Distress Dispersion and Systemic Risk in Networks

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Measurement Challenges in Macroprudential Policy Implementation:
Essential Data Elements for Preserving Financial Stability

Financial Interconnectedness

- CDS, interbank claims, securitized debt, M&A
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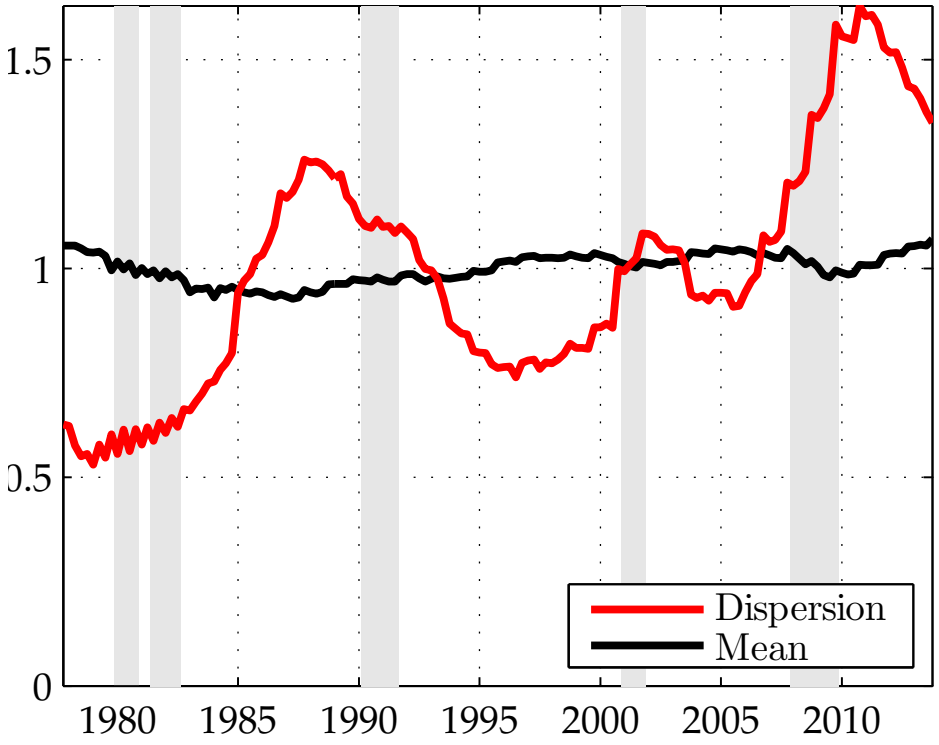
- Why do financial firms form networks? form networks efficiently?
- Existing studies limit to
  - exogenous network structures
  - network formation among homogeneous firms

    Castiglionesi and Navarro 2011, Farboodi 2014

This Paper Embeds Distress Heterogeneity

- asset illiquidity
- JP Morgan vs. Bear Stearns
- dispersion in financial distress



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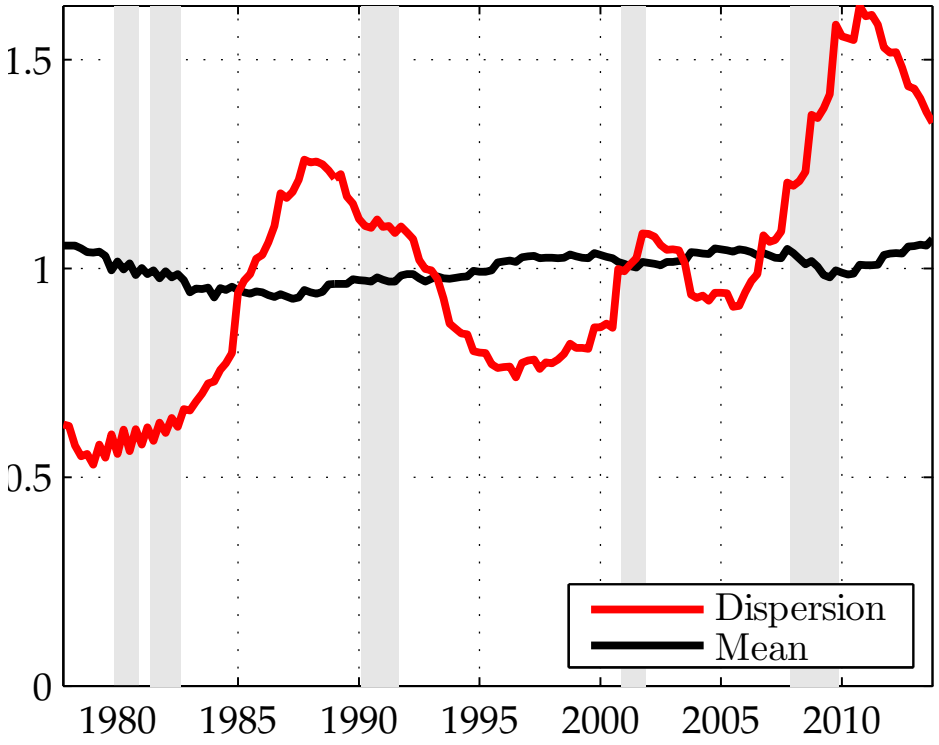

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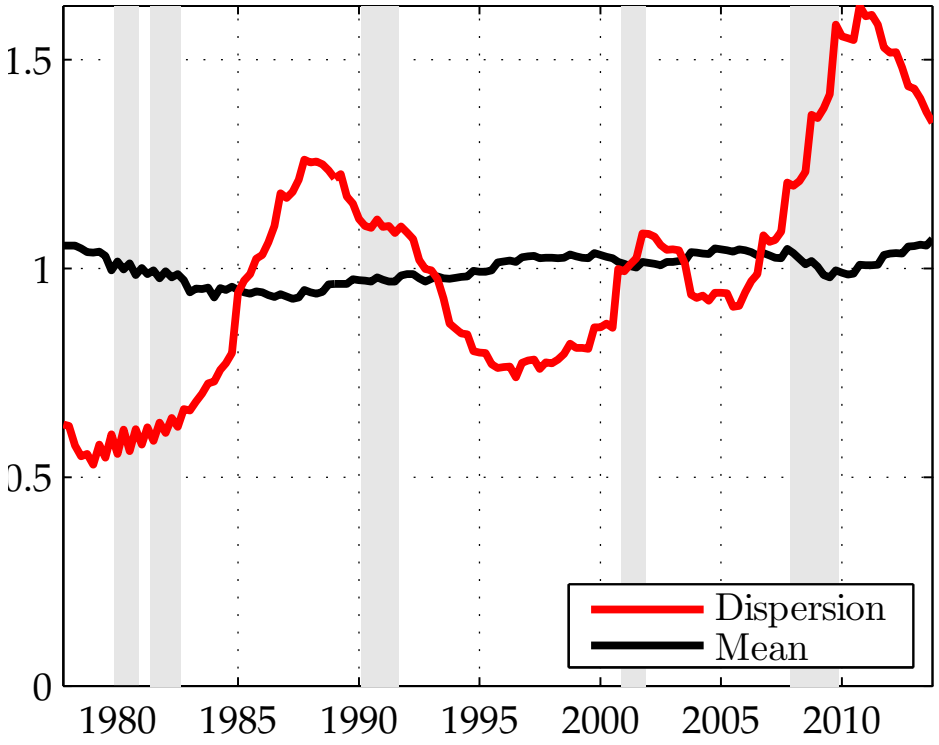

- Studies linkage formation among firms differing in financial distress
- Finding: distress dispersion endogenously generates inefficiency

  ☞ too many links with distressed, too few among non-distressed

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- Bilateral contingency
  - prices not contingent on the entire network
  - externalities not internalized

Contributions

1. Embed distress heterogeneity in network formation
   ☞ prediction on *network composition* is unique.
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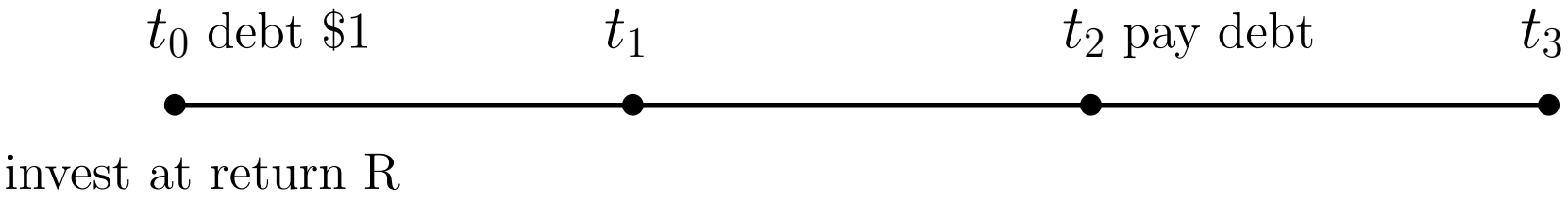
2. Dispersion of financial distress is a novel indicator for systemic risk.

3. Policy implications in the context of acquiring distressed firms

Model

Model Setup

N debt-financed firms, risk neutral, no discounting



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	$\nu_i = E[a_i]$	$a_i = \nu_i + \sigma\varepsilon_i$	$R - a_i$

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- Distress heterogeneity
  - distance to liquidation $z_i \equiv \frac{\nu_i - 1}{\sigma}$; i is distressed if $z_i < -1$
  - cross-sectional moments: $\bar{z}$, $\delta \propto Var(z_i)$

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	forward contracts	trade assets	pay prices

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  - distance to liquidation $z_i \equiv \frac{\nu_i - 1}{\sigma}$; i is distressed if $z_i < -1$
  - cross-sectional moments: $\bar{z}$, $\delta \propto Var(z_i)$
- Links: bilateral forward swap contracts for risk sharing

Network Formation

- Strategy: firm i proposes to buy l_{ij} of a_j paying unit price p_{ij} $l_{ij} \in \{0, \bar{l}\}$, $\bar{l} \in (0, 1)$; prices contingent on links
- A link is formed when both firms decide to trade (swap)

$$L_{ij} = L_{ji} = \min\{l_{ij}, l_{ji}\}$$

- Liquid asset holding $h_i(a, L)$, liquidation if $h_i < 1$

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$$L_{ij} = L_{ji} = \min\{l_{ij}, l_{ji}\}$$

- Liquid asset holding $h_i(a, L)$, liquidation if $h_i < 1$
- Final payoff

$$\Pi_i = \underbrace{h_i + R - a_i - 1}_{\text{asset net of debt}} - \underbrace{\mathbb{1}_{\text{liquidation}} c}_{\text{liquidation cost}} - \underbrace{\sum_{j \neq i} (p_{ij} - p_{ji}) L_{ij}}_{\text{net payments from swaps}}$$

An Example

	$E[\text{liquidity}]$
1	2.4
2	1.6
3	0.8
4	0

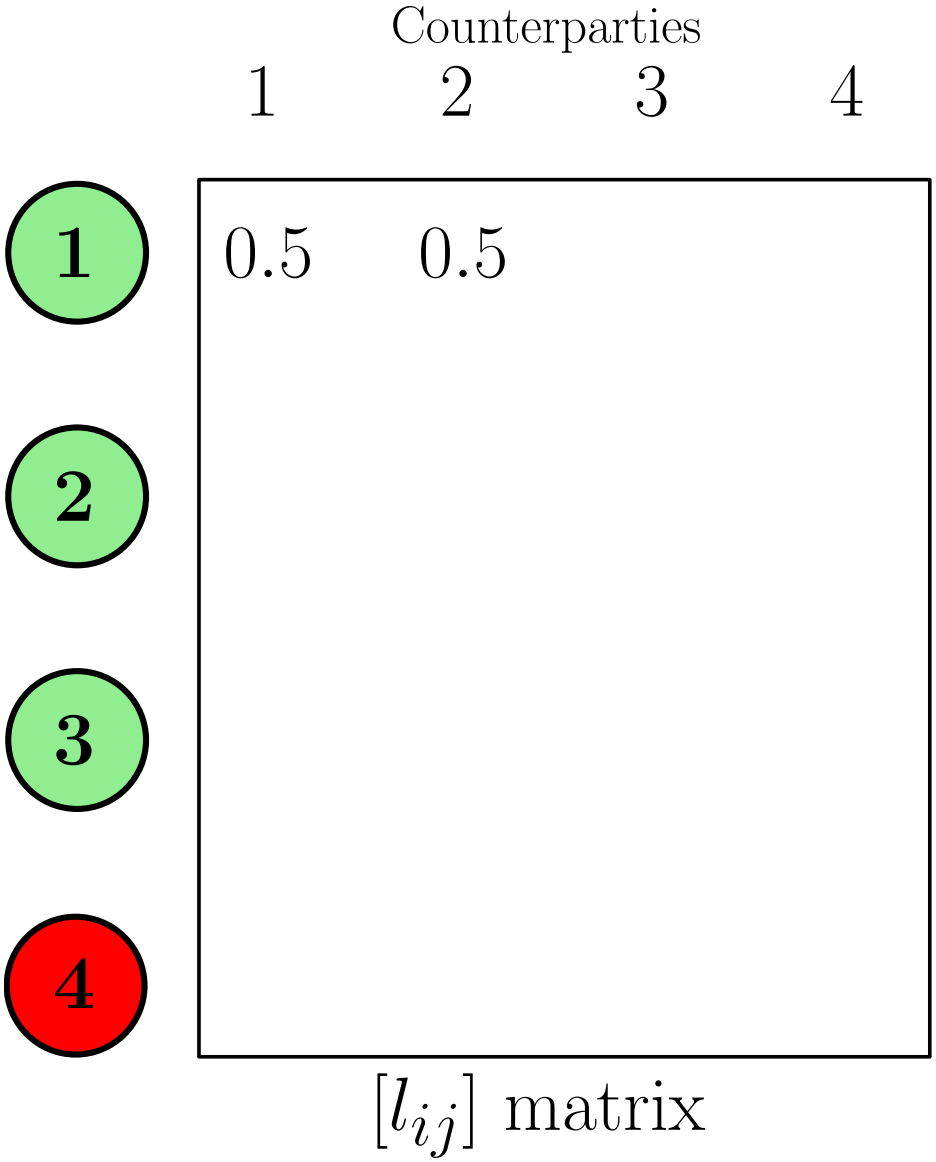
An Example

	E[liquidity]	distress
1	2.4	1.4
2	1.6	0.6
3	0.8	-0.2
4	0	-1

An Example

	E[liquidity]	distress	P[liquidation]	reservation value
1	2.4	1.4	0.08	0.92
2	1.6	0.6	0.27	0.73
3	0.8	-0.2	0.58	0.42
4	0	-1	0.84	0.16

An Example



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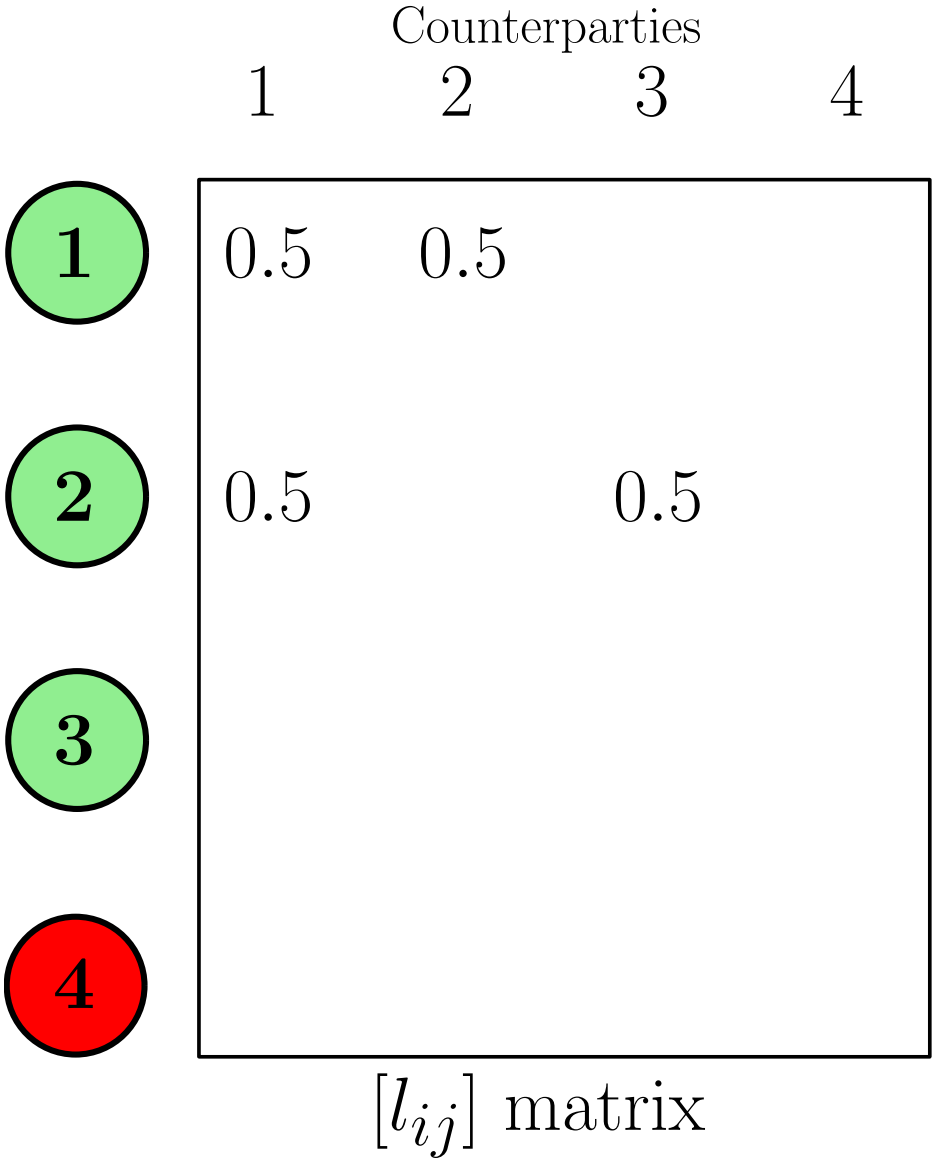

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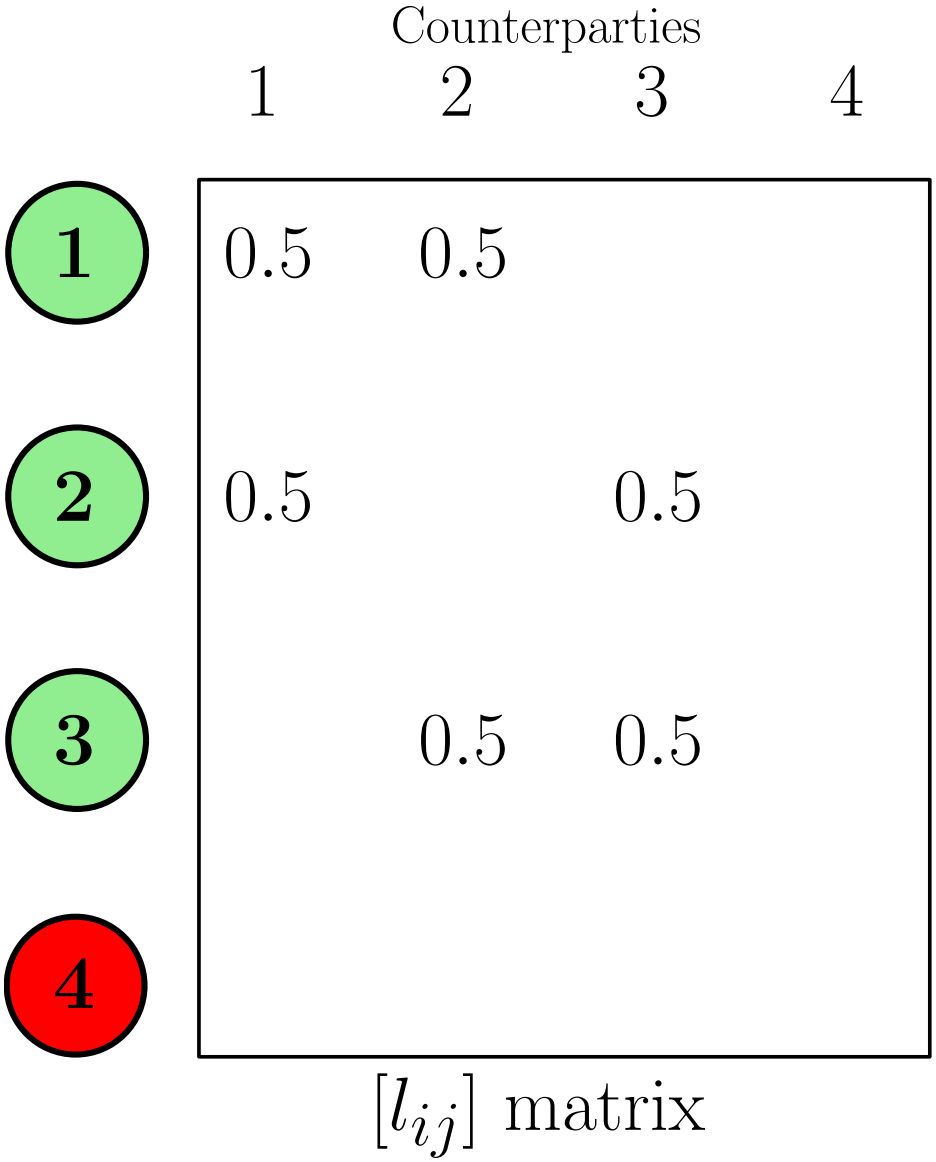

An Example

Counterparties

	1	2	3	4
1	0.5	0.5		
2	0.5		0.5	
3		0.5	0.5	
4	0.5			0.5

$[l_{ij}]$ matrix

An Example

Counterparties

$$
\begin{array}{c|cccc}
 & 1 & 2 & 3 & 4 \\
\hline
1 & 0.5 & 0.5 & & \\
2 & 0.5 & & 0.5 & \\
3 & & 0.5 & 0.5 & \\
4 & 0.5 & & & 0.5
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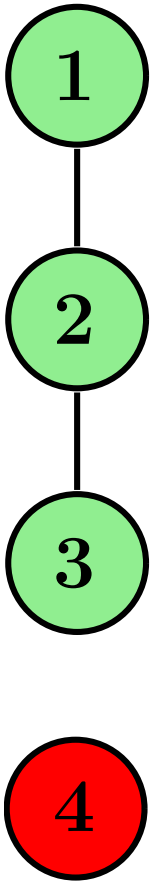

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1	**0.5**	**0.5**		
2	**0.5**		**0.5**	
3		**0.5**	**0.5**	
4				**1**

L matrix

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3		0.73		
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$[p_{ij}]$ matrix

Bilateral Prices and Asset Swaps

Assumptions:

1. Bilateral contingency: price written on direct links of i and j

$$p_{ij}\left(L_i, L_j, L_k\right) = p_{ij}\left(L_i, L_j, \hat{L}_k\right)$$

   - L_k not verifiable, Hart (1993) incomplete contracts

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4. Chain network

Equilibrium: network L^e and prices p^e

1. Optimality: firm i takes (l_{-i}, p_{-i}) as given and chooses (l_i, p_i)

$$\max_{(l_i, p_i)} \mathbb{E}_1 \left[\Pi_i(a, L, p)\right]$$

2. Feasibility: $L \times \mathbb{1}_{N\times 1} = L^\top \times \mathbb{1}_{N\times 1} = \mathbb{1}_{N\times 1}$.

3. Pairwise stability *(Jackson & Wolinsky 1996)*:

$$L^e_{ij} > 0 : \text{both firms prefer to be connected } \forall \hat{p}_{ij}, \hat{p}_{ji}$$

$$L^e_{ij} = 0 : \text{at least one is worse off to connect } \forall\, \hat{p}_{ij}, \hat{p}_{ji}$$

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$$\arg \min_{L_{ij} \in \{0, \bar{l}\}} \sum_i \Pr\left(h_i < 1\right) c.$$

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Proposition (Network Inefficiency)

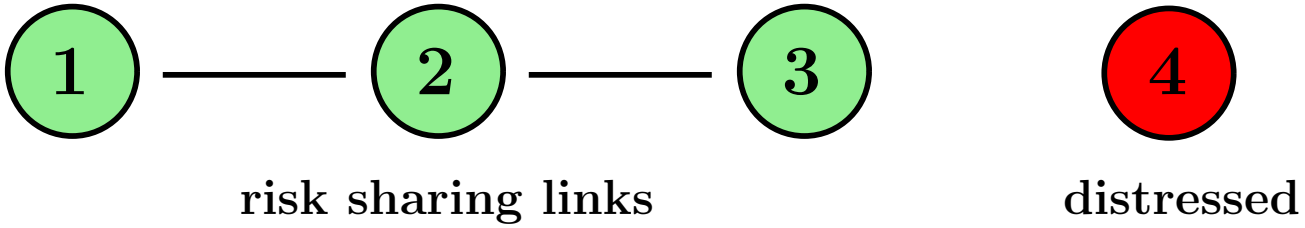
When dispersion δ is high

optimal network isolates the distressed firm (Prop 1)

equilibrium network has too many links with distressed for $N \geq 4$, and too few links among non-distressed for $N \geq 5$ (Prop 2,3).

Over-connection with the Distressed Firm

- Optimal



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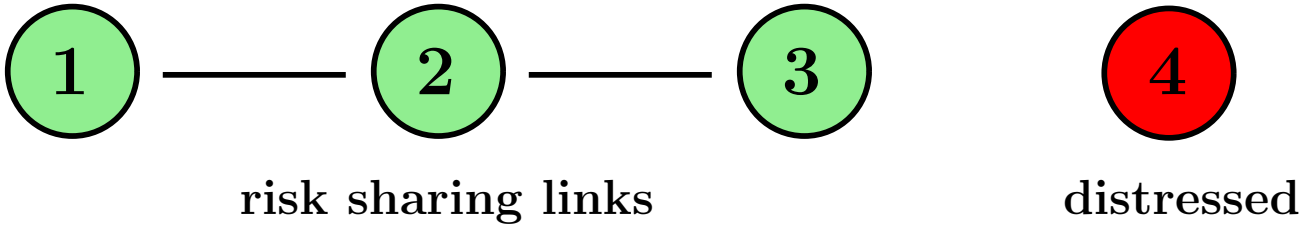

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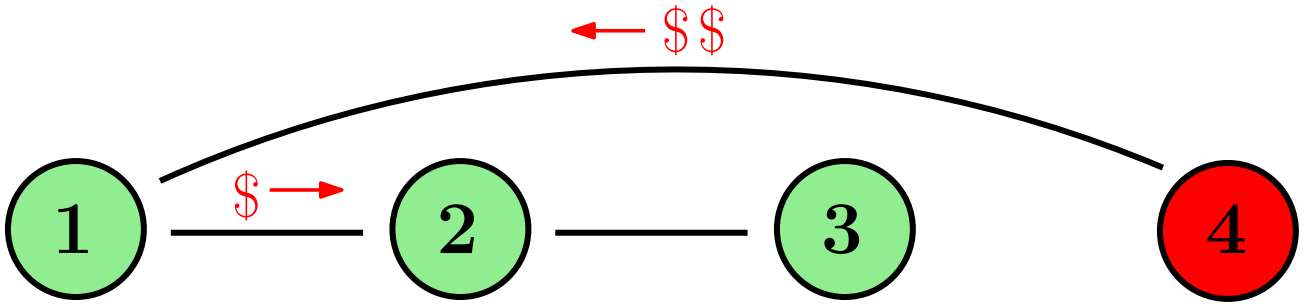

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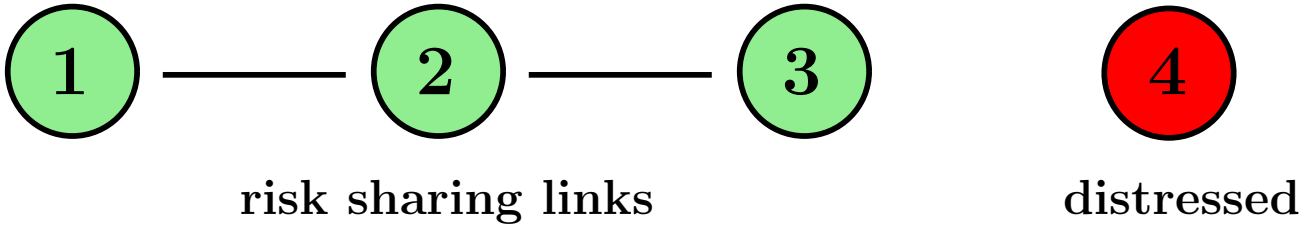

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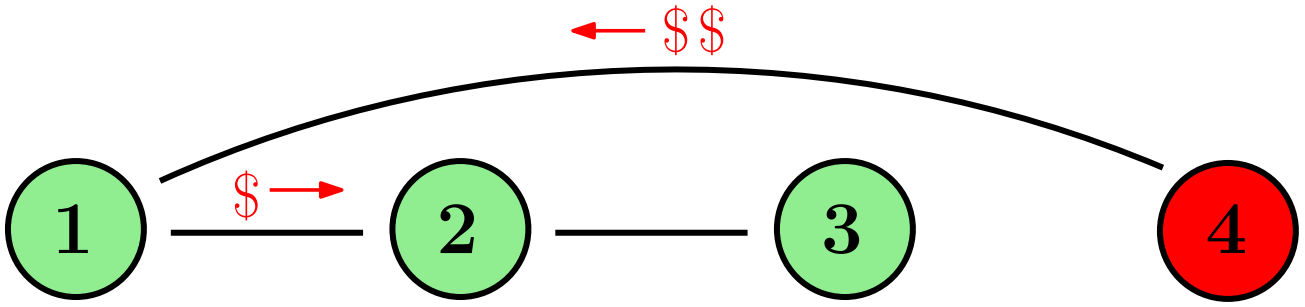

- Over-connection at equilibrium

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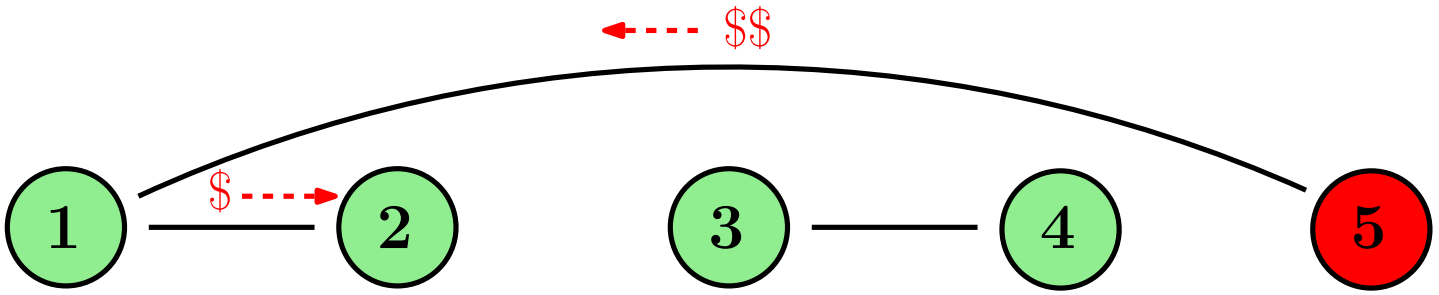

Inefficient Network Composition

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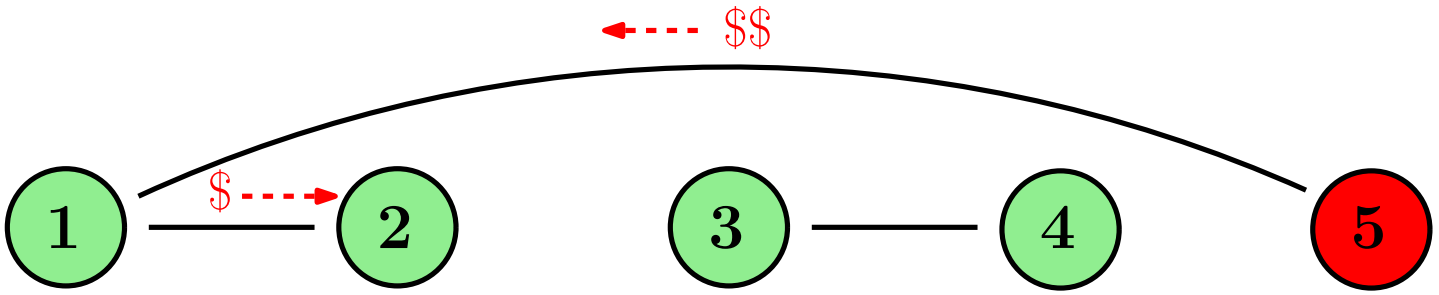

- Over-connection and under-connection at equilibrium
- Efficient number of links, inefficient network composition

Inefficiency Indicator: distress distribution

- Measures of inefficiency
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- Measures of inefficiency
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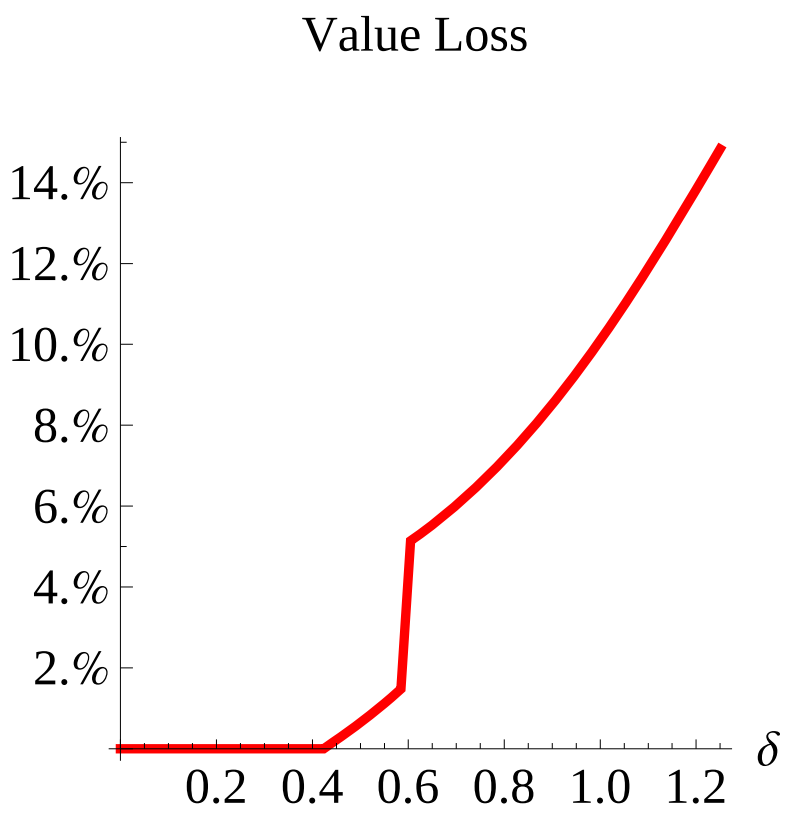
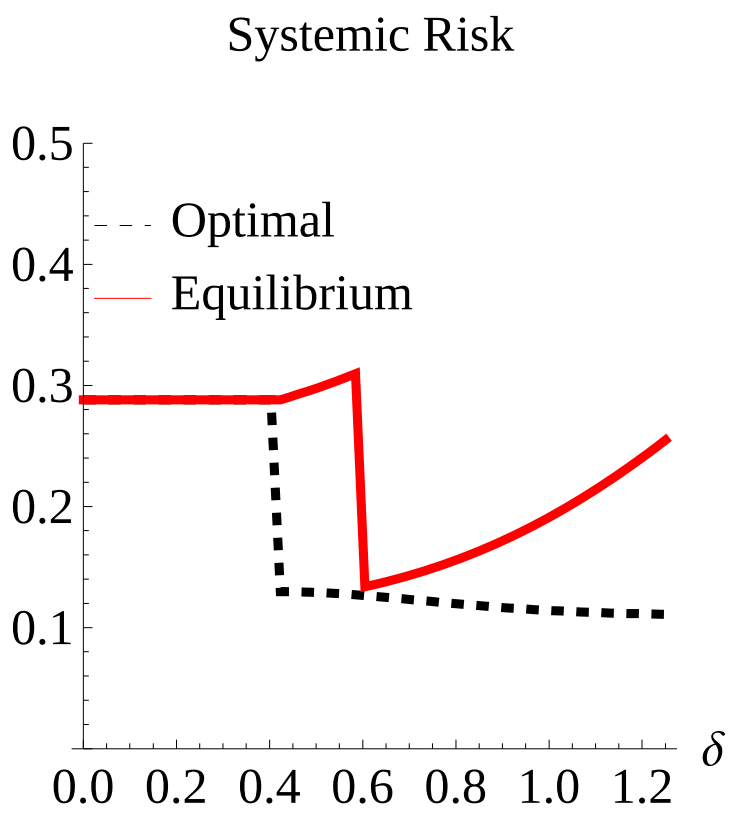
- Proposition: for $N = 4$, both value loss and excess systemic risk increase with dispersion δ.

Comparative Statics: inefficiency measures

- For $N = 5$, increase δ while adjusting $\bar{z}$





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2. If excess acquisitions are not banned
   - too-connected-to-fail problem
   - *ex post*: government bailout, subsidized acquisition

Empirical Evidence

Measuring Financial Distress by Z-Score

- $\text{Z-Score}_{i,t} = \log \dfrac{\overline{\text{ROA}_{i,t}} + \overline{\text{capital-to-asset ratio}_{i,t}}}{\sigma(\text{ROA}i,t)}$

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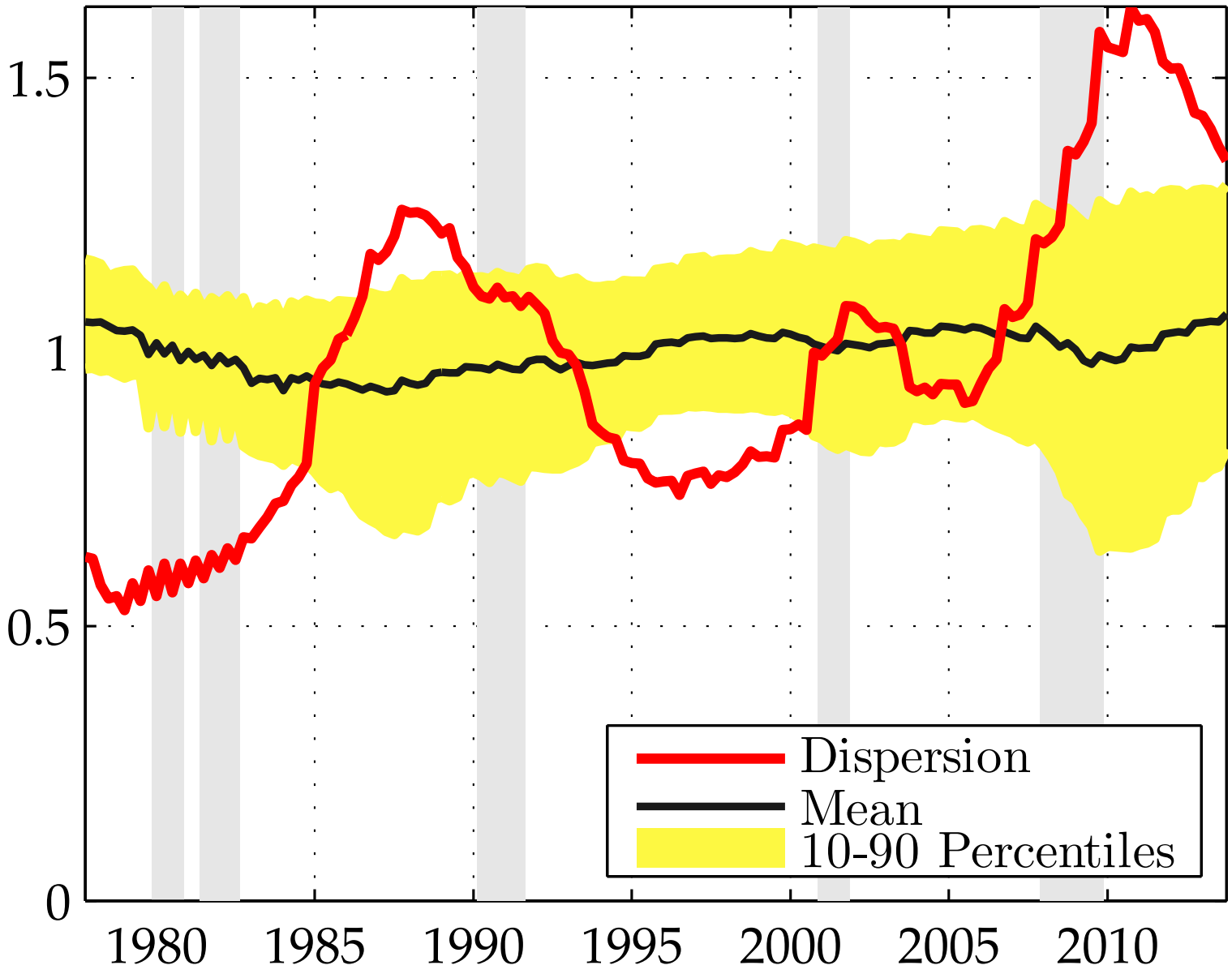
- Limitations

Cross-sectional Moments of Financials' Z-Score



Empirical Evidence: predictive regressions

Quarters	1	4	1	4
Forecasting	**Financial Conditions Index**		**Failure rate(%)**	
Dispersion	1.52**	4.72**	0.53***	2.07***
Mean	-8.95***	-32.32***	-3.81***	-17.12***
R^2	53.22	50.56	58.98	71.31
R^2 w/o disp	37.54	38.86	50.16	60.99
Forecasting	**Distressed acquisition(%)**		**Sml bk fed funds/assets**	
Dispersion	0.29***	1.34***	-0.01**	-0.04*
Mean	-1.19*	-3.90*	0.05	0.07
R^2	53.90	75.26	57.07	63.93
R^2 w/o disp	43.64	56.11	54.04	56.94

Note: Control for term spread, financial intermediary leverage, growth rate of corporate debt.

*, **, ***, statistical significance (Newey-West SE) at 5%, 1%, and 0.1%.

Conclusion

- Distress dispersion endogenously generates network inefficiency and systemic risk.
- Modeling heterogeneity gives unique prediction on network composition.
- Regulators should oversee the acquisition of distressed banks.
- Distress dispersion has predictive power for systemic risk.