Risky Mortgages in a DSGE Model

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Motivation

• The global financial crisis started with an increase in U.S. mortgage delinquencies

• Banks wrote down several hundred billion dollars in bad loans

• Liquidity crisis brought several financial institutions into or on the brink of bankruptcy

• Credit crunch and the Great Recession
Motivation

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U.S. Seriously Delinquent Mortgages

Percentage of total loans; Not seasonally adjusted

Source: Mortgage Bankers Association, National Delinquency Survey
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This Paper

- Focuses on an increase in mortgage delinquencies and its transmission to the rest of the economy
- Introduces endogenous default on mortgages in a DSGE model with housing
- Analyzes an unanticipated increase in mortgage risk
- Compares economies with different leverage ratios
- Compares different degrees of interest rate inertia in monetary policy
Results

1. An increase in mortgage risk
   ▶ raises mortgage default and the mortgage premium
   ▶ produces a credit crunch that generates a recession

2. Economies with lower mortgage risk have higher leverage ratios

3. High leverage ratios amplify the effects of a mortgage risk shock

4. Inertial monetary policies amplify the effects of a mortgage risk shock (zero lower bound scenario)
Literature

- **Housing Sector**: Iacoviello (2005), Iacoviello and Neri (2009), Calza, Monacelli and Stracca (2009), Aoki, Proudman and Vlieghe (2004)


The Model

Households

Fraction $\psi$ of impatient (Borrowers) and $1 - \psi$ of patient (Savers) households

- Consume a non-durable good, $C_t$
- Consume services from and accumulate houses, $H_{t+1}$
- Supply two types of labor, $N_{C,t}$ and $N_{H,t}$
- Savers make loans to Borrowers, $L_{t+1}$
Borrowers

$$\max_{C_t, H_{t+1}, N_{C,t}, N_{H,t}, L_{t+1}, \bar{\omega}_{t+1}} \sum_{t=0}^{\infty} \beta^t E_0 \{ U(X_t, N_{C,t}, N_{H,t}) \}, \quad 0 < \beta < 1$$

where

$$X_t \equiv \left[ (1 - \alpha) \frac{1}{\eta} C_t^{\frac{\eta-1}{\eta}} + \alpha \frac{1}{\eta} H_{t+1}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \quad \eta \geq 0,$$

subject to three constraints:

Budget constraint (nominal terms)

$$P_{C,t} C_t + P_{H,t} H_{t+1} + [1 - F(\bar{\omega}_t)](1 + R_{Z,t})L_t = L_{t+1} + W_{C,t} N_{C,t} + W_{H,t} N_{H,t} + (1 - \delta) [1 - G(\bar{\omega}_t)] P_{H,t} H_t,$$

Participation constraint

Incentive-compatibility constraint
Mortgage Risk

- Each household consists of many members
- The household decides total housing investment $H_{t+1}$
- The $i$-th member receives $H^i_{t+1}$ and finalizes the mortgage contract according to household instructions
- Idiosyncratic shock $\omega^i_{t+1}$ (observable by the member only) such that the ex-post housing stock is $\omega^i_{t+1} H^i_{t+1}$ (or ex-post housing value is $\omega^i_{t+1} p_{H,t+1} H^i_{t+1}$)
- $E_t(\omega^i_{t+1} H^i_{t+1}) = H_{t+1}$, i.e. there is no aggregate mortgage risk
- For $\omega^i_{t+1} \in [0, \bar{\omega}_{t+1})$ loans are defaulted; for $\omega^i_{t+1} \in [\bar{\omega}_{t+1}, \infty]$ loans are repaid
- Lenders pay the cost $\mu$ to monitor defaulting borrowers and seize the collateral
- Perfect insurance among household members
The Mortgage Contract

Participation constraint of lenders

\[
(1 + R_{L,t})L_{t+1} = \int_0^{\bar{\omega}_{t+1}} \omega_{t+1}(1 - \mu)(1 - \delta)P_{H,t+1}H_{t+1} f(\omega)d\omega + \\
\int_{\bar{\omega}_{t+1}}^{\infty} (1 + R_{Z,t+1})L_{t+1} f(\omega)d\omega
\]

Incentive-compatibility constraint

\[
\bar{\omega}_{t+1}(1 - \delta)P_{H,t+1}H_{t+1} = (1 + R_{Z,t+1})L_{t+1}
\]

\(R_{L,t}\) is the pre-determined and non-state-contingent rate of return on total loans

\(R_{Z,t+1}\) is the adjustable and state-contingent mortgage rate

\(\bar{\omega}_{t+1}\) is the threshold value of the idiosyncratic shock
Savers

\[
\max_{\tilde{C}_t, \tilde{H}_{t+1}, \tilde{N}_{C,t}, \tilde{N}_{H,t}, \tilde{L}_{t+1}} \sum_{t=0}^{\infty} \gamma^t E_0 \left\{ U(\tilde{X}_t, \tilde{N}_{C,t}, \tilde{N}_{H,t}) \right\}, \quad 0 < \beta < \gamma < 1
\]

subject to

\[
P_{C,t} \tilde{C}_t + P_{H,t} \tilde{H}_{t+1} + \tilde{L}_{t+1} = (1 + R_{L,t-1})\tilde{L}_t + W_{C,t} \tilde{N}_{C,t} + W_{H,t} \tilde{N}_{H,t}
\]

\[
+ \tilde{\Delta}_t + (1 - \delta)P_{H,t} \tilde{H}_t
\]

where \( \tilde{\Delta}_t \) are profits from firms
Intermediate Goods Producers

- Each sector has monopolistically competitive intermediate goods producers
- Continuum of differentiated goods \( i \in [0, 1] \)
- Firm \( i \) produces according to

\[
Y_{j,t}(i) = A_{j,t} \left[ \zeta \frac{1}{s} N_{j,t}(i) \frac{s-1}{s} + (1 - \zeta) \frac{1}{s} \tilde{N}_{j,t}(i) \frac{s-1}{s} \right]^{\frac{s}{s-1}}, \quad 0 < \zeta < 1, \; s > 0
\]
- Calvo price setting
Final Goods Producers

- Each sector has perfectly competitive final goods producers
- Flexible prices and CRS technology

\[ Y_{j,t} = \left( \int_0^1 Y_{j,t}(i) \frac{\varepsilon_j}{\varepsilon_i} \, di \right)^{\frac{\varepsilon_j}{\varepsilon_i-1}}, \quad \varepsilon_j > 1, \quad j = C, H \]
Monetary Policy

Monetary policy rule:

\[
\frac{1 + R_{L,t}}{1 + R_L} = A_{M,t} \left[ \pi_{\pi C,t}^{\phi_\pi} \right]^{1-\phi_r} \left[ \frac{1 + R_{L,t-1}}{1 + R_L} \right]^{\phi_r}, \quad \phi_\pi > 1, \, \phi_r < 1
\]

- Interest rate smoothing
- Monetary policy targets inflation in the non-durable sector
Functional Forms

Utility function:

\[ U(X_t, N_{C,t}, N_{H,t}) \equiv \ln X_t - \frac{\nu}{1 + \varphi} \left[ N_{C,t}^{1+\xi} + N_{H,t}^{1+\xi} \right]^{\frac{1+\varphi}{1+\xi}}, \quad \varphi, \xi \geq 0 \]

Leverage Ratio:

\[ \frac{l}{l + w_C N_c + w_H N_H} \]

Total output:

\[ Y_t = Y_{C,t} + p_{h,t} Y_{H,t} \]
Exogenous Shocks

\[
\ln A_{C,t} = \rho_C \ln A_{C,t-1} + \epsilon_{C,t}
\]

\[
\ln A_{H,t} = \rho_H \ln A_{H,t-1} + \epsilon_{H,t}
\]

\[
\ln A_{M,t} = \rho_M \ln A_{M,t-1} + \epsilon_{M,t}
\]

Idiosyncratic risk in the housing sector:

\[
\ln \omega_t \sim N \left( -\frac{\sigma^2_{\omega,t}}{2}, \sigma^2_{\omega,t} \right)
\]

Mortgage risk shock:

\[
\ln \frac{\sigma_{\omega,t}}{\sigma_{\omega}} = \rho_{\sigma} \ln \frac{\sigma_{\omega,t-1}}{\sigma_{\omega}} + \epsilon_{\sigma_{\omega,t}}
\]
## Benchmark Calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma$</td>
<td>0.99</td>
<td>Discount factor of Savers</td>
</tr>
<tr>
<td>$\beta$</td>
<td>0.98</td>
<td>Discount factor of Borrowers</td>
</tr>
<tr>
<td>$\psi$</td>
<td>0.5</td>
<td>Relative size of Borrower group</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.01</td>
<td>Rate of depreciation for housing</td>
</tr>
<tr>
<td>$\varepsilon_C$</td>
<td>7.5</td>
<td>Elasticity of substitution for $C$ goods</td>
</tr>
<tr>
<td>$\varepsilon_H$</td>
<td>7.5</td>
<td>Elasticity of substitution for $H$ goods</td>
</tr>
<tr>
<td>$\zeta$</td>
<td>3</td>
<td>Elasticity of substitution across labor inputs</td>
</tr>
<tr>
<td>$\zeta$</td>
<td>0.5</td>
<td>Share of Borrower labor in the production function</td>
</tr>
<tr>
<td>$\xi$</td>
<td>0.871</td>
<td>Elasticity of substitution across labor types</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.16</td>
<td>Share of housing in consumption bundle</td>
</tr>
<tr>
<td>$\nu$</td>
<td>2.5</td>
<td>Disutility from work</td>
</tr>
<tr>
<td>$\eta$</td>
<td>1</td>
<td>Elasticity of substitution between $C$ and $H$ goods</td>
</tr>
<tr>
<td>$\varphi$</td>
<td>1</td>
<td>Inverse of elasticity of labor supply</td>
</tr>
<tr>
<td>$\theta_C$</td>
<td>0.67</td>
<td>Calvo probability in $C$</td>
</tr>
<tr>
<td>$\theta_H$</td>
<td>0</td>
<td>Calvo probability in $H$</td>
</tr>
<tr>
<td>$\phi_\pi$</td>
<td>1.5</td>
<td>Taylor-rule coefficient on inflation</td>
</tr>
<tr>
<td>$\phi_r$</td>
<td>0.9</td>
<td>Taylor-rule coefficient on past nominal interest rate</td>
</tr>
<tr>
<td>$\rho_C$</td>
<td>0.9</td>
<td>Serial correlation of productivity shocks in $C$</td>
</tr>
<tr>
<td>$\rho_H$</td>
<td>0.9</td>
<td>Serial correlation of productivity shocks in $H$</td>
</tr>
<tr>
<td>$\rho_M$</td>
<td>0</td>
<td>Serial correlation of monetary policy shocks</td>
</tr>
<tr>
<td>$\sigma_\omega$</td>
<td>0.20</td>
<td>Standard deviation of idiosyncratic shocks</td>
</tr>
<tr>
<td>$\mu$</td>
<td>0.12</td>
<td>Monitoring cost</td>
</tr>
</tbody>
</table>
Low-Leverage Calibration: $\sigma_\omega = 0.6$

<table>
<thead>
<tr>
<th>Variable</th>
<th>Benchmark</th>
<th>Low Leverage</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output $C$</td>
<td>0.5407</td>
<td>0.5399</td>
<td>0.15</td>
</tr>
<tr>
<td>Output $H$</td>
<td>0.1465</td>
<td>0.1419</td>
<td>3.24</td>
</tr>
<tr>
<td>Consumption, Borrowers</td>
<td>0.4789</td>
<td>0.4887</td>
<td>-2.01</td>
</tr>
<tr>
<td>Consumption, Savers</td>
<td>0.6026</td>
<td>0.5912</td>
<td>1.93</td>
</tr>
<tr>
<td>Housing Demand, Borrowers</td>
<td>11.5421</td>
<td>10.5337</td>
<td>9.57</td>
</tr>
<tr>
<td>Housing Demand, Savers</td>
<td>17.7524</td>
<td>17.8431</td>
<td>-0.51</td>
</tr>
<tr>
<td>Hours Worked, Borrowers in $C$ Sector</td>
<td>0.5879</td>
<td>0.5789</td>
<td>1.55</td>
</tr>
<tr>
<td>Hours Worked, Borrowers in $H$ Sector</td>
<td>0.1617</td>
<td>0.1549</td>
<td>4.41</td>
</tr>
<tr>
<td>Hours Worked, Savers in $C$ Sector</td>
<td>0.4948</td>
<td>0.5019</td>
<td>-1.41</td>
</tr>
<tr>
<td>Hours Worked, Savers in $H$ Sector</td>
<td>0.1361</td>
<td>0.1343</td>
<td>1.37</td>
</tr>
<tr>
<td>Loans</td>
<td>2.1747</td>
<td>0.7980</td>
<td>172.54</td>
</tr>
<tr>
<td>Loan-to-Value Ratio*</td>
<td>59.17</td>
<td>24.37</td>
<td>142.80</td>
</tr>
<tr>
<td>Leverage Ratio*</td>
<td>80.12</td>
<td>60.01</td>
<td>33.51</td>
</tr>
<tr>
<td>Default Rate on Mortgages†</td>
<td>2.36</td>
<td>8.21</td>
<td>-71.22</td>
</tr>
<tr>
<td>External Finance Premium†</td>
<td>0.41</td>
<td>2.44</td>
<td>-83.20</td>
</tr>
<tr>
<td>Mortgage Interest Rate†</td>
<td>4.51</td>
<td>6.54</td>
<td>-31.04</td>
</tr>
</tbody>
</table>

* Percentage points.
†Annual, percentage points.
Credit Crunch

Mortgage Risk shock: increase in $\sigma_{\omega,t}$, the standard deviation of the distribution of idiosyncratic housing investment risk
Responses to a 40% Increase in $\sigma_{\omega,t}$: Benchmark Calibration

Note: Default rate is annual and in percentage points. Loans are difference from steady state, multiplied by 100. All other variables are percentage point deviation from steady state.
Responses to a 40% Increase in $\sigma_{\omega.t}$: Benchmark Calibration
Responses to a 40% Increase in $\sigma_{\omega,t}$: Low-Leverage Calibration
Responses to a 40% Increase in $\sigma_{\omega,t}$: Low-Leverage Calibration
Credit Crunch and Leverage

- Credit crunch is deeper in high-leverage economies
- Stronger adverse effects on Borrowers
- Loans, consumption of non-durable goods, and housing investment fall more
- Deeper fall in total output
Responses to a 40% Increase in $\sigma_{\omega,t}$ with Non-inertial Rule
Responses to a 40% Increase in $\sigma_{\omega,t}$ with Non-inertial Rule

\[ \phi_r = 0.9 \]
\[ \phi_r = 0.5 \]
\[ \phi_r = 0 \]
Interest Rate Flexibility

- Interest rate flexibility is important in the response to a mortgage risk shock
- Policy rate is cut more aggressively and non-durable consumption falls less
- Housing prices increase (because Borrowers and Savers increase hours in the housing sector by less)
- Strong inertial rules mimic a zero bound scenario where interest rate cannot be lowered further and the negative effects of a mortgage risk shock are amplified
Responses to a 25 basis points Monetary Shock

- Aggr Consumption
- Output
- Output H
- Rel Price H
- Default Rate
- Loans
Responses to a 25 basis points Monetary Shock
Monetary Policy Shock and Sectoral Co-movement

- Representative agent models with sticky non-durable and flexible durable prices display negative co-movement in response to a monetary shock - see Barsky et al. (2007), Carlstrom and Fuerst (2006)

- Empirical evidence supports positive co-movement - see Erceg and Levin (2006)

- Models with credit constraints display positive co-movement only with sticky durable prices - see Monacelli (2009)

- Our model displays positive co-movement with sticky durable prices

- Role of wage stickiness in the housing sector
Conclusions and Extensions

Our model under-predicts the fall in total output and real housing prices seen in the Great Recession

- Perverse effect of monitoring costs. Make the housing sector response: adjustment costs in the housing sector
- Wage stickiness to dampen the output response in the housing sector
- Financial intermediation to provide capital to firms to amplify the effects of mortgage risk shocks
- Consider fixed-rate multi-year contracts and ARM contracts with nonstandard features
VAR Evidence: Innovation to Delinquencies

Notes: VAR estimated from 1980Q1 to 2009Q4. The dashed lines indicate the +/- one standard error bands. The Choleski ordering is DELHP, RR, DP, QQHP, CCHP, IHHP. Vertical axis: percent deviation from baseline.
VAR Evidence: IR of Delinquencies to Innovation to All Variables

- Response of DELHP to DELHP
- Response of DELHP to RR
- Response of DELHP to DP
- Response of DELHP to QQHP
- Response of DELHP to CCHP
- Response of DELHP to IHHP