Concerted Efforts?  
Monetary Policy and Macro-Prudential Tools  

Andrea Ferrero  
University of Oxford  

Richard Harrison  
Bank of England  

Benjamin Nelson  
Rokos Capital  

20th Central Bank Macroeconomic Modeling Workshop  
on Policy Coordination  

Banque de France  
Paris, 17 November 2017  

* The views expressed in this paper do not necessarily reflect the position of either the Bank of England or Rokos Capital.
Boom-Bust Cycle in Debt and House Prices
A New Normal?

- Several **macro-prudential tools** introduced in response to crisis, e.g.
  - Capital requirements
  - LTV limits
A New Normal?

- Several macro-prudential tools introduced in response to crisis, e.g.
  - Capital requirements
  - LTV limits

- New resulting policy framework
  - Monetary policy: Interest rate setting
  - Financial stability: Macro-prudential tools
A New Normal?

- Several macro-prudential tools introduced in response to crisis, e.g.
  - Capital requirements
  - LTV limits

- New resulting policy framework
  - Monetary policy: Interest rate setting
  - Financial stability: Macro-prudential tools

- How should monetary and macro-prudential policies conducted?

*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
What We Do

- Simple framework to study interaction of monetary and macro-pru policies
  - Nominal rigidities (Woodford, 2003)
  - Borrowers and savers (Kiyotaki and Moore, 1997)
  - Explicit role of financial intermediation (Curdia and Woodford, 2017)
What We Do

- Simple framework to study interaction of monetary and macro-pru policies
  - Nominal rigidities (Woodford, 2003)
  - Borrowers and savers (Kiyotaki and Moore, 1997)
  - Explicit role of financial intermediation (Curdia and Woodford, 2017)

- Normative analysis
  - Joint optimal policy plan in “normal times” (analytics)
  - Boom-bust scenario with occasionally-binding constraints (numerical analysis)
What We Do

- Simple framework to study interaction of monetary and macro-pru policies
  - Nominal rigidities (Woodford, 2003)
  - Borrowers and savers (Kiyotaki and Moore, 1997)
  - Explicit role of financial intermediation (Curdia and Woodford, 2017)

- Normative analysis
  - Joint optimal policy plan in “normal times” (analytics)
  - Boom-bust scenario with occasionally-binding constraints (numerical analysis)

- Focus on implications of macro-pru for monetary policy
  - Pervasive spillovers between monetary policy and macro-prudential regulation
  - Tightening of macro-pru at ZLB endogenously prolong duration of recession
Outline

1. Model sketch and credit market equilibrium

2. Optimal policy: Analytical results

3. Quantitative experiments: Boom-bust scenario
Overview

- Introduce nominal rigidities in Justiniano, Primiceri and Tambalotti (2016)
Overview

- Introduce nominal rigidities in Justiniano, Primiceri and Tambalotti (2016)
- 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
  - Equity adjustment costs $\Rightarrow$ Equity pays a premium over deposits

Overview

- Introduce nominal rigidities in Justiniano, Primiceri and Tambalotti (2016)
- 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
  - Equity adjustment costs $\Rightarrow$ Equity pays a premium over deposits
Overview

- Introduce nominal rigidities in Justiniano, Primiceri and Tambalotti (2016)

- 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
  - Equity adjustment costs ⇒ Equity pays a premium over deposits

- Financial intermediaries channel funds from savers to borrowers
Overview

- Introduce nominal rigidities in Justiniano, Primiceri and Tambalotti (2016)

- 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
  - Equity adjustment costs $\Rightarrow$ Equity pays a premium over deposits

- 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

- Introduce nominal rigidities in Justiniano, Primiceri and Tambalotti (2016)
- 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
  - Equity adjustment costs ⇒ Equity pays a premium over deposits
- 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 NK supply side with sticky prices
Credit Market Equilibrium

- Underlying credit market equilibrium (real economy) 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: $\Theta_t \downarrow$

![Graph showing credit demand and supply with tightened LTV ratios](image)
Macro-Pru Tools and Credit Market Equilibrium

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

1 Model sketch and credit market equilibrium

2 Optimal policy: Analytical results

3 Quantitative experiments: Boom-bust scenario
LQ Approximation

Loss function

\[ \mathcal{L}_0 \propto \frac{1}{2} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left( x_t^2 + \lambda \pi_t^2 + \lambda_c \tilde{c}_t^2 + \lambda_h \tilde{h}_t^2 + \lambda_\kappa \kappa_t^2 \right) \]
LQ Approximation

- Loss function

\[ \mathcal{L}_0 \propto \frac{1}{2} E_0 \sum_{t=0}^{\infty} \beta^t \left( x_t^2 + \lambda_{\pi} \pi_t^2 + \lambda_c \tilde{c}_t^2 + \lambda_h \tilde{h}_t^2 + \lambda_k \kappa_t^2 \right) \]

- Output gap and inflation due to nominal rigidities
LQ Approximation

- Loss function

\[ \mathcal{L}_0 \propto \frac{1}{2} E_0 \sum_{t=0}^{\infty} \beta^t \left( x_t^2 + \lambda_\pi \pi_t^2 + \lambda_c \tilde{c}_t^2 + \lambda_h \tilde{h}_t^2 + \lambda_\kappa \kappa_t^2 \right) \]

- Output gap and inflation due to nominal rigidities

- Consumption and housing gaps due to lack of risk sharing
LQ Approximation

- **Loss function**

\[
\mathcal{L}_0 \propto \frac{1}{2} E_0 \sum_{t=0}^{\infty} \beta^t \left( x_t^2 + \lambda_\pi \pi_t^2 + \lambda_{c\tilde{c}} \tilde{c}_t^2 + \lambda_{h\tilde{h}} \tilde{h}_t^2 + \lambda_{\kappa\kappa} \kappa_t^2 \right)
\]

- Output gap and inflation due to nominal rigidities
- Consumption and housing gaps due to lack of risk sharing
- Inverse of leverage due to equity adjustment costs

Special cases:
- Flexible prices: \( \lambda_\pi = 0 \) and \( x_t = 0 \)
- Exogenous leverage constraints: \( \lambda_{\kappa\kappa} \) with appropriate constraints
- Segmented housing markets: \( \tilde{h}_t = 0 \) for all \( t \)
LQ Approximation

- Loss function

\[ \mathcal{L}_0 \propto \frac{1}{2} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left( x_t^2 + \lambda_\pi \pi_t^2 + \lambda_c \tilde{c}_t^2 + \lambda_h \tilde{h}_t^2 + \lambda_\kappa \kappa_t^2 \right) \]

- Output gap and inflation due to nominal rigidities
- Consumption and housing gaps due to lack of risk sharing
- Inverse of leverage due to equity adjustment costs

Special cases:

- Flexible prices: \( \lambda_\pi = 0 \) and \( x_t = 0 \)
- Exogenous leverage constraints: \( \lambda_\kappa \kappa_t^2 \) t.i.p.
- Segmented housing markets: \( \tilde{h}_t = 0 \ \forall t \)
LQ Approximation

- Phillips curve

\[ \pi_t = \gamma x_t + \beta E_t \pi_{t+1} + u_t^m \]
LQ Approximation

- Phillips curve
  \[ \pi_t = \gamma x_t + \beta \mathbb{E}_t \pi_{t+1} + u^m_t \]

- IS curve (Savers’ Euler equation)
  \[ x_t - \tilde{\zeta} \tilde{c}_t = -\sigma^{-1} (i_t - \mathbb{E}_t \pi_{t+1}) + \mathbb{E}_t (x_{t+1} - \tilde{\zeta} \tilde{c}_{t+1}) + v_{t}^{gap} \]
LQ Approximation

- Phillips curve
  \[ \pi_t = \gamma x_t + \beta E_t \pi_{t+1} + u_t^m \]

- IS curve (Savers’ Euler equation)
  \[ x_t - \bar{\zeta} \bar{c}_t = -\sigma^{-1} (i_t - E_t \pi_{t+1}) + E_t (x_{t+1} - \bar{\zeta} \bar{c}_{t+1}) + \nu_t^{cgap} \]

- Binding borrowing constraint
  \[ d_t^b = \theta_t + q_t + (1 - \bar{\zeta}) \tilde{h}_t \]

- Evolution of debt
  \[ d_t^b = \frac{1}{\beta_s} (i_{t-1} + \psi \kappa_{t-1} + d_{t-1}^b - \pi_t) + (1 - \bar{\zeta}) (\tilde{h}_t - \tilde{h}_{t-1}) + \frac{1 - \bar{\zeta}}{\eta} \tilde{c}_t \]
LQ Approximation

- House prices

\[ q_t = -(i_t - \mathbb{E}_t \pi_{t+1}) + \frac{\sigma \omega}{\omega + \beta} \mathbb{E}_t x_{t+1} + \frac{\tilde{\zeta} \tilde{\mu}}{\omega + \beta} \theta_t - \frac{\tilde{\zeta}(1 - \tilde{\mu})}{\omega + \beta} \psi \kappa_t + \frac{\beta}{\omega + \beta} \mathbb{E}_t q_{t+1} + \nu^h_t \]
LQ Approximation

- **House prices**

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

- **Housing gap**

\[
\tilde{h}_t = - \frac{\omega - \tilde{\zeta}(\beta_s - \beta_b)}{\sigma_h \tilde{\zeta} \omega} (i_t - \mathbb{E}_t \pi_{t+1}) + \frac{\beta_s - \beta_b}{\sigma_h \omega} (q_t - \mathbb{E}_t q_{t+1}) \\
- \frac{\sigma}{\sigma_h \tilde{\zeta}} (x_t - \mathbb{E}_t x_{t+1}) + \frac{\sigma}{\sigma_h} \tilde{c}_t + \frac{\tilde{\mu}}{\sigma_h \omega} \theta_t - \frac{1 - \tilde{\mu}}{\sigma_h \omega} \psi \kappa_t + \nu_t^{hgap}
\]
Optimal Monetary Policy

- Abstract from ZLB and assume borrowing constraint always binds

- Optimal targeting rule for monetary policy

\[ x_t + \gamma \lambda \pi_t + \Omega_c \tilde{c}_t = 0 \]

with \( \Omega_c > 0 \)
Optimal Monetary Policy

- Abstract from ZLB and assume borrowing constraint always binds

- Optimal targeting rule for monetary policy

\[ x_t + \gamma \lambda \pi_t + \Omega_c \tilde{c}_t = 0 \]

with \( \Omega_c > 0 \)

- If \( \tilde{c}_t = 0 \), same targeting rule as in baseline NK model
- If \( \tilde{c}_t \neq 0 \), “risk-sharing-adjusted” monetary policy tradeoff
Optimal Monetary Policy

- Abstract from ZLB and assume borrowing constraint always binds

- Optimal targeting rule for monetary policy

  \[ x_t + \gamma \lambda \pi_t + \Omega c \tilde{c}_t = 0 \]

  with \( \Omega_c > 0 \)

  - If \( \tilde{c}_t = 0 \), same targeting rule as in baseline NK model
  - If \( \tilde{c}_t \neq 0 \), “risk-sharing-adjusted” monetary policy tradeoff

- Monetary policy concerned with distributional considerations
Optimal Macro-Prudential Policy

- Two rules (two instruments: LTV ratios and capital requirements)

1. Optimal capital requirements

\[ \kappa_t = \Phi_h \tilde{h}_t + \Phi_c \tilde{c}_t, \]

with \( \Phi_h, \Phi_c > 0 \)

- Positive housing and/or consumption gap \( \Rightarrow \) Tighter capital requirements
- Static, no aggregate considerations
Optimal Macro-Prudential Policy

- Two rules (two instruments: LTV ratios and capital requirements)
- Define single state variable for policy problem

\[ S_t \equiv d_t^b + i_t + \psi \kappa_t - \beta_s h_t^b \]

- Can then rewrite law of motion of debt and borrowing constraint as

\[ S_t = \frac{1}{\beta_s} (S_t - \pi_t) + i_t + \psi \kappa_t + (1 - \xi)(1 - \beta_s) \tilde{h}_t + \frac{1 - \xi}{\eta} \tilde{c}_t \]

\[ S_t = \theta_t + q_t + i_t + \psi \kappa_t + (1 - \xi)(1 - \beta_s) \tilde{h}_t \]
Optimal Macro-Prudential Policy

- Two rules (two instruments: LTV ratios and capital requirements)

2. Optimal LTV ratio (implicit)

\[ V_t + F_x x_t + F_\pi \pi_t + F_c \tilde{c}_t + F_h \tilde{h}_t = 0 \]

where \( V_t \) measures marginal effect of current decisions on future losses

\[ V_t = B_x E_t x_{t+1} + B_\pi E_t \pi_{t+1} + B_c E_t \tilde{c}_{t+1} + B_h E_t \tilde{h}_{t+1} + \beta B_S E_t V_{t+1} \]

- Dynamic tradeoff between current stimulus and its effects on future losses

\[ V_t \equiv \frac{\partial E_t \mathcal{L}_{t+1}}{S_t} \]

- Accounts for effect of macro-pru on aggregate and distributional variables
Optimal Monetary and Macro-Prudential Policies

- Pervasive spillovers between monetary and macro-prudential policies

- Optimal monetary policy affected by lack of full risk-sharing

- Optimal macro-prudential policy features
  - Static rule for capital requirements function of distributional gaps
  - Dynamic rule that trades off current stimulus and effects on future losses
Outline

1. Model sketch and credit market equilibrium

2. Optimal policy: Analytical results

3. Quantitative experiments: Boom-bust scenario
Calibration

- Introduce slow-moving debt to capture \( \text{corr}(hp, d^b) \)

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \beta_s )</td>
<td>Savers’ discount factor</td>
<td>0.995</td>
</tr>
<tr>
<td>( \beta_b )</td>
<td>Borrowers’ discount factor</td>
<td>0.9922</td>
</tr>
<tr>
<td>( \sigma )</td>
<td>IES (consumption)</td>
<td>1</td>
</tr>
<tr>
<td>( \varphi )</td>
<td>Inverse Frisch elasticity</td>
<td>1</td>
</tr>
<tr>
<td>( \gamma_d )</td>
<td>Debt limit inertia</td>
<td>0.7</td>
</tr>
<tr>
<td>( \gamma )</td>
<td>Slope of Phillips curve</td>
<td>0.008</td>
</tr>
<tr>
<td>( \xi )</td>
<td>Fraction of borrowers in economy</td>
<td>0.57</td>
</tr>
<tr>
<td>( \eta )</td>
<td>Debt/GDP ratio</td>
<td>1.8</td>
</tr>
<tr>
<td>( \Theta )</td>
<td>LTV ratio</td>
<td>0.7</td>
</tr>
<tr>
<td>( \psi )</td>
<td>Elasticity of funding cost to capital ratio</td>
<td>0.0125</td>
</tr>
<tr>
<td>( \sigma_h )</td>
<td>IES (housing)</td>
<td>5</td>
</tr>
<tr>
<td>( \rho_h )</td>
<td>Housing demand shock persistence</td>
<td>0.95</td>
</tr>
</tbody>
</table>

Ferrero, Harrison & Nelson (Oxford, BoE, Rokos)

Concerted Efforts?

17 November 2017
Experiment and Solution Method

- Generate boom-bust scenario for house prices (similar to US experience)
  - Sequence of positive “news shock” on house prices followed by collapse
  - Negative shock large enough so that nominal interest rate hits ZLB
    \[
    \mathbb{E}_t u^h_K > \mathbb{E}_{t-1} u^h_K \quad t = 1, \ldots K - 1
    \]
    \[
    u^h_K < \mathbb{E}_1 u^h_K
    \]

- Solve model using occasionally-binding constraints (Holden and Paetz, 2012)
Pre-Crisis Status Quo

- 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

- Suppose policymaker seeks to minimize
  \[
  L_t^{FIT} \equiv E_t \sum_{i=0}^{\infty} \beta^i \left( x_{t+i}^2 + \lambda \pi \pi_{t+i}^2 \right)
  \]
  - No macro-prudential objective

- Assume policymaker operates under discretion
  - Hard to hit ZLB under commitment
  - Without ZLB, optimal targeting rule is
    \[
    x_t + \lambda \pi \gamma \pi_t = 0
    \]
Pre-Crisis Status Quo

- **Real house price**
- **Debt**
- **Multiplier on borrowing constraint**
- **Output gap, per cent**
- **Quarterly inflation, per cent**
- **Nominal policy rate**
- **Consumption gap, per cent**
- **Housing gap, per cent**

Graphs show the impact of different economic indicators with and without borrowing constraint bounds.

- Red line: No bounds applied
- Blue dashed line: Bounds applied
Introducing Macro-Prudential Policy

- Macro-prudential authority also operates under discretion, minimizes

\[ \mathcal{L}_{0}^{MP} = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left( \lambda_c \tilde{c}_t^2 + \lambda_h \tilde{h}_t^2 + \lambda_k \kappa_t^2 \right) \]

- Focus on use of LTV instrument

- Monetary policy continues to operate under flexible inflation targeting
Introducing Macro-Prudential Policy

- Real house price
- Debt
- Multiplier on borrowing constraint
- Output gap, per cent
- Quarterly inflation, per cent
- Nominal policy rate
- Consumption gap, per cent
- Housing gap, per cent
- Loan to value ratio, per cent
- Lending rate

Monetary policy
Monetary policy plus LTV & bank capital
Monetary policy plus LTV
Macro-Pru Tightening after the Crash

- Many macro-pru authorities currently considering tightening
  - Increase LTV and/or capital requirements to ensure financial stability

- What are implications for monetary policy during crisis (ZLB period)?
  - Monetary policy continues to operate under flexible inflation targeting
Macro-Pru Tightening after the Crash

- Real house price
- Debt
- Multiplier on borrowing constraint
- Output gap, per cent
- Quarterly inflation, per cent
- Nominal policy rate
- Consumption gap, per cent
- Housing gap, per cent
- Loan to value ratio, per cent
- Lending rate

No LTV tightening
LTV tightening
Conclusions

- Financial crisis extended objectives and toolkit of central banks
  - Macro-Prudential policy: LTV limits and capital requirements
Conclusions

- Financial crisis extended objectives and toolkit of central banks
  - Macro-Prudential policy: LTV limits 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
Conclusions

- Financial crisis extended objectives and toolkit of central banks
  - Macro-Prudential policy: LTV limits 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 objectives outside scope of this paper
Impatient Households (Borrowers)

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

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

- Budget constraint

$$P_tC_t^b - D_t^b + Q_tH_t^b = W_t^bL_t^b - R_{t-1}^bD_{t-1}^b + Q_{tH_{t-1}}^b + \Omega_t^b - T_t^b,$$

- Collateral constraint (Kiyotaki and Moore, 1997)

$$D_t^b \leq \Theta_t Q_tH_t^b$$

with $\Theta_t \in (0, 1)$
Patient Households (Savers)

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

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

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

- Budget constraint

$$
P_tC_s^t + D_s^t + E_s^t + \Gamma(E_s^t) + (1 + \tau^h)Q_tH_s^t =

W_tL_s^t + R_{t-1}^d D_{t-1}^s + R_{t-1}^e E_{t-1}^s + Q_tH_{t-1}^s + \Omega_t^s - T_t^s,
$$

where $\Gamma(E_s^t)$ is cost of changing equity position (Jermann and Quadrini, 2012)

$$
\Gamma(E_s^t) \equiv \frac{\Psi}{2} \left[ \frac{E_s^t}{\tilde{\kappa}\zeta D_t^b / (1 - \zeta)} - 1 \right]^2 \frac{\tilde{\kappa}\zeta D_t^b}{1 - \zeta}
$$
Financial Intermediaries

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

<table>
<thead>
<tr>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loans</td>
<td>Deposits</td>
</tr>
<tr>
<td>$D^b_t$</td>
<td>$D^s_t$</td>
</tr>
<tr>
<td>Equity</td>
<td>$E^s_t$</td>
</tr>
</tbody>
</table>

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

$E_t \geq \tilde{\kappa}_t D^b_t$

Always binding in equilibrium for banks to be relevant

Zero profit condition

$R^b_t = \tilde{\kappa}_t R^e_t + (1 - \tilde{\kappa}_t) R^d_t$
# Financial Intermediaries

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

<table>
<thead>
<tr>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loans $D^b_t$</td>
<td>Deposits $D^s_t$</td>
</tr>
<tr>
<td>Equity</td>
<td>Equity</td>
</tr>
</tbody>
</table>

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

$$ E^s_t \geq \tilde{\kappa}_t D^b_t $$

- Always binding in equilibrium for banks to be relevant
Financial Intermediaries

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

<table>
<thead>
<tr>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loans $D_t^b$</td>
<td>Deposits $D_t^s$</td>
</tr>
<tr>
<td>Equity $E_t^s$</td>
<td>Equity $E_t^s$</td>
</tr>
</tbody>
</table>

- 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**
  \[ Y_t = \xi C^b_t + (1 - \xi)C^s_t + \Gamma_t \]

- **Housing market**
  \[ H = \xi H^b_t + (1 - \xi)H^s_t \]

- **Aggregate balance sheet of financial sector**
  \[ \xi D^b_t = (1 - \xi)(D^s_t + E^s_t) \]

- **Evolution of per-capita real private debt**
  \[ \frac{D^b_t}{P_t} = \frac{R^b_{t-1}}{\Pi_t} \frac{D^b_{t-1}}{P_{t-1}} + C^b_t - Y_t + \frac{Q^b_t}{P_t} (H^b_t - H^b_{t-1}) + T^b, \]
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 $\Rightarrow$ Endogenous spreads

- Nelson and Pinter (2013) show steady state is unchanged
  - Compare using same loss function
Comparison with Nelson and Pinter (2017)

Demand shock

![Graphs showing demand shock analysis](chart.png)
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

[Graphs showing the impact of TFP shock on various economic indicators over time, including output, inflation, and interest rate.]