Risk Incentives in an Interbank Network

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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

- **OTC Financial Markets**: Duffie et al. (2005), Lagos and Rocheteau (2009), Afonso and Lagos (2012), Acharya and Bisin (2014).
- **Financial Networks**: Allen and Gale (2000), Freixas et al. (2000), Atkeson et al. (2013), Fique and Page (2013), Acemoglu et al. (2015).
- **Strategic Formation of Financial Networks**: Cohen-Cole et al. (2011), Zawadowski (2013), Farboodi (2014), Glode and Opp (2014).
- **Bank Herding**: Acharya (2009), Acharya and Yorulmazer (2008).

Example

- 2 periods, 3 banks
- Banks own long-term asset a, senior claims v

$$\text{bad} : a = v - \varepsilon < v$$
$$\text{good} : a = v + \varepsilon > v$$

- 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

State	Bank 1	Bank 2	Bank 3
s_1	$v - \varepsilon$	$v + \varepsilon$	$v + \varepsilon$
s_{23}	$v + \varepsilon$	$v - \varepsilon$	$v - \varepsilon$
s_3	$v + \varepsilon$	$v + \varepsilon$	$v - \varepsilon$

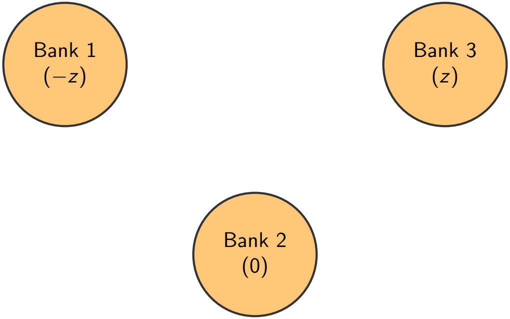
- 1 and 3 are negatively correlated
- 2 is (partially) correlated with both

Endowments:

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

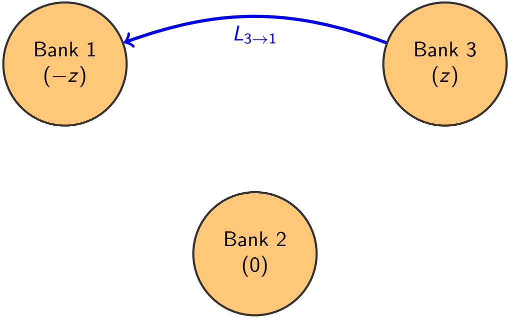
Default is socially costly, with zero recovery rate.

Autarky



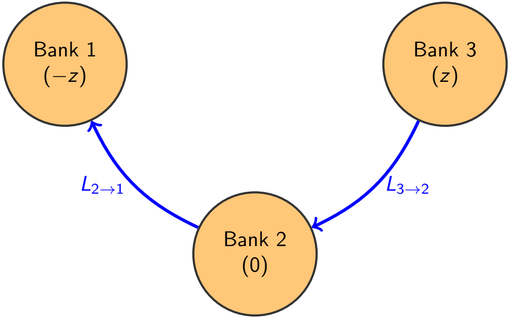
- Bank 1 borrows from outside at rate r
- Bank 3 willing to offer a cheaper contract
- Gains from trade, avoid costly liquidity technology

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

$$\ell_{ij}$$

- Interbank lending forms a credit network

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

This network is

- directed

$$\ell_{ij} \neq \ell_{ji}$$

- weighted

$$\ell_{ij} \in \mathbb{R}^+$$

Flow of Funds and Payoffs

Banks must clear liquidity positions at $t = 0$

$$\underbrace{\sum_{j \neq i} \ell_{ij} + c_i}_{\text{outflows}} = \underbrace{\sum_{j \neq i} \ell_{ji} + v_i + z_i}_{\text{inflows}}$$

Profits at $t = 1$

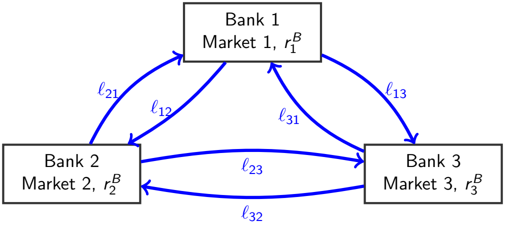
$$\pi_i^+(R_i, \boldsymbol{\theta}) = \left[R_i a_i + c_i + \sum_{j \neq i} \theta_j r_{ij} \ell_{ij} - \sum_{j \neq i} r_{ji} \ell_{ji} - f(v_i) - d_i \right]^+$$

where

$$f' > 0 \qquad f'' > 0$$

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 $\mathbf{L}, \mathbf{c}$.

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

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

Costs of Default: Fraction δ of total assets is recovered, $\delta R_i a_i$

- $\pi_i^+(R_i, \boldsymbol{\theta})$ depends on counterparty defaults and repayments
- ...which in turn may depend on π_i!
- Fixed point problem as in Eisenberg and Noe (2001), with costs of default.

Banks' Problem at $t = 0$

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

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

subject to

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

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

$$c_i : 1 \leq r_i$$

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

Equilibrium

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

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

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

$$B_i = \sum_{j \neq i} \ell_{ji}, \forall i \in N$$

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

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

Results

- **Perceived Repayments**

$$\tilde{\theta}_{i\to j} \equiv \mathbb{E}[\theta_j | \pi_i \geq 0]$$

- **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 $i \nrightarrow k$ if

$$\tilde{\theta}_{j\to k} \times \tilde{\theta}_{i\to j} \geq \tilde{\theta}_{i\to k}$$

Six Bank Example

Parameter	Value
N	6
a_i	1
d_i	0.8
$f(v)$	$\left(\psi_1 + \frac{1}{2}\psi_2 v\right) \cdot v$
ψ_1	1
ψ_2	5
δ	0.7

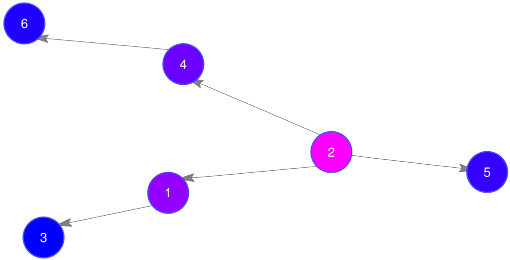
Distributions

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

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

Six Bank Example

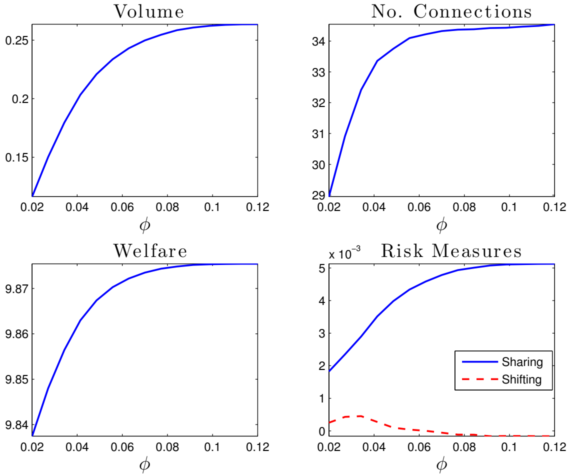
Bank	s_i	r_i	Pr[default]	Risk Shifting	Risk Sharing
1	0.05	2.46%	2.40%	2.40%	−2.40%
2	0.15	0.00%	0.00%	0.00%	0.00%
3	−0.10	34.23%	25.50%	2.05%	74.50%
4	0.01	2.14%	2.10%	2.10%	−2.10%
5	−0.05	11.54%	10.35%	−0.85%	19.20%
6	−0.06	17.72%	15.05%	−0.55%	37.10%



Policy - Cap on Lending

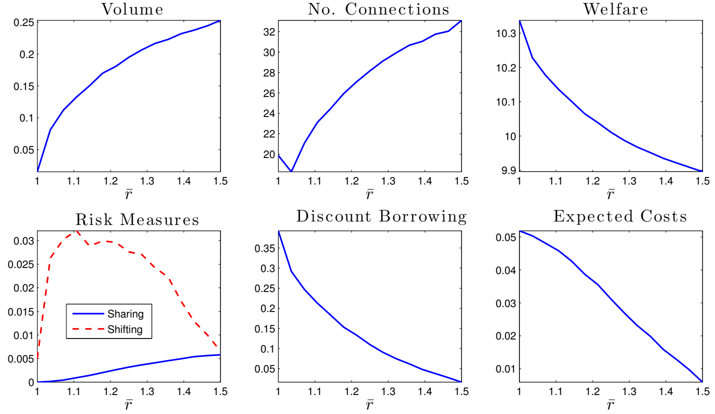
$$\sum_{i \neq j} \ell_{ij} \leq f(a_i, d_i, z_i; \phi)$$

Equivalent to a leverage constraint



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)

Policy	$\mathbb{E}[W]$	$\mathbb{E}[r]$	$\mathbb{E}[vol]$	$\mathbb{E}[\text{costs}]$
No Policy	10.0619	1.68%	0.357	0
Unexpected	10.0721	1.68%	0.357	0.0347
Expected	10.1090	0.00%	0.487	0.0334

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