Monetary Policy Implementation in an Interbank Network: Effects on Systemic Risk

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6-7 October 2014, ECB conference on ”Non standard monetary policy measures”
Motivation

- Monetary policy and financial stability: effects of liquidity provision by central bank on risk and investment
- Traditionally measured through Taylor rule responding to financial variables
- Transmission mechanism shall be evaluated through interbank market micro-structure
- Effects on risk and liquidity depend upon network externalities
Monetary Policy Trade-offs

Effects on individual banks:

1. Lender of last resort makes illiquid banks more resilient
2. Increases liquidity available for long term investment
3. Fall of interbank rates: induces asset substitution between interbank lending and investment in non liquid assets
Monetary Policy Trade-offs

- Effects of systemic risk:
  1. By reducing the risk of illiquidity reduces probability of bank defaults
  2. By reducing interbank borrowing it reduces the scope of interconnections
  3. By increasing investment in long term assets it increases the scope of pecuniary externalities
Scope of Model

- Banks solve portfolio optimization choosing between bank lending/borrowing and long term investment
- Network in interbank market featuring both contagion through interconnection and pecuniary externalities
- Central bank injects liquidity to achieve a certain target rate
- Though plausible calibrated parameters assess the effects of liquidity injection on systemic risk
Banks feature regulatory and liquidity constraints
Assess effects of monetary policy for different regulatory requirements
Optimal combination policy
Past Literature

- No model with monetary policy implemented through direct liquidity provision into networked interbank market
- Bartolini, Bertola and Prati 2002: model of the interbank money market with role for central bank intervention
- Literature on banking networks:
  1. Random networks: Gai and Kapadia 2010
  2. Contagion through interconnection and pecuniary externalities: Cifuentes, Ferrucci and Shin 2005
  3. Contagion through learning: Caballero and Simsek 2014
Banks and Interbank Markets

- Endogenous dynamic network model:
  1. Optimizing banks: choosing interbank lending/borrowing and non-liquid assets
  2. Banks are heterogenous in their returns to investment
  3. Endogenous price process (tatonnement): central Walrasian auctioneer (Duffie and Zhu 2010)

- Analyze evolution of systemic risk: Shapley values from non-cooperative game theory
The Model

- $N$ banks: $N \in \{1, \ldots, n\}$ finite evolving set of banks (nodes)
- $g_{i,j} \neq 0$ link (directed network): cross borrowing and lending
- $n \times n$ square adjacency matrix $G(t)$ describes the (endogenous) connections
- Banks objective function:

$$E(\pi^i) = l^i \cdot r^{rf} + \frac{r^i}{p} \cdot e^i - b^i \cdot r^{rf} \cdot \frac{1}{1 - \zeta PD^i}$$
Banks’ Constraints

\[ c^i \geq \alpha \cdot d \]
\[ er^i = \frac{c^i + p \cdot e^i + l^i - d^i - b^i}{\chi_1 \cdot p \cdot e^i + \chi_2 l^i} \geq \gamma + \tau \]
\[ e^i \geq 0. \]
After banks’ optimization, summing up all supplied and demanded funds: suppose \( F_{\text{demand}} < F_{\text{supply}} \).

Risk-free rate: \( r_0^{rf} \leq r_0^{rf} \leq \bar{r}_0^{rf} \). New lending rate: \( r_1^{rf} = \frac{r_0^{rf} + r_0^{rf}}{2} \)

Once price has been determined clearing of trading is done with ’closest matching partners

\( PD^i \), derived endogenously via iterative algorithm
Heterogenous returns but single price emerges

Inverse demand function:

\[ p = \exp(-\varphi \sum_i s_i), \]
Systemic Risk

Ratio of assets from all defaulting banks subsequent to a shock to non-liquid assets:

$$\Phi = \frac{\sum_{\text{def}} \text{assets}_{\text{def}}}{\sum_{i} \text{assets}_i},$$

$\text{def} \in i$ indexes banks that are in default after the financial system has absorbed the shock
Shock Algorithm

- Shock: a loss in banks’ non-liquid asset holdings. Eisenberg and Noe 2001
- If bank cannot fulfill its capital requirement, it sells non-liquid assets and could default on debt obligations
- Downward pressure on prices: further sales might lead to default
- Insolvent banks (negative equity-value) transmit shocks to their creditors
### Table: Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Distribution</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>0.1</td>
<td>$N(65, 10)$</td>
<td></td>
</tr>
<tr>
<td>$\chi_1$</td>
<td>1</td>
<td>$U(0, 0.15)$</td>
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</tr>
<tr>
<td>$\chi_2$</td>
<td>0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\gamma$</td>
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<td></td>
</tr>
<tr>
<td>$d$</td>
<td>500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\zeta$</td>
<td>0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$e$</td>
<td></td>
<td></td>
<td>$N(\mu, \sigma^2, \rho)$</td>
</tr>
<tr>
<td>$r'$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Psi$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
loan or bond investment relative to their equity. Note that lenders provide

**Financial System in Baseline Setting**

```
6% of fin. syst.
500% of banks’ equity
Interbank rate: 3.6824%
NLA–E ratio: 797.5772%
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Figure 2: Financial System in Baseline Scenario

The figure displays a random financial system drawn from the parameter values on Table 2. Each bank is represented by a red ball, with the banks’ identifiers in the middle of the ball. The diameter of a ball indicates the bank’s size, measured by the sum of its risk weighted assets relative to the sum of all risk weighted assets in the financial system. An arrow pointing from bank A to bank B shows that bank A has lent money to bank B, with the thickness of the arrow indicating the amount of funds lent relative to banks’ equity. Below each of the stylized financial system there are four further indicators. First, the red ball gives an indication about the percentage of the financial systems a specific ball designates. Second, the thickness of the black line below gives an indication about how much lending a representative arrow designates relative to banks’ equity. Third, the interbank rate is the equilibrium interest rate realizing on the interbank market. Fourth, the non-liquid-assets-to-equity (NLA–E) ratio gives an indication about how much banks have invested on average in non-liquid assets relative to their equity.

about 5-6 times their capital on the interbank market. This number is about
Figure 3: Evolution of systemic risk, ratio of non-liquid asset to equities and ratio of liquid assets to equities under different values of capital requirements and under two scenarios, with and without central bank intervention.
network is higher for cases in which the interbank interest rate increases beyond the central bank interest rate corridor and lower for cases in which the interbank interest rate decreases below the threshold. In particular for low levels of the capital requirement ratio, when the interest rate on the interbank market tends to be above the central bank intervention threshold, the central bank increases liquidity in the system via providing additional funds. This results in a higher non-liquid assets to equity ratio relative to the case without central bank intervention, increasing the scope for contagion via firesales. Therefore, systemic risk is higher with central bank interventions at low capital requirement ratios.

As a robustness analysis of the interplay between regulatory policies, central bank intervention and systemic risk, we repeat our analysis for a range of liquidity requirement ratios. Figure 4 shows the evolution of sys-

![Figure 4: Evolution of systemic risk, ratio of non-liquid asset to equities and ratio of interbank loans to equities under different values of liquidity ratios and under two scenarios, with and without central bank interventions.](image)
Conclusions

- Monetary policy transmission in interbank markets with network and pecuniary externalities
- Given parameters pecuniary externalities prevail and liquidity injections increases systemic risk
- Systemic risk always decreases with higher capital ratios, it increases with central bank interventions and higher liquidity ratios