Concerted Efforts?
Monetary Policy and Macro-Prudential Tools

Andrea Ferrero
University of Oxford

Richard Harrison
Bank of England

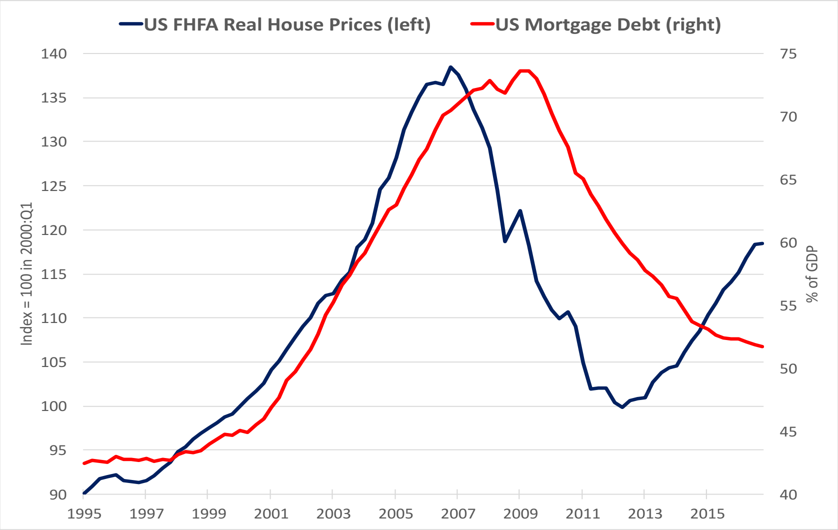
Benjamin Nelson
Centre for Macroeconomics

2^{nd} Annual European Central Bank Macroprudential Policy and Research Conference

Frankfurt, 11 May 2017

* *The views expressed in this paper do not necessarily reflect the position of the Bank of England.*

Boom-Bust Cycle in House Prices and Debt



A New Normal?

With the recovery in the UK economy broadening and gaining momentum in recent months, the Bank of England is now focussed on turning that recovery into a durable expansion. To do so, our policy tools must be used in concert.

Mark Carney
Financial Stability Report Press Conference
26 June 2014

A New Normal?

> *With the recovery in the UK economy broadening and gaining momentum in recent months, the Bank of England is now focussed on turning that recovery into a durable expansion. To do so, our policy tools must be used in concert.*

Mark Carney
Financial Stability Report Press Conference
26 June 2014

- New era of central banking
  - Monetary policy: Interest rate setting
  - Financial stability: Macro-prudential tools

What We Do

- Simple framework to study interaction of monetary and macro-pru policies
  - Introduce nominal rigidities in Justiniano, Primiceri and Tambalotti (2016)
  - Explicit role of financial intermediation (Curdia and Woordford, 2017)

What We Do

- Simple framework to study interaction of monetary and macro-pru policies
  - Introduce nominal rigidities in Justiniano, Primiceri and Tambalotti (2016)
  - Explicit role of financial intermediation (Curdia and Woordford, 2017)

- Normative analysis
  - Joint optimal policy plan (some analytics)
  - Boom-bust scenario (numerical analysis)

What We Do

- Simple framework to study interaction of monetary and macro-pru policies
  - Introduce nominal rigidities in Justiniano, Primiceri and Tambalotti (2016)
  - Explicit role of financial intermediation (Curdia and Woordford, 2017)
- Normative analysis
  - Joint optimal policy plan (some analytics)
  - Boom-bust scenario (numerical analysis)
- Focus on implications of macro-pru for monetary policy
  - Pervasive spillovers between monetary policy and macro-prudential regulation
  - Macro-pru facilitates debt-deleveraging process and alleviates ZLB constraint

Selected Related Literature

- Coordinated monetary and macro-prudential policies
  - Angelini, Neri and Panetta (2012), Angeloni and Faia (2013), Bean et al. (2010), De Paoli and Paustian (2013)
- Bank capital requirements and monetary policy
  - Christiano and Ikeda (2016), Clerc et al. (2015), Gertler, Kiyotaki and Queralto (2012), Van den Heuvel (2016)
- ZLB constraint, deleveraging, and macro-prudential policy
  - Eggertsson and Krugman (2012), Farhi and Werning (2016), Guerrieri and Lorenzoni (2015), Korinek and Simsek (2016)
- Empirical studies
  - Akinci and Olmstead-Rumsey (2017), Cerutti, Claessens and Laeven (2015), Gambacorta and Murcia (2016), Meeks (2017)

Outline

1. **Model and credit market equilibrium**
2. Optimal policy: Analytical results
3. Quantitative experiments: Boom-bust scenario

Overview

- Patient and impatient households, differ in their individual discount factor
  - Impatient households would like to borrow to purchase housing services
  - Patient household save via deposits and equity of financial intermediaries

Overview

- Patient and impatient households, differ in their individual discount factor
  - Impatient households would like to borrow to purchase housing services
  - Patient household save via deposits and equity of financial intermediaries
- Financial intermediaries channel funds from savers to borrowers

Overview

- Patient and impatient households, differ in their individual discount factor
  - Impatient households would like to borrow to purchase housing services
  - Patient household save via deposits and equity of financial intermediaries
- Financial intermediaries channel funds from savers to borrowers
- Financial frictions
  - Collateral constraint on impatient households (Kiyotaki and Moore, 1997)
  - Capital requirement on financial intermediaries (He and Krishnamurty, 2013)

Overview

- Patient and impatient households, differ in their individual discount factor
  - Impatient households would like to borrow to purchase housing services
  - Patient household save via deposits and equity of financial intermediaries
- Financial intermediaries channel funds from savers to borrowers
- Financial frictions
  - Collateral constraint on impatient households (Kiyotaki and Moore, 1997)
  - Capital requirement on financial intermediaries (He and Krishnamurty, 2013)
- Standard New Keynesian supply side with nominal rigidities

Impatient Households (Borrowers)

- Continuum of measure $\xi \in (0,1)$, maximize

$$\mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \beta_b^t \left[\left(1 - e^{-zC_t^b}\right) + \frac{\chi_H^b}{1-\sigma_h} (H_t^b)^{1-\sigma_h} - \frac{\chi_L^b}{1+\varphi} (L_t^b)^{1+\varphi} \right] \right\}$$

- Budget constraint

$$P_t C_t^b - D_t^b + Q_t H_t^b = W_t^b L_t^b - R_{t-1}^b D_{t-1}^b + Q_t H_{t-1}^b + \Omega_t^b - T_t^b,$$

- Collateral constraint (Kiyotaki and Moore, 1997)

$$D_t^b \leq \Theta_t Q_t H_t^b$$

with $\Theta_t \in (0,1)$

Patient Households (Savers)

- Continuum of measure $1-\xi$, maximize

$$\mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \beta_s^t \left[\left(1 - e^{-zC_t^s}\right) + \frac{\chi_H^s}{1-\sigma_h} (H_t^s)^{1-\sigma_h} - \frac{\chi_L^s}{1+\varphi} (L_t^s)^{1+\varphi} \right] \right\}$$

with $\beta_s \in (\beta_b, 1)$

- Budget constraint

$$P_t C_t^s + D_t^s + E_t^s + \Gamma(E_t^s) + (1+\tau^h) Q_t H_t^s = W_t^s L_t^s + R_{t-1}^d D_{t-1}^s + R_{t-1}^e E_{t-1}^s + Q_t H_{t-1}^s - T_t^s + \Omega_t^s,$$

where $\Gamma(E_t^s)$ is equity adjustment cost (Jermann and Quadrini, 2012)

Financial Intermediaries

- Balance sheet at time t (after borrowers and lenders decisions)

Assets		**Liabilities**	
Loans	D_t^b	Deposits	D_t^s
		Equity	E_t^s

Financial Intermediaries

- Balance sheet at time t (after borrowers and lenders decisions)

Assets		**Liabilities**	
Loans	D_t^b	Deposits	D_t^s
		Equity	E_t^s

- Leverage constraint/Capital requirement (He and Krishnamurthy, 2013)

$$E_t^s \geq \tilde{\kappa}_t D_t^b$$

  - Always binding in equilibrium for banks to be relevant

Financial Intermediaries

- Balance sheet at time t (after borrowers and lenders decisions)

Assets		**Liabilities**	
Loans	D_t^b	Deposits	D_t^s
		Equity	E_t^s

- Leverage constraint/Capital requirement (He and Krishnamurthy, 2013)

$$E_t^s \geq \tilde{\kappa}_t D_t^b$$

  - Always binding in equilibrium for banks to be relevant

- Zero profit condition

$$R_t^b = \tilde{\kappa}_t R_t^e + (1 - \tilde{\kappa}_t) R_t^d$$

Supply

- Standard New Keynesian supply side
- Retailers package differentiated intermediate goods with CES technology
- Intermediate goods produced with technology linear in labor

$$Y_t(f) = A_t L_t(f)$$

  - Labor aggregate

$$L_t(f) \equiv [L_t^b(f)]^{\xi} [L_t^s(f)]^{1-\xi}$$

  - Corresponding wage index

$$W_t \equiv (W_t^b)^{\xi} (W_t^s)^{1-\xi}$$

  - Staggered price setting (Calvo, 1983)

Equilibrium

- Goods market

$$Y_t = \xi C_t^b + (1-\xi) C_t^s + \Gamma_t$$

- Housing market

$$H = \xi H_t^b + (1-\xi) H_t^s$$

- Aggregate balance sheet of financial sector

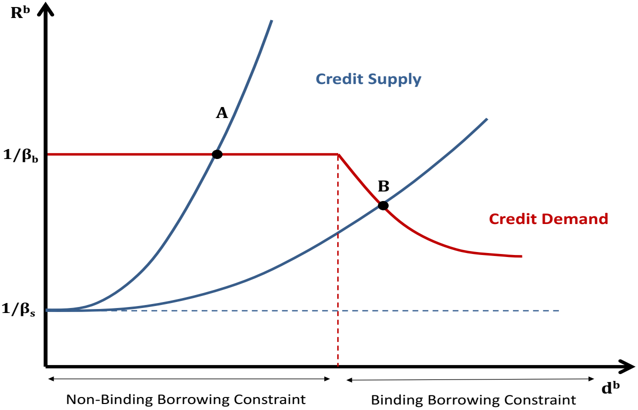
$$\xi D_t^b = (1-\xi)(D_t^s + E_t^s)$$

- Evolution of per-capita real private debt

$$\frac{D_t^b}{P_t} = \frac{R_{t-1}^b}{\Pi_t} \frac{D_{t-1}^b}{P_{t-1}} + C_t^b - Y_t + \frac{Q_t}{P_t}(H_t^b - H_{t-1}^b) + \mathcal{T}^b,$$

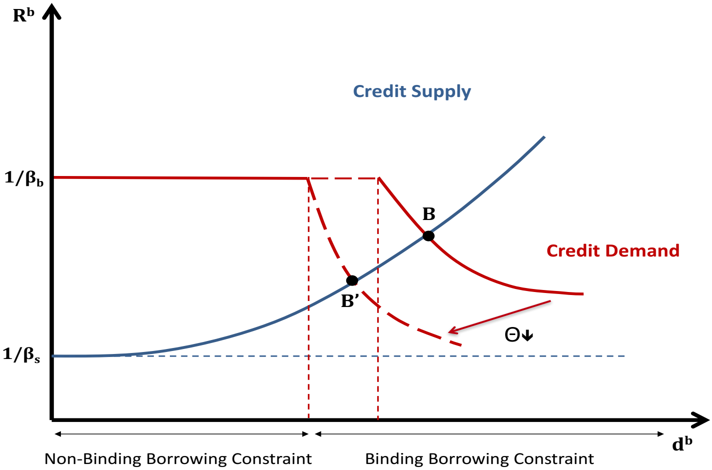
Credit Market Equilibrium

- Underlying credit market equilibrium corresponds to JPT
  - Sequence of static equilibria that can be represented in (d^b, R^b) space
  - Location of equilibrium depends on parameter values (not multiple equilibria)



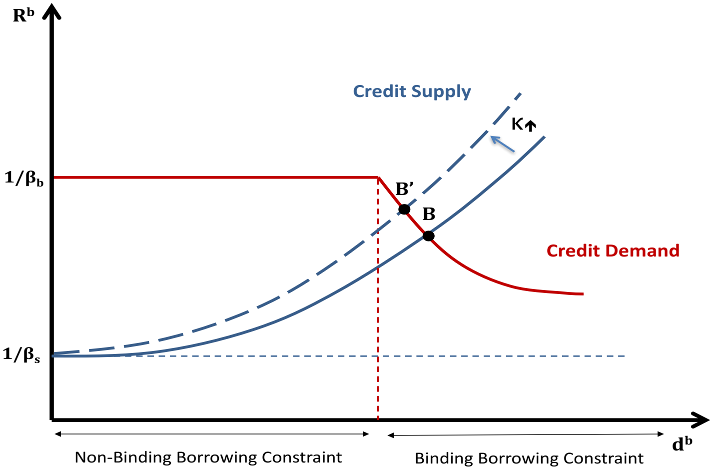
Macro-Pru Tools and Credit Market Equilibrium

- Tightening of LTV ratios: $\Theta_t \downarrow$



Macro-Pru Tools and Credit Market Equilibrium

- Tightening of capital requirements: $\tilde{\kappa}_t \uparrow$



Outline

1. Credit market equilibrium
2. **Interaction between monetary and macro-prudential policy**
3. Quantitative experiments

LQ Approximation

- Loss function

$$\mathcal{L}_0 \equiv \frac{\sigma + \varphi}{2} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[x_t^2 + \lambda_\pi \pi_t^2 + \lambda_\kappa \kappa_t^2 + \lambda_c (c_t^b - c_t^s)^2 + \lambda_h (h_t^b - h_t^s)^2 \right]$$

LQ Approximation

- Loss function

$$\mathcal{L}_0 \equiv \frac{\sigma + \varphi}{2} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[x_t^2 + \lambda_\pi \pi_t^2 + \lambda_\kappa \kappa_t^2 + \lambda_c (c_t^b - c_t^s)^2 + \lambda_h (h_t^b - h_t^s)^2 \right]$$

  - Standard terms in inflation and (efficient) output gap

LQ Approximation

- Loss function

$$\mathcal{L}_0 \equiv \frac{\sigma + \varphi}{2} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[x_t^2 + \lambda_\pi \pi_t^2 + \lambda_\kappa \kappa_t^2 + \lambda_c (c_t^b - c_t^s)^2 + \lambda_h (h_t^b - h_t^s)^2 \right]$$

  - Standard terms in inflation and (efficient) output gap
  - Terms due to financial frictions
    - Lack of risk-sharing
    - Equity adjustment costs

LQ Approximation

- Loss function

$$\mathcal{L}_0 \equiv \frac{\sigma + \varphi}{2} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[x_t^2 + \lambda_\pi \pi_t^2 + \lambda_\kappa \kappa_t^2 + \lambda_c (c_t^b - c_t^s)^2 + \lambda_h (h_t^b - h_t^s)^2 \right]$$

  - Standard terms in inflation and (efficient) output gap
  - Terms due to financial frictions
    - ⋆ Lack of risk-sharing
    - ⋆ Equity adjustment costs

- Standard NK Phillips curve

$$\pi_t = \gamma x_t + \beta \mathbb{E}_t \pi_{t+1} + u_t^m,$$

LQ Approximation

- IS curve (Savers' Euler equation)

$$x_t - \xi(c_t^b - c_t^s) = -\sigma^{-1}(i_t - \mathbb{E}_t \pi_{t+1}) + \mathbb{E}_t[x_{t+1} - \xi(c_{t+1}^b - c_{t+1}^s)] + \nu_t^{cgap}$$

LQ Approximation

- IS curve (Savers' Euler equation)

$$x_t - \xi(c_t^b - c_t^s) = -\sigma^{-1}(i_t - \mathbb{E}_t \pi_{t+1}) + \mathbb{E}_t[x_{t+1} - \xi(c_{t+1}^b - c_{t+1}^s)] + \nu_t^{cgap}$$

- Binding borrowing constraint

$$d_t^b = \theta_t + q_t + (1-\xi)(h_t^b - h_t^s)$$

- Evolution of debt

$$d_t^b = \frac{1}{\beta_s}(i_{t-1} + \psi\kappa_{t-1} + d_{t-1}^b - \pi_t) + (1-\xi)[(h_t^b - h_t^s) - (h_{t-1}^b - h_{t-1}^s)] + \frac{1-\xi}{\eta}(c_t^b - c_t^s)$$

LQ Approximation

- House prices

$$q_t = -(i_t - \mathbb{E}_t \pi_{t+1}) + \frac{\sigma\omega}{\omega+\beta}\mathbb{E}_t x_{t+1} + \frac{\xi\tilde{\mu}}{\omega+\beta}\theta_t - \frac{\xi(1-\tilde{\mu})}{\omega+\beta}\psi\kappa_t + \frac{\beta}{\omega+\beta}\mathbb{E}_t q_{t+1} + \nu_t^h$$

LQ Approximation

- House prices

$$q_t = -(i_t - \mathbb{E}_t \pi_{t+1}) + \frac{\sigma\omega}{\omega+\beta}\mathbb{E}_t x_{t+1} + \frac{\xi\tilde{\mu}}{\omega+\beta}\theta_t - \frac{\xi(1-\tilde{\mu})}{\omega+\beta}\psi\kappa_t + \frac{\beta}{\omega+\beta}\mathbb{E}_t q_{t+1} + \nu_t^h$$

- Housing gap

$$h_t^b - h_t^s = -\frac{\omega - \xi(\beta_s - \beta_b)}{\sigma_h \xi \omega}(i_t - \mathbb{E}_t \pi_{t+1}) + \frac{\beta_s - \beta_b}{\sigma_h \omega}(q_t - \mathbb{E}_t q_{t+1}) - \frac{\sigma}{\sigma_h \xi}(x_t - \mathbb{E}_t x_{t+1}) + \frac{\sigma}{\sigma_h}(c_t^b - c_t^s) + \frac{\tilde{\mu}}{\sigma_h \omega}\theta_t - \frac{1-\tilde{\mu}}{\sigma_h \omega}\psi\kappa_t + \nu_t^{hgap}$$

Optimal Macro-Prudential Policy with Flex Prices

- Suppose **prices are flexible** and no mark-up shocks
  - Also **abstract from costs of changing capital requirements** ($\lambda_\kappa = 0$)

Optimal Macro-Prudential Policy with Flex Prices

- Suppose **prices are flexible** and no mark-up shocks
  - Also **abstract from costs of changing capital requirements** ($\lambda_\kappa = 0$)

$\Rightarrow$ Macro-prudential authority can fully stabilize housing and consumption gap

Optimal Macro-Prudential Policy with Flex Prices

- Suppose **prices are flexible** and no mark-up shocks
  - Also **abstract from costs of changing capital requirements** ($\lambda_\kappa = 0$)

$\Rightarrow$ Macro-prudential authority can fully stabilize housing and consumption gap

- Can monetary policy fully stabilize inflation?
  - NO! Only in expectations: Optimal monetary policy rule is $\mathbb{E}_t \pi_{t+1} = 0$

Optimal Macro-Prudential Policy with Flex Prices

- Suppose **prices are flexible** and no mark-up shocks
  - Also **abstract from costs of changing capital requirements** ($\lambda_\kappa = 0$)

$\Rightarrow$ Macro-prudential authority can fully stabilize housing and consumption gap

- Can monetary policy fully stabilize inflation?
  - NO! Only in expectations: Optimal monetary policy rule is $\mathbb{E}_t \pi_{t+1} = 0$
- Intuition: Inflation surprises make private debt state-contingent

$$d_t^b = \frac{1}{\beta_s} \left[\frac{1}{1-\tilde{\mu}} d_{t-1}^b - (\pi_t - \mathbb{E}_{t-1}\pi_t) \right] + \nu_t^b$$

  - Similar to interaction of monetary and fiscal policy (Chari et al., 1991)

Optimal Macro-Prudential Policy with Flex Prices

- Suppose **prices are flexible** and no mark-up shocks
  - **Allow for costs of changing capital requirements** ($\lambda_\kappa > 0$)

Optimal Macro-Prudential Policy with Flex Prices

- Suppose **prices are flexible** and no mark-up shocks
  - **Allow for costs of changing capital requirements** $(\lambda_\kappa > 0)$
- Still optimal to use ex-post inflation surprises to stabilize private debt

Optimal Macro-Prudential Policy with Flex Prices

- Suppose **prices are flexible** and no mark-up shocks
  - **Allow for costs of changing capital requirements** ($\lambda_\kappa > 0$)
- Still optimal to use ex-post inflation surprises to stabilize private debt
- Stabilization tradeoff between housing and consumption gap

Optimal Macro-Prudential Policy with Flex Prices

- Suppose **prices are flexible** and no mark-up shocks
  - **Allow for costs of changing capital requirements** ($\lambda_\kappa > 0$)
- Still optimal to use ex-post inflation surprises to stabilize private debt
- Stabilization tradeoff between housing and consumption gap
- Optimal targeting rules for macro-prudential policy

$$\lambda_\kappa \kappa_t = \varphi_\kappa \lambda_h (h_t^b - h_t^s)$$

$$\lambda_c (c_t^b - c_t^s) = \varphi_h \lambda_h (h_t^b - h_t^s)$$

Optimal Macro-Prudential Policy with Sticky Prices

- With **sticky prices**, inflation volatility highly suboptimal (Siu, 2004)

- Optimal targeting rule for monetary policy

$$x_t + \gamma \lambda_\pi \pi_t + \frac{\sigma}{\psi} \lambda_\kappa \kappa_t - \mathcal{M}_{\kappa t} = 0$$

where macro-prudential policy gap is

$$\mathcal{M}_{\kappa t} \equiv \frac{\eta}{1-\xi} \left[\xi \sigma \frac{\lambda_\kappa}{\psi} \kappa_t - \lambda_c (c_t^b - c_t^s) - \xi \alpha_h \lambda_h (h_t^b - h_t^s) \right]$$

Optimal Macro-Prudential Policy with Sticky Prices

- With **sticky prices**, inflation volatility highly suboptimal (Siu, 2004)
- Optimal targeting rule for monetary policy

$$x_t + \gamma \lambda_\pi \pi_t + \frac{\sigma}{\psi} \lambda_\kappa \kappa_t - \mathcal{M}_{\kappa t} = 0$$

where macro-prudential policy gap is

$$\mathcal{M}_{\kappa t} \equiv \frac{\eta}{1-\xi} \left[\xi \sigma \frac{\lambda_\kappa}{\psi} \kappa_t - \lambda_c (c_t^b - c_t^s) - \xi \alpha_h \lambda_h (h_t^b - h_t^s) \right]$$

- Optimal targeting rules for macro-prudential policy

$$\begin{aligned} \frac{\eta}{1-\xi} \zeta_h \lambda_h (h_t^b - h_t^s) &= \frac{\lambda_\kappa}{\psi} \kappa_t + \mathcal{M}_{\kappa t} \\ \mathcal{M}_{\kappa t} &= \frac{\tilde{\mu} \zeta_h}{\sigma_h \omega} \lambda_h (h_t^b - h_t^s) + \beta \mathbb{E}_t \mathcal{M}_{\kappa t+1} \end{aligned}$$

Optimal Monetary and Macro-Prudential Policies

- Pervasive spillovers between monetary and macro-prudential policies

Optimal Monetary and Macro-Prudential Policies

- Pervasive spillovers between monetary and macro-prudential policies

- With flexible prices, ex-post inflation surprises stabilize private debt
  - Macro-prudential policy focuses on consumption and housing gaps
  - Full stabilization if varying capital requirements is not costly

Optimal Monetary and Macro-Prudential Policies

- Pervasive spillovers between monetary and macro-prudential policies
- With flexible prices, ex-post inflation surprises stabilize private debt
  - Macro-prudential policy focuses on consumption and housing gaps
  - Full stabilization if varying capital requirements is not costly
- With sticky prices, ex-post inflation volatility too costly
  - Inflation targeting affected by macro-prudential policy gap
  - Macro-prudential policy gap
    - Depends on current and future housing gaps
    - Prevents static targeting of risk-sharing objectives

Outline

1. Credit market equilibrium

2. Interaction between monetary and macro-prudential policy

3. **Quantitative experiments**

Calibration

Parameter	Description	Value
β_s	Savers' discount factor	0.995
β_b	Borrowers' discount factor	0.9922
σ	IES (consumption)	1
φ	Inverse Frisch elasticity	1
γ_d	Debt limit inertia	0.7
γ	Slope of Phillips curve	0.008
ξ	Fraction of borrowers in economy	0.57
η	Debt/GDP ratio	1.8
Θ	LTV ratio	0.7
ψ	Elasticity of funding cost to capital ratio	0.0125
σ_h	IES (housing)	5
ρ_h	Housing demand shock persistence	0.95

- Introduce slow-moving debt to capture $corr(hp, d^b) < 1$

$$D_t^b(i) \leq \gamma_d D_{t-1}^b(i) + (1 - \gamma_d)\,\Theta_t Q_t H_t^b(i)$$

Calibration

Parameter	Description	Value
β_s	Savers' discount factor	0.995
β_b	Borrowers' discount factor	0.9922
σ	IES (consumption)	1
φ	Inverse Frisch elasticity	1
γ_d	Debt limit inertia	0.7
γ	Slope of Phillips curve	0.008
ξ	Fraction of borrowers in economy	0.57
η	Debt/GDP ratio	1.8
Θ	LTV ratio	0.7
ψ	Elasticity of funding cost to capital ratio	0.0125
σ_h	IES (housing)	5
ρ_h	Housing demand shock persistence	0.95

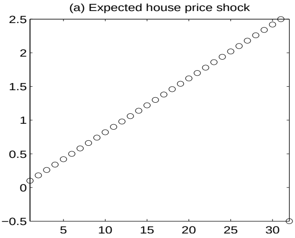
- Introduce slow-moving debt to capture $corr(hp, d^b) < 1$

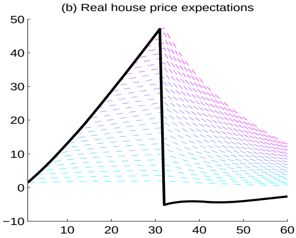
$$D_t^b(i) \leq \gamma_d D_{t-1}^b(i) + (1-\gamma_d)\,\Theta_t Q_t H_t^b(i)$$

Experiment

- Generate boom-bust scenario for house prices
  - Similar to US experience (more extreme than UK)
  - Want to negative shock large enough so that interest rate hits ZLB
- Scenario generated via "news shock"

$$\mathbb{E}_t u_K^h > \mathbb{E}_{t-1} u_K^h \qquad t = 1, \ldots K-1$$
$$u_K^h < \mathbb{E}_1 u_K^h$$





Flexible Inflation Targeting

- Suppose policymaker seeks to minimize

$$\mathcal{L}_t^{FIT} \equiv \mathbb{E}_t \sum_{i=0}^{\infty} \beta^i \left(x_{t+i}^2 + \lambda_\pi \pi_{t+i}^2 \right)$$

  - No macro-prudential objective (pre-crisis status quo)

Flexible Inflation Targeting

- Suppose policymaker seeks to minimize

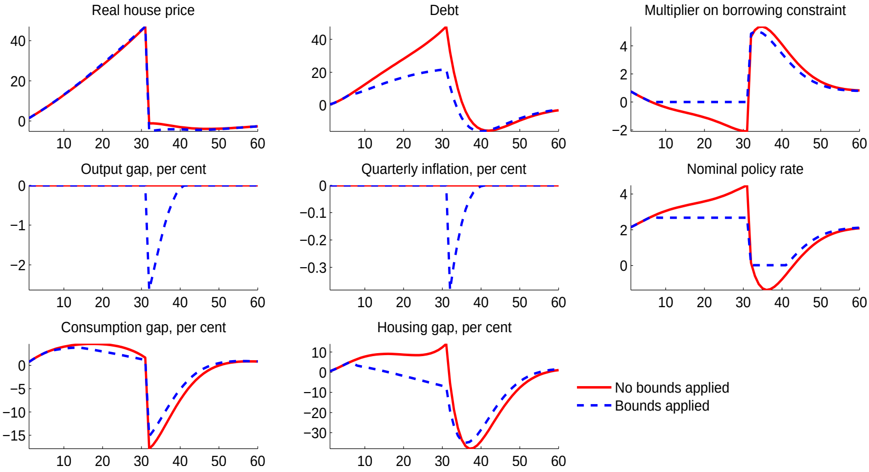
$$\mathcal{L}_t^{FIT} \equiv \mathbb{E}_t \sum_{i=0}^{\infty} \beta^i \left(x_{t+i}^2 + \lambda_\pi \pi_{t+i}^2 \right)$$

  - No macro-prudential objective (pre-crisis status quo)

- Assume policymaker operates under discretion
  - Hard to hit ZLB under commitment
  - Without ZLB, optimal targeting rule is

$$x_t + \lambda_\pi \gamma \pi_t = 0$$

Flexible Inflation Targeting



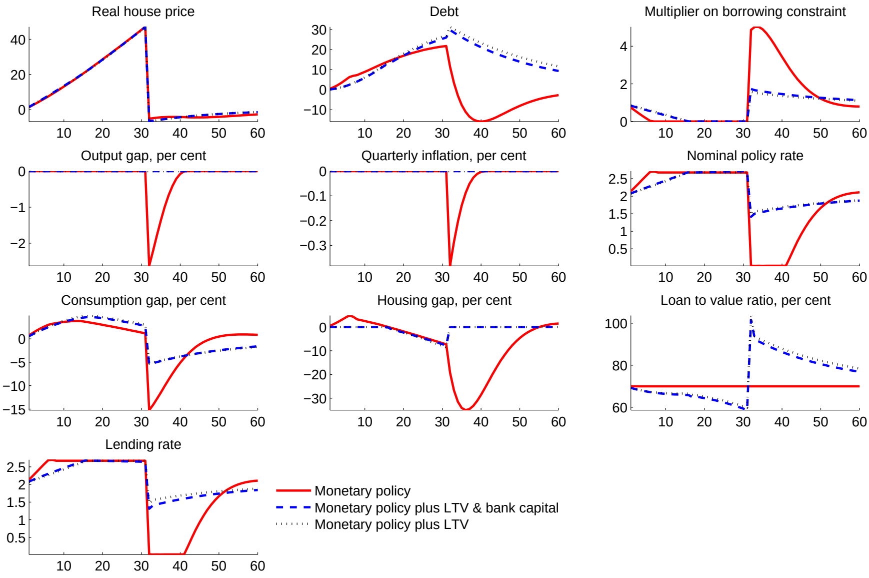
Flexible Inflation Targeting and Macro-Prudential Policy

- Macro-prudential authority also operates under discretion, minimizes

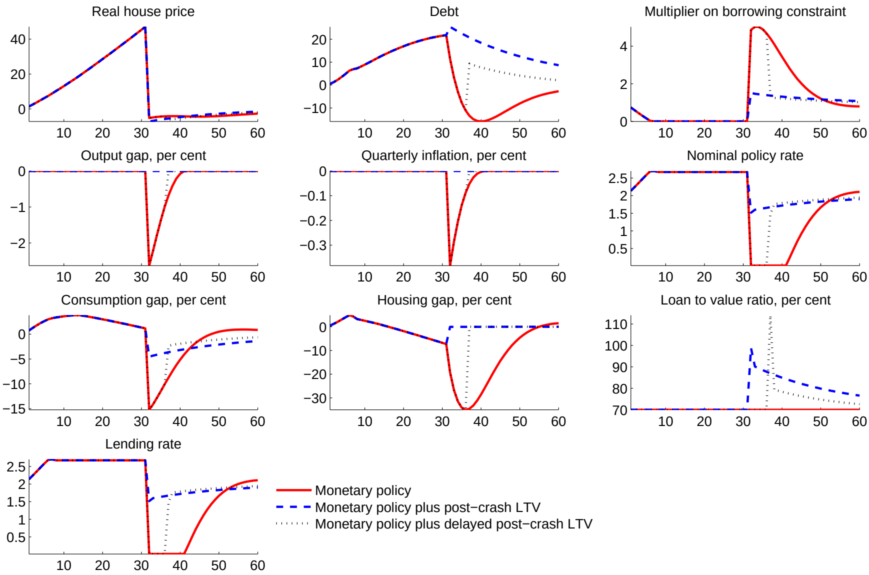
$$\mathcal{L}_0^{MP} = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\lambda_c (c_t^b - c_t^s)^2 + \lambda_h (h_t^b - h_t^s)^2 + \lambda_\kappa \kappa_t^2 \right]$$

- Focus on use of LTV instrument
- Also study incremental contribution of capital requirements
- Monetary policy continues to operate under flexible inflation targeting

Flexible Inflation Targeting and Macro-Prudential Policy



Macro-Prudential Policy after the Crash



Conclusions

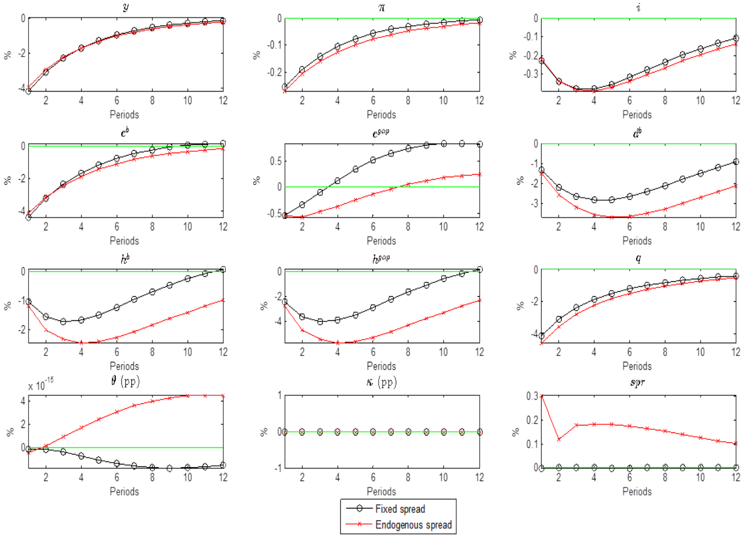
- Financial crisis extended objectives and toolkit of central banks
  - Macro-Prudential policy: LTV ratios and capital requirements
- This paper has focused on implications of macro-pru for monetary policy
  - Illustrated how inflation targeting affected by macro-prudential policy targets
- Macro-prudential policy especially useful to escape ZLB situations
  - But must be used very aggressively
  - In directions that may encourage economy to undertake even more debt
  - May conflict with financial stability objective outside scope of this paper

Robustness: Endogenous Spreads

- Credit spreads exogenous in our model
  - May affect macro-pru policy that encourages more borrowing in a slump
  - When spreads are likely to rise, hence deterring additional borrowing
- Replace banking system with framework in Gertler and Kiyotaki (2010)
  - Moral hazard $\implies$ Endogenous spreads
- Nelson and Pinter (2013) show steady state is unchanged
  - Compare using same loss function

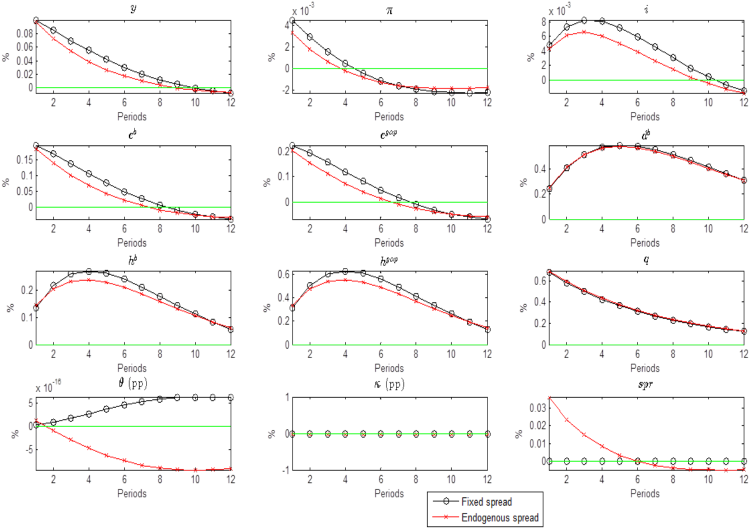
Comparison with Nelson and Pinter (2017)

Demand shock



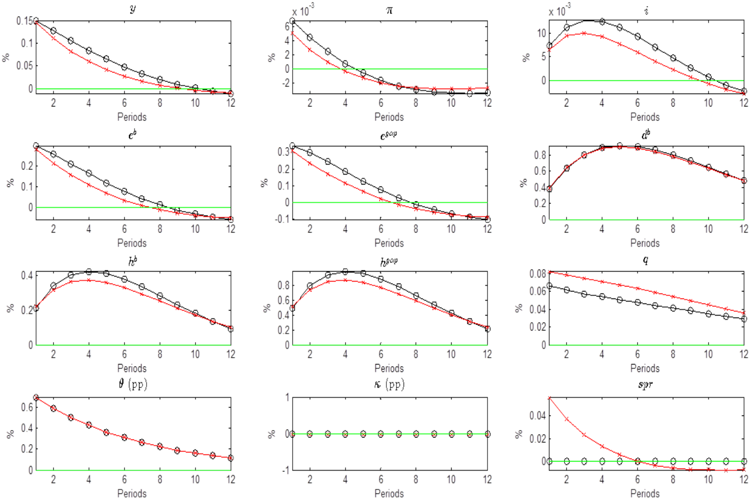
Comparison with Nelson and Pinter (2017)

Housing demand shock



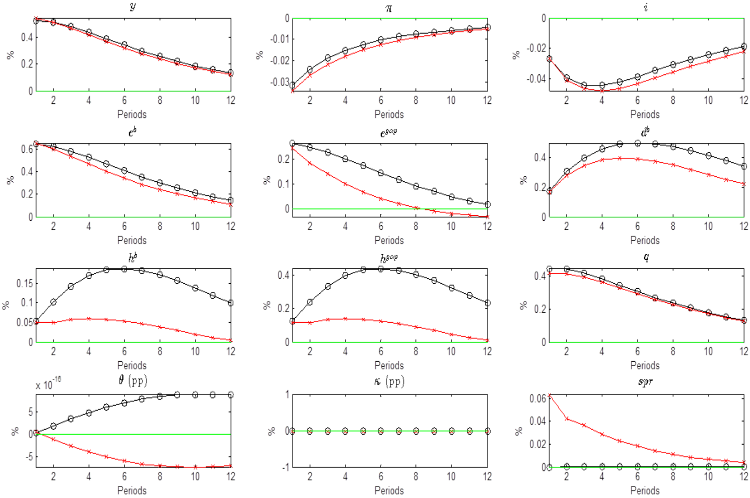
Comparison with Nelson and Pinter (2017)

LTV shock



Comparison with Nelson and Pinter (2017)

TFP shock



Methodology

- Occasionally-binding constraints
  - Use methodology of Holden and Paetz (2012)
  - Similar to Guerrieri and Iacoviello (2015)

- Treats occasionally-binding constraints as a regime
  - Takes into accounts possibility that constraint does not bing at $t+1$ conditional on constraint binding at t (and vice versa)

Methodology

- Occasionally-binding constraints
  - Use methodology of Holden and Paetz (2012)
  - Similar to Guerrieri and Iacoviello (2015)
- Treats occasionally-binding constraints as a regime
  - Takes into accounts possibility that constraint does not bing at $t+1$ conditional on constraint binding at t (and vice versa)
- Doesn't account for risk that future shocks may cause constraint to bind
  - Linear approximation within each regime
  - Overall piece-wise linear solution
- Neither precautionary savings nor skewness but highly tractable