Financial Stability and Optimal Interest-Rate Policy

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Federal Reserve Board

The New Normal of Monetary Policy, March 2015

The views expressed herein are of the authors and do not represent the opinions of the Federal Reserve Board of Governors or the Federal Reserve System.
Motivation

- Should interest-rate policy be altered in response to changes in credit conditions?
  - Focus on optimal policy.

- Intertemporal trade-off between costs and benefits of leaning against financial imbalances.
  - Reduced economic activity today in exchange for lower likelihood of crises tomorrow.
  - How quantitatively relevant?
What We Do

▶ Build a New Keynesian model with endogenous financial crises.

▶ Characterize optimal interest-rate policy in presence of endogenous probability of a crisis.
  ▶ Non-linear quadratic approach.

▶ Characterize optimal interest-rate policy accounting for parameter uncertainty.
  ▶ Bayesian and Robust Control approaches.
What We Find

- Optimal interest-rate adjustment in response to credit conditions is very small under baseline calibration.
What We Find

- Optimal interest-rate adjustment in response to credit conditions is *very small* under baseline calibration.

- Optimal policy can call for *larger* interest-rate adjustments when crisis probability is more sensitive to credit imbalances or crisis is expected to be severe.
What We Find

- Optimal interest-rate adjustment in response to credit conditions is very small under baseline calibration.

- Optimal policy can call for larger interest-rate adjustments when crisis probability is more sensitive to credit imbalances or crisis is expected to be severe.

- Uncertainty over the crisis probability and its sensitivity to monetary policy calls for more aggressive interest-rate policy.
  
  - Deviation from attenuation principle (Brainard (1967)).
Outline

The Model
Calibration
Baseline Results
Sensitivity Analysis
Role of Uncertainty
Conclusions
The Model

- New Keynesian sticky-price model with an endogenous financial crisis event.

- Crisis follows a Markov process. Transition probability depends on aggregate financial conditions.

- Two periods, denoted $t = 1$ and $t = 2$.

- Trade-off: Tighter interest-rate policy in normal times can lower output in $t = 1$ and reduce probability of crisis occurring in period $t=2$. 
Private Sector

Output gap $y$, inflation $\pi$, and credit conditions $L$ in $t = 1$:

\[
y_1 = E_1^{ps} y_2 - \sigma [i_1 - E_1^{ps} \pi_2]
\]
\[
\pi_1 = \kappa y_1 + E_1^{ps} \pi_2
\]
\[
L_1 = \rho_L L_0 + \phi_i i_1 + \phi_y y_1 + \phi_\pi \pi_1 + \phi_0.
\]

In period $t = 2$ output gap and inflation can take values:

\[
(y_2, \pi_2) = \begin{cases} 
(y_2, nc, \pi_2, nc), & \text{with probability } 1 - \gamma_1 \\
(y_2, c, \pi_2, c), & \text{with probability } \gamma_1 
\end{cases}
\]

with $y_2, c < y_2, nc = 0$ and $\pi_2, c < \pi_2, nc = 0$ and

\[
\gamma_1 = \frac{\exp(h_0 + h_1 L_1)}{1 + \exp(h_0 + h_1 L_1)}
\]

$E_1^{ps}$ non-rational private sector expectations in $t = 1$. 
Private Sector

- Private sector expectations are optimistic on crisis probability. Supporting evidence from surveys.
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- Deviation from rational expectations: Private sector perceives crisis probability as fixed and negligible (not a function of $L_1$):

$$ (y_2, \pi_2) = \begin{cases} (y_{2, nc}, \pi_{2, nc}), & \text{with probability } 1 - \varepsilon \\ (y_{2, c}, \pi_{2, c}), & \text{with probability } \varepsilon \end{cases} $$
Private Sector

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$$(y_2, \pi_2) = \begin{cases} (y_2, nc, \pi_2, nc), & \text{with probability } 1 - \varepsilon \\ (y_2, c, \pi_2, c), & \text{with probability } \varepsilon \end{cases}$$

- Assumption eliminates precautionary saving motive. Focus on intertemporal policy trade-off.
Central Bank’s Problem

- The policy problem: choose policy rate in \( t=1 \) given initial credit conditions, \( L_0 \):

\[
WL_1 = \min_{i_1} u(y_1, \pi_1) + \beta E_1[WL_2]
\]

subject to the private sector equilibrium conditions.
Central Bank’s Problem

- The policy problem: choose policy rate in $t=1$ given initial credit conditions, $L_0$:

$$WL_1 = \min_{i_1} u(y_1, \pi_1) + \beta E_1[WL_2]$$

subject to the private sector equilibrium conditions.

- Per-period welfare loss:

$$u(y_1, \pi_1) = \frac{1}{2}(\lambda y_1^2 + \pi_1^2).$$
Central Bank’s Problem

▶ The policy problem: choose policy rate in t=1 given initial credit conditions, \( L_0 \):

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WL_1 = \min_{i_1} u(y_1, \pi_1) + \beta E_1[WL_2]
\]

subject to the private sector equilibrium conditions.

▶ Per-period welfare loss:

\[
u(y_1, \pi_1) = \frac{1}{2}(\lambda y_1^2 + \pi_1^2).
\]

▶ Expected welfare loss in period \( t = 2 \):

\[
E_1[WL_2] = (1 - \gamma_1)WL_{2,nc} + \gamma_1 WL_{2,c}
\]

where:

\[
WL_{2,nc} = u(y_{2,nc}, \pi_{2,nc}), \quad WL_{2,c} = \frac{u(y_{2,c}, \pi_{2,c})}{1 - \beta \mu}
\]
# Calibration - NK block

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Parameter Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard parameters</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta$</td>
<td>Discount Factor</td>
<td>0.995</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>Interest-rate sensitivity of output</td>
<td>1.0</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>Slope of the Phillips Curve</td>
<td>0.024</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>Weight on output stabilization</td>
<td>1/16</td>
</tr>
<tr>
<td>$i^*$</td>
<td>Long-Run Natural Rate of Interest</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>Parameters related to the second period</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$y_{2,nc}$</td>
<td>Output gap in the non-crisis state</td>
<td>0</td>
</tr>
<tr>
<td>$\pi_{2,nc}$</td>
<td>Inflation gap in the non-crisis state</td>
<td>0</td>
</tr>
<tr>
<td>$WL_{2,nc}$</td>
<td>Loss in the non-crisis state</td>
<td>0</td>
</tr>
<tr>
<td>$y_{2,c}$</td>
<td>Output gap in the crisis state</td>
<td>-0.1</td>
</tr>
<tr>
<td>$\pi_{2,c}$</td>
<td>Inflation gap in the crisis state</td>
<td>$-0.02/4$</td>
</tr>
<tr>
<td>$\mu$</td>
<td>Persistence of the crisis state</td>
<td>$7/8$</td>
</tr>
<tr>
<td>$WL_{2,c}$</td>
<td>Loss in the crisis state</td>
<td>$\frac{u(y_{2,c}, \pi_{2,c})}{1-\beta\mu}$</td>
</tr>
<tr>
<td>$\epsilon$</td>
<td>Perceived crisis probability</td>
<td>0.05/100</td>
</tr>
</tbody>
</table>
Calibration - Crisis Probability

- Calibrate transition probability parameters:
  \[ \gamma_1 = \frac{\exp(h_0 + h_1 L_1)}{1 + \exp(h_0 + h_1 L_1)} \]

- Credit conditions:
  \[ L_1 = \phi_0 + \rho_L L_0 + \phi_y y_1 + \phi_i i_1 + \phi_\pi \pi_1 + \varepsilon_1 \]
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- Adapt Schularick and Taylor (2012) findings: \( L \) cumulative 5-year growth rate of real bank loans.
Calibration - Crisis Probability

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\[ \gamma_1 = \frac{\exp(h_0 + h_1 L_1)}{1 + \exp(h_0 + h_1 L_1)} \]

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- Adapt Schularick and Taylor (2012) findings: \( L \) cumulative 5-year growth rate of real bank loans.

- Growth of real bank loans can depend on \((y, \pi, i)\)

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<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Parameter Value</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>( h_0 )</td>
<td>Constant term</td>
<td>-3.396</td>
<td>0.54</td>
</tr>
<tr>
<td>( h_1 )</td>
<td>Coefficient on ( L )</td>
<td>1.88</td>
<td>0.57</td>
</tr>
<tr>
<td>( \rho_L )</td>
<td>Coefficient on the lagged ( L )</td>
<td>0.95</td>
<td></td>
</tr>
<tr>
<td>( \phi_0 )</td>
<td>Intercept</td>
<td>((1 - \rho_L) * 0.2)</td>
<td></td>
</tr>
<tr>
<td>( \phi_i )</td>
<td>Coefficient on the policy rate</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>( \phi_y )</td>
<td>Coefficient on output gap</td>
<td>0.18</td>
<td>0.04</td>
</tr>
<tr>
<td>( \phi_\pi )</td>
<td>Coefficient on inflation gap</td>
<td>-1</td>
<td>-</td>
</tr>
</tbody>
</table>
Basic Trade-off

Output Gap Today

Policy Rate (Ann. %)
Loss Today: $u(y_1, \pi_1)$

Continuation Loss: $\beta E_1[W_L]$

Overall Loss: $u(y_1, \pi_1) + \beta E_1[W_L]$

Inflation Today

Policy Rate (Ann. %)

Quarterly Crisis Probability (%)

*With $L_0 = 0.2$ ($L_0$ is the lagged 5-yr growth rate of real bank loans)
Optimal Policy

- Output Gap (%)
- Inflation (Ann. %)
- Policy Rate (Ann. %)
- Quarterly Crisis Probability (%)

Graphs showing the relationships between lagged credit conditions ($L_0$), output gap, inflation, policy rate, and quarterly crisis probability.
Sensitivity Analysis

Crisis probability more sensitive to policy rate (higher $h_1$ and $\phi_y$).

More Effective Baseline

More Sensitivity Results
Motivation:

- Parameters related to crises are particularly uncertain because crises are infrequent.
Optimal Policy with Parameter Uncertainty

4 Sources of Uncertainty:

- $h_1$: Elasticity of crisis probability to credit conditions.
- $\phi_y$: Elasticity of credit conditions to output.
- $(\pi_{2,c}, y_{2,c})$: “Severity” of the crisis.
- $(\sigma, \kappa)$: Elasticity of today’s output/inflation to policy rate.

2 Types of Policymaker:

- Bayesian
- Robust
2 Types of Policymakers

Bayesian policymaker:

$$\min_{i_1} E_{1,\theta} \left[ u(y_1, \pi_1) + \beta WL_2 \right]$$

Robust policymaker:

$$\min_{i_1} \left[ \max_{\theta \in [\theta_{min}, \theta_{max}]} u(y_1, \pi_1) + \beta E_1[WL_2] \right]$$

where $\theta$ is the set of parameters subject to uncertainty.
## Calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncertain Elasticity of Crisis Prob. to Credit Conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$h_{1,\text{min}}$</td>
<td>0.74</td>
<td>1/3</td>
</tr>
<tr>
<td>$h_{1,\text{base}}$</td>
<td>1.88</td>
<td>1/3</td>
</tr>
<tr>
<td>$h_{1,\text{max}}$</td>
<td>3.02</td>
<td>1/3</td>
</tr>
<tr>
<td>Uncertain Severity of Srisis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\pi_{2,c,\text{min}}$</td>
<td>$-0.03/4$</td>
<td>1/3</td>
</tr>
<tr>
<td>$\pi_{2,c,\text{base}}$</td>
<td>$-0.02/4$</td>
<td>1/3</td>
</tr>
<tr>
<td>$\pi_{2,c,\text{max}}$</td>
<td>$-0.01/4$</td>
<td>1/3</td>
</tr>
<tr>
<td>$y_{2,c,\text{min}}$</td>
<td>$-0.15$</td>
<td>1/3</td>
</tr>
<tr>
<td>$y_{2,c,\text{base}}$</td>
<td>$-0.1$</td>
<td>1/3</td>
</tr>
<tr>
<td>$y_{2,c,\text{max}}$</td>
<td>$-0.05$</td>
<td>1/3</td>
</tr>
</tbody>
</table>
Uncertain crisis prob. \((h_1)\)

\[ h_1: \text{Elasticity of crisis prob. to credit conditions} \]
Trade-off faced by the Bayesian Policymaker

Output Gap Today

Inflation Today

Exp. Loss Today: $E[u(y_1, \pi_1)]$

Continuation Loss: $\beta E_1[WL_2]$

Exp. Overall Loss: $E[u(y_1, \pi_1) + \beta WL_2]$

Exp. Quarterly Crisis Prob. (%)
Fig: The Effects of a Mean-Preserving Spread on $h_1$ for the Crisis Probability Function: $\gamma_1 = \frac{\exp(h_0+h_1L_1)}{1+\exp(h_0+h_1L_1)}$
Objective function of the hypothetical evil agent

\[ u(y_1, \pi_1) + \beta E_1[W L_2] \]
Uncertain severity of the crisis \((y_{2,c}, \pi_{2,c})\)

*(\(y_{2,c}, \pi_{2,c}\)): Output gap and inflation in the crisis*
Table: Effects of Uncertainty on Optimal Policy Rate

<table>
<thead>
<tr>
<th></th>
<th>Bayesian</th>
<th>Robust</th>
</tr>
</thead>
<tbody>
<tr>
<td>$h_1$</td>
<td>Higher</td>
<td>Higher</td>
</tr>
<tr>
<td>$(\pi_2, c, y_2, c)$</td>
<td>Higher</td>
<td>Higher</td>
</tr>
<tr>
<td>$(\sigma, \kappa)$</td>
<td>Lower</td>
<td>Lower</td>
</tr>
</tbody>
</table>
Conclusions

- Solve for optimal interest-rate policy in a New Keynesian model with endogenous financial crises.
  - Optimal adjustment to interest rates in response to credit conditions is very small under baseline calibration.
  - Optimal policy can call for larger interest-rate adjustments under alternative/plausible calibrations.

- Compute optimal policy under parameter uncertainty.
  - Bayesian and robust-control central banks should respond more aggressively when probability and severity of financial crises are uncertain.
THANK YOU
Output Growth and Inflation Expectations in the Great Recession: Evidence from the SPF

- Every quarter, participants in the Survey of Professional Forecasters (SPF) report the probability distribution of the growth rate of real average GDP and CPI expected over the current and next calendar years.
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Great Recession episode:
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Great Recession episode:
- Realized average real GDP fell by -0.29% in 2008, and -2.81% in 2009.
Output Growth and Inflation Expectations in the Great Recession: Evidence from the SPF

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- Great Recession episode:
  - Realized average real GDP fell by -0.29% in 2008, and -2.81% in 2009.
  - CPI inflation recorded a negative entry in 2008:Q4 and quickly reverted into positive territory.
Output Growth and Inflation Expectations in the Great Recession: Evidence from the SPF

Figure: Probability of Negative Growth of Average Real GDP in 2008 and 2009

(a) 2008

(b) 2009
Output Growth and Inflation Expectations in the Great Recession: Evidence from the SPF

Figure: Probability of Negative Growth of Average CPI in 2008 and 2009

(a) 2008

(b) 2009
Output Growth and Inflation Expectations in the Great Recession: Evidence from the SPF

Output Growth and Inflation Expectations in the Great Recession: Evidence from the SPF


- Expectations that recession will be lengthy and costly is updated with a lag to unfolding of events.

Expectations that recession will be lengthy and costly is updated with a lag to unfolding of events.

Forecasters’ expectations for GDP growth and CPI inflation do not seem to respond preemptively to the accumulation of financial imbalances in the 2000s.
Sensitivity Analysis (II)

Larger declines in output and inflation during a crisis (lower $y_{2,c}$ and $\pi_{2,c}$).

- Output Gap (%)
- Inflation (Ann. %)
- Policy Rate (Ann. %)
- Quarterly Crisis Prob. (%)
Sensitivity Analysis (III)

Today’s output and inflation less sensitive to policy rate (lower $\sigma$ and $\kappa$).

Graphs showing:
- Output Gap (%)
- Inflation (Ann. %)
- Policy Rate (Ann. %)
- Quarterly Crisis Prob. (%)
Calibration Crisis Probability

- Predictor in annual terms:

\[ L^a_t = \sum_{s=0}^{4} \Delta \log \frac{B_{i,t-s}}{P_{i,t-s}} \]

- Predictor in quarterly terms:

\[ L^q_t := \sum_{s=0}^{19} \Delta \log \frac{B_{t-s}}{P_{t-s}} \approx \Delta \log \frac{B_t}{P_t} + \frac{19}{20} L^q_{t-1} \]

applied to post-war U.S. data:

![Graphs](https://via.placeholder.com/150)

(c) Annual Predictor

(d) Quarterly trailing sum
Calibration Bank Lending Growth

- Quarterly real credit growth: \( \Delta \log \frac{B_t}{P_t} = \Delta \log B_t - \pi_t \)
Calibration Bank Lending Growth

- Quarterly real credit growth: \( \Delta \log \frac{B_t}{P_t} = \Delta \log B_t - \pi_t \)
- We estimate a process for nominal bank lending growth:

  \[
  \Delta \log B_t = c + \phi_i i_t + \phi_y y_t + \varepsilon^B_t
  \]

  instrumenting \( i_t \) and \( y_t \) with their lagged values.
Calibration Bank Lending Growth

- Quarterly real credit growth: $\Delta \log \frac{B_t}{P_t} = \Delta \log B_t - \pi_t$
- We estimate a process for nominal bank lending growth:

  $$\Delta \log B_t = c + \phi_i i_t + \phi_y y_t + \epsilon_t^B$$

  instrumenting $i_t$ and $y_t$ with their lagged values.
- So that:

  $$L_1 \approx \rho L L_0 + \phi_0 + \phi_y y_1 + \pi_1 + \epsilon_1$$

<table>
<thead>
<tr>
<th>Parameter</th>
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<th>SE</th>
</tr>
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<tbody>
<tr>
<td>$\rho_L$</td>
<td>Coefficient on the lagged $L$</td>
<td>19/20</td>
<td></td>
</tr>
<tr>
<td>$\phi_0$</td>
<td>Intercept</td>
<td>$(1 - \rho_L) \times 0.2$</td>
<td></td>
</tr>
<tr>
<td>$\phi_i$</td>
<td>Coefficient on the policy rate</td>
<td>0</td>
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