_{t+1}}\underbrace{(1-x_{t+1})}_{\text{future runs}}\underbrace{(1-\theta+\theta\Phi_{t+1})}_{\text{future constraints}}\left(\frac{\overbrace{R^b_{t+1}}^{\text{credit risk}}}{Q^b_t}-\frac{1}{Q^d_t}\right)\right]=\underbrace{\kappa_t\mu_t}_{\text{current constraints}}$$

- Run risk also affects deposit rates

$$Q^d_t=\mathbb{E}_t\left[\frac{\Lambda_{t+1}}{\Pi_{t+1}}\left(1-x_{t+1}+x_{t+1}\frac{1}{u^R_{t+1}}\right)\right]$$

back

Producers

- Hire labor and borrow to produce varieties $i \in [0,1]$

$$Y_t = \left[\int_0^1 Y_t(i)^{\frac{\varepsilon}{\varepsilon-1}} \mathrm{d}i\right]^{\frac{\varepsilon-1}{\varepsilon}}$$

- Owned by savers with SDF $\Lambda^s_{t,t+1}$
- Monopolistically competitive, Rotemberg menu costs

$$\text{Menu Costs}_t(i) = P_t Y_t \frac{\eta}{2}\left(\frac{P_t(i)}{P_{t-1}(i)\Pi} - 1\right)^2$$

Firm FOC + Symmetric Price Setting = Standard Phillips Curve

$$\frac{\Pi_t}{\bar{\Pi}}\left(\frac{\Pi_t}{\bar{\Pi}} - 1\right) = \mathbb{E}_t\left[\Lambda^s_{t,t+1}\frac{Y_{t+1}}{Y_t}\frac{\Pi_{t+1}}{\bar{\Pi}}\left(\frac{\Pi_{t+1}}{\bar{\Pi}} - 1\right)\right] + \frac{\varepsilon}{\eta}\left(\frac{\varepsilon-1}{\varepsilon} - \frac{w_t}{A_t}\right)$$

Back

Savers

- Invest in bank deposits at rate Q_t^d or government debt at rate Q_t
- Own all banks and firms, receive total profits Γ_t

$$V_t^s(D_{t-1}, B_{t-1}^g) = \max_{c_t^s, n_t^s, B_t^g, D_t} \left\{ u(c_t^s, n_t^s) + \beta \mathbb{E}_t V_{t+1}^s \right\}$$

s.t.

$$c_t^s + Q_t B_t^g + Q_t^d D_t \leq (1-\tau) w_t n_t^s + \frac{R_t^{\text{deposits}} D_{t-1} + B_{t-1}^g}{\Pi_t} + \Gamma_t - T_t$$

- Γ_t = net transfers from corporate and financial sectors

Back

Calibration

1. *Households*

Moment	Target	Parameter
Fraction Borrowers	Parker et al. (2013)	$\chi = 0.475$
Avg. Maturity	5 years	$\gamma = 1/20$
Max LTV Ratio	85%	$\underline{m} = 0.1160$
Debt/GDP	80%	$\xi = 0.0899$
Avg. Delinquency Rate	2%	$\sigma^b = 4.351$

2. *Banks*

Moment	Target	Parameter
Book Leverage	8	$\theta = 0.9179$
Capital Requirement	8.5%	$\kappa = 0.085$
Avg. Lending Spread	2%	$\varpi = 0.005$
Avg. TED Spread	0.2%	$\lambda^d = 0.10$
Prob. of Financial Crises	2.5%	$p = 0.10$

other parameters
TFP Shock
Solution Method

back to presentation

Calibration - Standard NK Parameters

Parameter	Description	Value	Target/Reason
β	Discount Factor	0.995	2% Real Rate
σ	Risk Aversion/EIS	1	Standard
φ	Frisch Elasticity	1	Standard
ε	CES	6	Mark-up $=$ 20%
η	Menu Cost	98.06	$\sim$ Calvo $= 0.80$
Π	Steady state Inflation	2% annual	U.S.
ϕ_Π	Taylor Rule Inflation	1.5	Standard
ϕ_Y	Taylor Rule GDP	0.5/4	Standard
λ^b, λ^d	Losses given default	$0.3, 0.1$	FDIC estimates

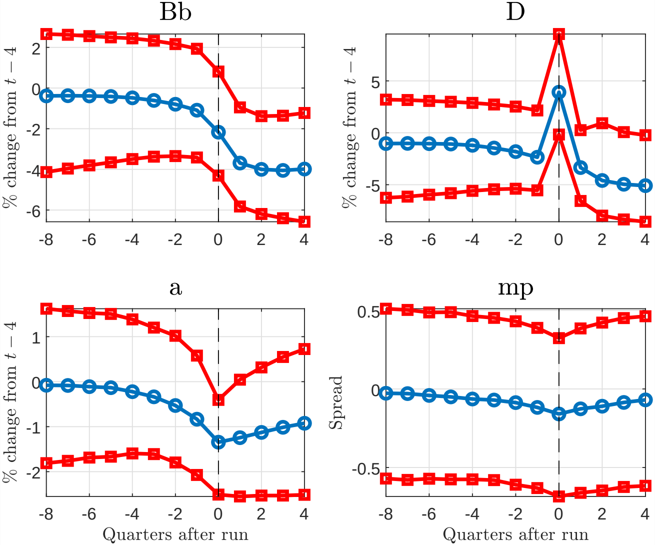
back

Model Solution

- Two occasionally binding constraints, aggregate shocks
- Collocation + Time Iteration (Judd, Kubler, and Schmedders, 2002)
  1. Discretize grid of states $(B^b_{t-1}, D_{t-1}, A_t, \mu_t, \omega_t)$
  2. Guess approximants for policy fcns. to evaluate expectations
  3. Solve for current policy fcns. at each gridpoint
  4. Update approximants using solution for current policies
- "Iterates backwards in time" until policies converge
- Challenging due to lack of well-established convergence results
- Garcia and Zangwill (1981) method to handle inequalities

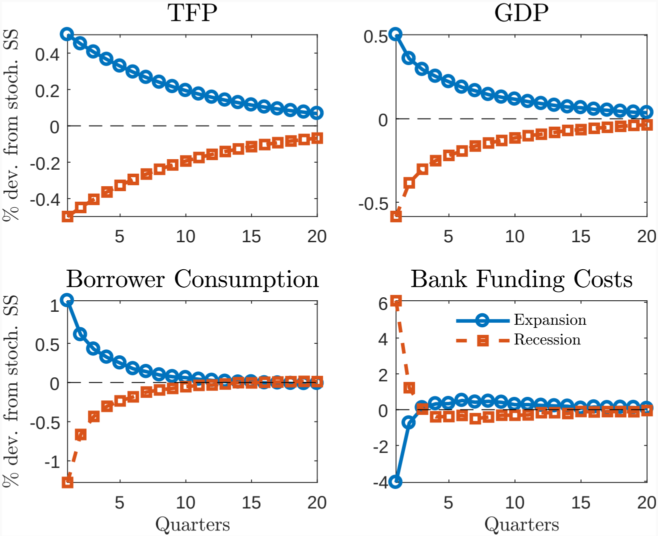
▸ back

Path to the Crisis



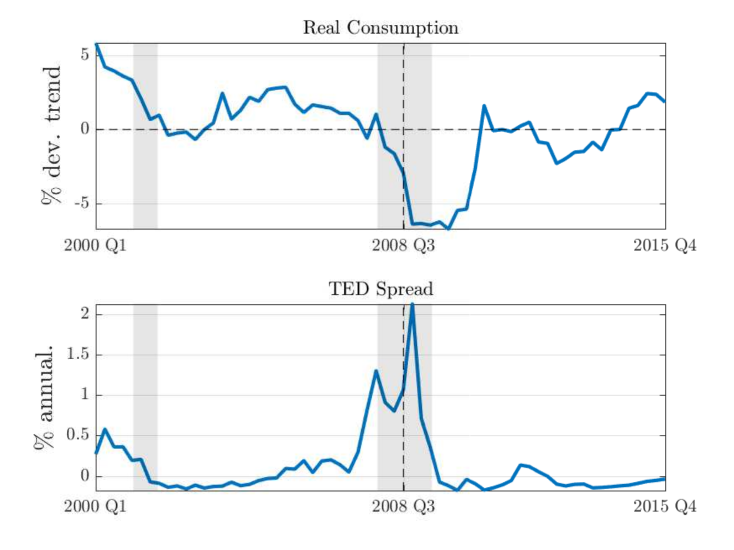
back

TFP Shock



Back

Data



Real Consumption
% dev. trend
5
0
-5
2000 Q1
2008 Q3
2015 Q4
TED Spread
% annual.
2
1.5
1
0.5
0
2000 Q1
2008 Q3
2015 Q4

back

Particle Smoother Algorithm

Model in state space form (w./ additive Gaussian measurement error)

$$
\begin{aligned}
X_t &= f(X_{t-1}, \epsilon_t) \\
Y_t &= g(X_t) + \eta_t \\
\eta_t &\sim \mathcal{N}(0, \Sigma)
\end{aligned}
$$

Particle filter output:

$$\left\{p(X_t | Y^t)\right\}_{t=0}^{T}$$

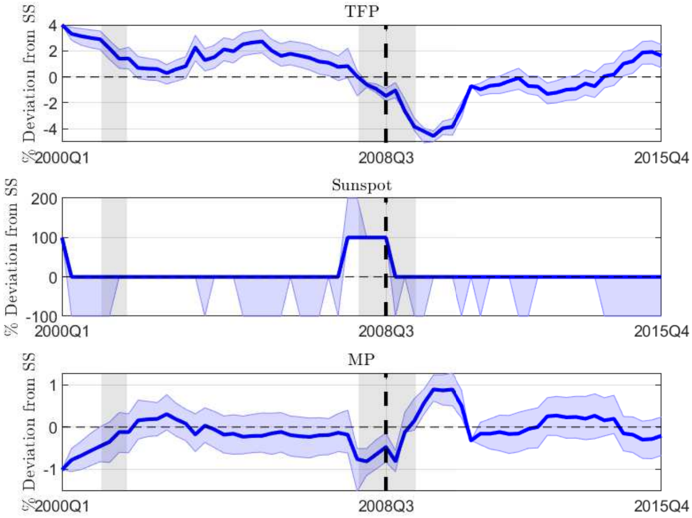
1. Initialize $\{x_0^i, \pi_0^i\}_{i=1}^N$ by drawing uniformly from ergodic distr.
2. **Prediction**: for each particle i, draw ϵ_t^i and compute $x_{t|t-1}^i = f(x_{t-1}^i, \epsilon_t^i)$
3. **Filtering**: for each $x_{t|t-1}^i$, compute weight

$$\pi_t^i = \frac{p(y_t | x_{t|t-1}^i; \gamma) p(x_t | x_{t|t-1}^i; \gamma)}{h(x_t | y^t, x_{t-1}^i)}$$

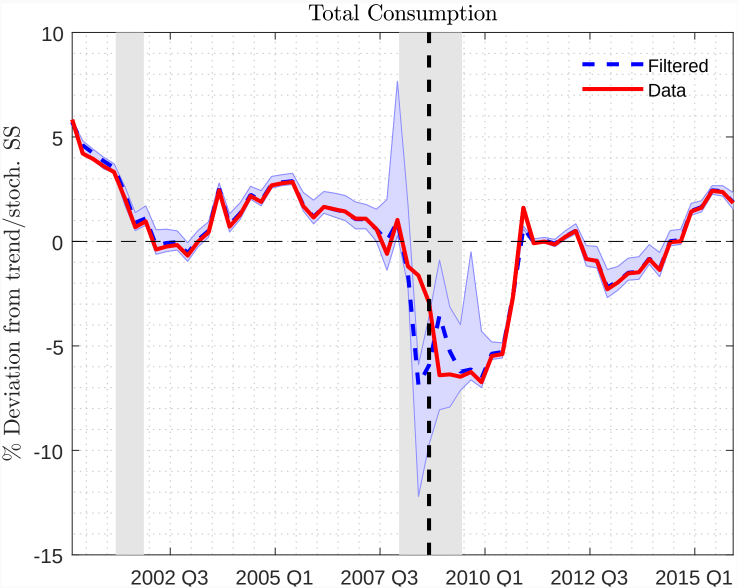
4. **Sampling**: use weights to draw N particles with replacement from $\{x_{t|t-1}^i\}_{i=1}^N$, call them $\{x_t^i\}_{i=1}^N$

back

Estimated Shocks

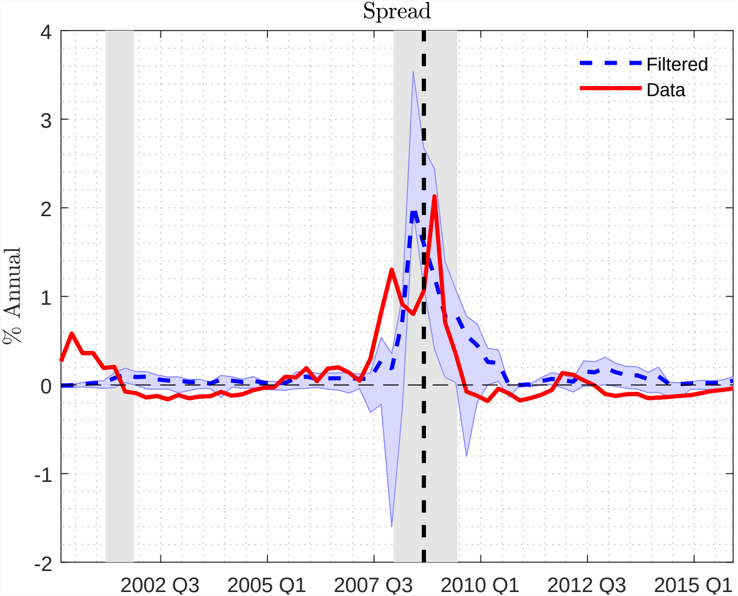


Consumption: Model vs. Data



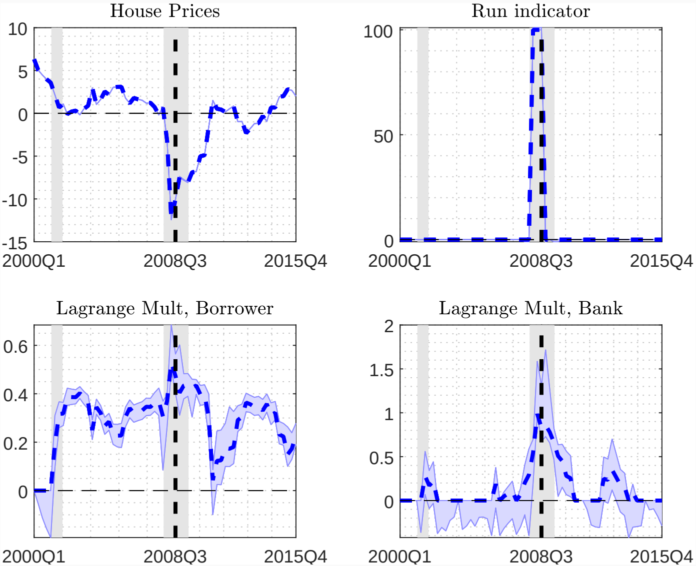
back

TED Spread: Model vs. Data



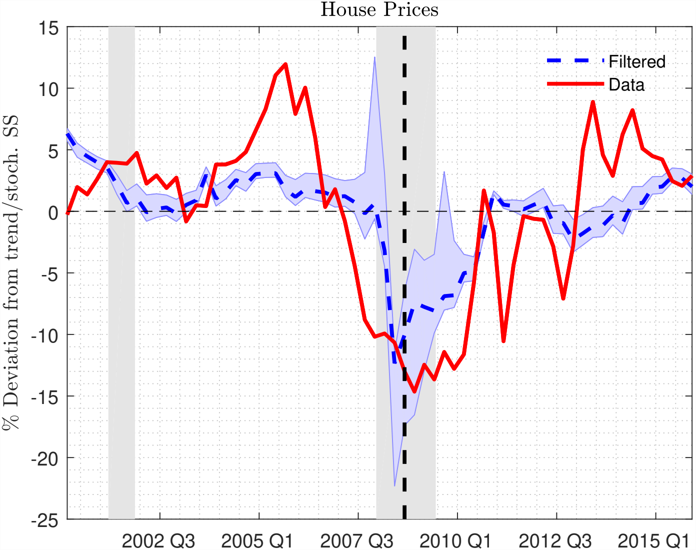
back

Other Filtered Series



back

Filtered House Prices



back