Risk Incentives in an Interbank Network

Miguel Faria-e-Castro
New York University

Endogenous Financial Networks and Equilibrium Dynamics
Banque de France

July 10, 2015
Financial Crises and Bank Herding

- Non-anonymous markets
- Limited liability
- Risk shifting

Incentives to

- Correlate failures
- Endogenous intermediation?
This Model

Main features:
- Non-anonymous market for debt contracts
- Liquidity shocks motivate risky debt contracts
- *Direct* (counterparty) and *indirect* (systemic) risk
- Endogenous network formation
- Arbitrary number of heterogeneous banks

Main results:
- “Risk-based” intermediation
- Bank herding, risk-shifting behavior
- Network structure amplifies risk
- Policy: caps on lending, LOLR, creditor bailouts
Literature


- **Bank Herding**: Acharya (2009), Acharya and Yorulmazer (2008).
Example

- 2 periods, 3 banks
- Banks own long-term asset $a$, senior claims $v$
  - bad: $a = v - \varepsilon < v$
  - good: $a = v + \varepsilon > v$
- Payoffs are non-pledgeable $\Rightarrow$ debt contracts
- Banks endowed with net liquidity position $z$
- Liquidity technology at rate $r$, or borrow from bank with liquidity surplus
Example continued

Assume the following payoff structure

<table>
<thead>
<tr>
<th>State</th>
<th>Bank 1</th>
<th>Bank 2</th>
<th>Bank 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>$s_1$</td>
<td>$v - \epsilon$</td>
<td>$v + \epsilon$</td>
<td>$v + \epsilon$</td>
</tr>
<tr>
<td>$s_2$</td>
<td>$v + \epsilon$</td>
<td>$v - \epsilon$</td>
<td>$v - \epsilon$</td>
</tr>
<tr>
<td>$s_3$</td>
<td>$v + \epsilon$</td>
<td>$v + \epsilon$</td>
<td>$v - \epsilon$</td>
</tr>
</tbody>
</table>

- 1 and 3 are negatively correlated
- 2 is (partially) correlated with both

Endowments:

$$z_1 = -z$$
$$z_2 = 0$$
$$z_3 = z$$

Default is socially costly, with zero recovery rate.
Autarky

- Bank 1 borrows from outside at rate $r$
- Bank 3 willing to offer a cheaper contract
- Gains from trade, avoid costly liquidity technology
3 lends to 1

- Dominates autarky as long as $r > 1$
- Socially optimal
May not be stable...

Under certain conditions,

- Bank 2 willing to lend to 1 at a lower rate
- Bank 3 willing to lend to 2 at a lower rate
- Pairwise stable, but inefficient equilibrium
- Bank 3 now defaults in state $s_{23}$!

Limited Liability + Non-Anonymous Market = Systemic Risk
General Model - Environment

- Two dates $t = 0, 1$
- One good, cash (liquidity)
- $N$ islands, each populated by a representative bank and depositors
- Banks indexed by long-term assets and initial deposits $(a_i, d_i)$
- $t = 0$: liquidity shock $z_i$, banks may engage in debt contracts.
- $t = 1$: Illiquid long-term assets pay $R_i \sim g(R)$, contracts are settled
Interbank Lending

- Banks lend to each other to clear liquidity positions
- Lending from bank $i$ to bank $j$

$$l_{ij}$$

- Interbank lending forms a credit network

$$L = \begin{bmatrix}
0 & l_{12} & \ldots & l_{1N} \\
l_{21} & 0 & \ldots & l_{2N} \\
\vdots & \vdots & \ddots & \vdots \\
l_{N1} & l_{N2} & \ldots & 0
\end{bmatrix}$$

This network is
- **directed**

$$l_{ij} \neq l_{ji}$$

- **weighted**

$$l_{ij} \in \mathbb{R}^+$$
Flow of Funds and Payoffs

Banks must clear liquidity positions at $t = 0$

$$\sum_{j \neq i} \ell_{ij} + c_i = \sum_{j \neq i} \ell_{ji} + v_i + z_i$$

- **Outflows**
- **Inflows**

Profits at $t = 1$

$$\pi_i^+(R_i, \theta) = \left[ R_i a_i + c_i + \sum_{j \neq i} \theta_j r_{ij} \ell_{ij} - \sum_{j \neq i} r_{ji} \ell_{ji} - f(v_i) - d_i \right]^+$$

where

$$f' > 0 \quad f'' > 0$$
Networked Markets

- Bank \( i \) borrows from a competitive market \( i \)
- Other banks can participate to lend to \( i \)

- One interest rate in each market \( r_i^B \)
- Identity of the lender is irrelevant (converse not true!)

\[
B_i \equiv \sum_{j \neq i} \ell_{ji}
\]
**Equilibrium at** \( t = 1 \)

At \( t = 1 \), banks have chosen their portfolios \( L, c \).

Limited liability \( \Rightarrow \) bank unable to repay debts for low values of \( R_i \)

1. Available assets: \( R_i a_i + c_i - f(v_i) + \text{repayments} \)
2. Senior debt: \( d_i \)
3. Junior debt: \( r_i^B B_i \)

**Costs of Default**: Fraction \( \delta \) of total assets is recovered, \( \delta R_i a_i \)

- \( \pi_i^+(R_i, \theta) \) depends on counterparty defaults and repayments
- ...which in turn may depend on \( \pi_i \)!
- Fixed point problem as in Eisenberg and Noe (2001), with costs of default.
Banks’ Problem at $t = 0$

Take $\theta(R; L, c)$ and prices as given.

$$\max_{c_i, v_i, \{\ell_{ij}\}_{j \neq i}, B_i} \mathbb{E}_R[\pi^+_i(R, \theta)]$$

subject to

$$\text{FF} : \sum_{j \neq i} \ell_{ij} + c_i = B_i + v_i + z_i$$

Optimality implies $r^B_i = f'(v_i) \equiv r_i$,

$$c_i : 1 \leq r_i$$

$$\ell_{ij} : \mathbb{E}[\theta_j | \pi_i \geq 0] r_j \leq r_i, \quad \forall j \neq i$$
Equilibrium

A Competitive Equilibrium consists of a collection of portfolio allocations \( L \in \mathbb{R}^{N \times N}, c \in \mathbb{R}^N \); prices \( r \in \mathbb{R}^N \); and a repayment rule \( \theta(R; L, c) \in \mathbb{R}^N \) such that:

1. Given expected repayments \( \mathbb{E}[\theta(R; L, c)] \) and prices \( r \), portfolio allocations \( L, c \) solve the bank’s problem for each representative bank \( i \in N \).

2. Prices are such that all \( N \) interbank credit markets clear

\[
B_i = \sum_{j \neq i} l_{ji}, \forall i \in N
\]

and defined as \( r_i = f'(v_i) \) whenever \( B_i = 0 \).

3. For each joint realization of long-term asset payoffs \( R \sim G(R), \theta(R; L, c) \) constitutes a repayment equilibrium.
Results

- **Perceived Repayments**
  \[ \tilde{\theta}_{i \to j} = \mathbb{E}[\theta_j | \pi_i \geq 0] \]

- **Interest Rate Dispersion**: if \( i \to j \)
  \[ r_j \geq r_j \tilde{\theta}_{i \to j} = r_i \geq r_i \]

- **Herding Behavior**: if \( i \to j \)
  \[ r_j \tilde{\theta}_{i \to j} = r_i \]

- **Risk-Based Intermediation**: \( i \to j, j \to k, \) but \( i \not\to k \) if
  \[ \tilde{\theta}_{j \to k} \times \tilde{\theta}_{i \to j} \geq \tilde{\theta}_{i \to k} \]
Six Bank Example

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N$</td>
<td>6</td>
</tr>
<tr>
<td>$a_i$</td>
<td>1</td>
</tr>
<tr>
<td>$d_i$</td>
<td>0.8</td>
</tr>
<tr>
<td>$f(v)$</td>
<td>$(\psi_1 + \frac{1}{2} \psi_2 v) \cdot v$</td>
</tr>
<tr>
<td>$\psi_1$</td>
<td>1</td>
</tr>
<tr>
<td>$\psi_2$</td>
<td>5</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Distributions

$G_i \equiv \mathcal{U}[0.8, 1.2]$

$z_i \sim \mathcal{U}[-0.15, 0.15]$,  \[ \sum_{i=1}^{N} z_i = 0 \]
# Six Bank Example

<table>
<thead>
<tr>
<th>Bank</th>
<th>( s_i )</th>
<th>( r_i )</th>
<th>( \text{Pr[default]} )</th>
<th>Risk Shifting</th>
<th>Risk Sharing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.05</td>
<td>2.46%</td>
<td>2.40%</td>
<td>2.40%</td>
<td>-2.40%</td>
</tr>
<tr>
<td>2</td>
<td>0.15</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>3</td>
<td>-0.10</td>
<td>34.23%</td>
<td>25.50%</td>
<td>2.05%</td>
<td>74.50%</td>
</tr>
<tr>
<td>4</td>
<td>0.01</td>
<td>2.14%</td>
<td>2.10%</td>
<td>2.10%</td>
<td>-2.10%</td>
</tr>
<tr>
<td>5</td>
<td>-0.05</td>
<td>11.54%</td>
<td>10.35%</td>
<td>-0.85%</td>
<td>19.20%</td>
</tr>
<tr>
<td>6</td>
<td>-0.06</td>
<td>17.72%</td>
<td>15.05%</td>
<td>-0.55%</td>
<td>37.10%</td>
</tr>
</tbody>
</table>
Policy - Cap on Lending

\[
\sum_{i \neq j} \ell_{ij} \leq f(a_i, d_i, z_i; \phi)
\]

Equivalent to a leverage constraint

![Graphs of Volume, No. Connections, Welfare, and Risk Measures against \(\phi\) with x 10^{-3} Risk Measures showing Sharing and Shifting lines.]
Policy - Discount Window Lending

- Captures riskier borrowers
- Reduces both direct and indirect risks in the system
- May destroy risk-sharing links and induce formation of risk-shifting ones
Policy - Creditor Bailouts

- Expectation of bailout lowers rates and curbs risk shifting
- No time consistency issues
- Systemic insurance, as in Dell’Ariccia and Ratnovski (2013)

<table>
<thead>
<tr>
<th>Policy</th>
<th>$\mathbb{E}[W]$</th>
<th>$\mathbb{E}[r]$</th>
<th>$\mathbb{E}[vol]$</th>
<th>$\mathbb{E}[\text{costs}]$</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Policy</td>
<td>10.0619</td>
<td>1.68%</td>
<td>0.357</td>
<td>0</td>
</tr>
<tr>
<td>Unexpected</td>
<td>10.0721</td>
<td>1.68%</td>
<td>0.357</td>
<td>0.0347</td>
</tr>
<tr>
<td>Expected</td>
<td>10.1090</td>
<td>0.00%</td>
<td>0.487</td>
<td>0.0334</td>
</tr>
</tbody>
</table>
Conclusion

- **Key ingredients:**
  1. Idiosyncratic shocks
  2. Limited liability
  3. Non-anonymous markets

- **Results:**
  1. Risk-based intermediation
  2. Bank herding
  3. Endogenous amplification of risk
  4. Role for policy