Financial Contagion in Networks: An Experiment

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Introduction

- The architecture of financial system play a central role in shaping systemic risk.

- Much of the popular discussion has been directed at some special features of financial networks
  - “too-big” or “too-interconnected” to fail

- There has been a growing interest on more general aspects of networks and their relationship to financial contagion.
Introduction


  “the regulation of the network is needed to ensure appropriate control of large, interconnected institutions […] the financial network should be structured so as to reduce the chances of future systemic collapse”


  “better information on connections between firms in the financial network is a key factor to building a more resilient financial system.”
Introduction

- Recent theoretical efforts have been made largely on two distinct directions:
  - contagion via transmission of shocks (e.g., Allen and Gale, 2000; Acemoglu et al., 2015; Elliot et al., 2014)
  - informational contagion (e.g., Caballero and Simsek, 2013)

- Identifying the roles of network and information and the significance of each channel has important implications on policies.
Challenges

- Hard to observe the exact structure of financial networks
- Endogeneity
  - Financial structure emerges endogenously
- Unobservable confounds
  - information, beliefs, preferences, etc.
What We Do Here

- We investigate the roles of network and information structures on contagion and price formation via a laboratory experiment.
  
  - The structures of financial networks and information are directly controlled.
  
  - We establish empirically the causal impacts of each channel.

- We extend the tool of market experiments à la Smith (1962) into the contexts of financial contagion in networks.
Key Features of Our Setup

- Trade-off between liquidity and return (e.g., Diamond and Dybvig, 1983)

- Architectures of financial linkages (e.g., Allen and Gale, 2000; Freixas, et al., 2000)

- Competitive market institution – continuous double-auction institution
Setup

- $N$ number of financial agents, each of whom (agent $n$) are endowed with
  - One unit of a (long-term) asset
  - A per-unit value of the long-term asset, $R_n$
  - Cross-holdings of short-term debt (financial network)

Initial balance sheet of an agent $n$

<table>
<thead>
<tr>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Short-term debt claim with face value $y_n$</td>
<td>• Short-term debt claim with face value $y_n$</td>
</tr>
<tr>
<td>• One unit of a (long-term) asset</td>
<td></td>
</tr>
</tbody>
</table>
Financial Linkages

Circle 6 network

- A directed edge from $j$ to $i$ means that agent $j$ owes $y$ amount of cash via short-term debt to agent $i$.

- We focus on the class of financial networks in which each edge carries the same amount of debt claims as $y$. 
Financial Linkages

Core-Periphery 6 network

![Diagram of Core-Periphery 6 network]
Timeline

Period 0 (trading decision)

- Agents learn that one agent will become distressed and need $\theta$ at period 1.
- Each agent makes a trading decision of the (long-term) asset: buy / sell one unit or no trade.
- The long-term asset is completely illiquid at period 1.

Period 1

- Cross-debt claims are cleared.
- Agents who are unable to pay fully the short-term debt go bankrupt.

Period 2

- Agents receive returns of the long-term asset if they are solvent.
Circle 6 network

- Under **full information**, agents know that one agent (agent 1) is hit by a shock of size $\theta$.
- Under **no information**, agents do not know the identity of a shock recipient.
Period 1: Clearing System

- Let $p_n (\leq y_n)$ denote agent $n$’s payment to her creditors and $q_n (\leq y_n)$ the amount of payment received by agent $n$ from her debtors.

- Liquidity need of agent $n$

\[ y_n - q_n + \theta 1\{d = 0\} \]

- Eisenberg and Noe (2001) show that a payment vector $p = (p_1, ..., p_N)$ always exists and is unique.

- If an agent is unable to pay the full amount of debts ($p_n < y_n$), she goes bankrupt and receives nothing from her long-term asset at period 2.
Experimental Design

• Treatments
  • Networks: Circle 6, Circle 15, Core-periphery 6, Core-periphery 15
  • Information: full vs. no information on shock position

• Heterogeneous values of the long-term asset return
  • 6-person networks: 6 evenly-spaced values between 850 and 1150.
  • 15-person networks: 15 evenly-spaced values between 860 and 1140.

• Three different values of shock size:
  \[ \theta_L (= 50) < \theta_M (= 1200) < \theta_H (= 3000 \text{ or } 5000) \]
Double-Auction Institution

- Trading lasts for 90 seconds.
- The market for long-term asset consists of agents in the network.
- Anonymous trading (no revelation of traders’ identity)

**Selling the asset**
- Post an ask price or accept a bid price submitted by another agent in the market

**Buying the asset**
- Post a bid price or accept an ask price submitted by another agent in the market
Experimental Screen: Decision
Experimental Screen: Decision

BOX 1

BOX 2

BOX 3

BOX 4
Experimental Screen: Results

Trading summary: During trading, you sold your unit of the asset for 1100.00 tokens.

Stage 1 earnings: -4178.57 tokens

You are bankrupt
Experimental Procedure

- 16 sessions with 252 UCL students in total.

- Subjects repeated the market experiment in a fixed group in 21 times (the first 3 are practice rounds).

- 7 rounds for each of the three shock sizes ($\theta_L < \theta_M < \theta_H$)

- Two further (incentivized) experiments
  - Comprehension task of which network positions go bankrupt when computer agents uses a pre-determined strategy of trading at a fixed price.
  - Risk preference experiment (Holt and Laury, 2002)
Three Benchmarks

1. No Shock: $\theta = 0$
   - Complete separation of short-term debts and long-term asset market

2. Benchmark I: competitive equilibrium as if there is no shock
   - Network effects with no endogenous price response.

3. Benchmark II: competitive equilibrium with the assumption that the shocked person always sells its asset.
   - Network effects with endogenous price response.
Financial Contagion

- Financial contagion with $x\%$ is defined to occur if $x\%$ of agents go bankrupt.

Contagion with 60%
Contagion: Data vs. Benchmarks

Contagion: 60% of bankruptcy

Contagion in Benchmark I: 60% of bankruptcy

Contagion in Benchmark II (lower bound): 60% of bankruptcy
Network Effects on Contagion

- Effects of network structure on contagion are large and significant

- Under full information,
  - (Circle 6) <** (Core-periphery 6)
  - (Circle 15) <*** (Core-periphery 15)

- Under no information
  - (Circle 6) <*** (Core-periphery 6)
  - (Circle 15) <*** (Core-periphery 15)
Information Effects on Contagion

- No effect of information structure on contagion.

- In the circle networks,
  - (Circle 6 under full info) \(=\) (Circle 6 under no info)
  - (Circle 15 under full info) \(=\) (Circle 15 under no info)

- In the core-periphery networks,
  - (CP 6 under full info) \(=\) (CP 6 under no info)
  - (CP 15 under full info) \(=\) (CP 15 under no info)
Bankruptcy

- Shock matters for bankruptcy.
- Shock recipient
- Shock size
- Distance from shock

- Comprehension task matters for bankruptcy: the smarter the individual is, the less likely he goes bankrupt.
Buy & Sell Decisions

- Structural factors matters for trading.
  - Asset value
  - Shock recipient
  - Distance from shock

- Comprehension task matters for trading: the smarter the individual is, the more likely he sells his asset.
Takeaway Points

● We find strong impacts of network topology on contagion and bankruptcy.

● There is little impact of information on contagion.

   ● We thus find little evidence on the amplification of contagion through such informational channel as Caballero and Simsek (2013).

● Structural and behavioural factors matter for bankruptcy and trading decisions.
### Price Formation

<table>
<thead>
<tr>
<th></th>
<th>Circle 6</th>
<th>CP 6</th>
<th>Circle 15</th>
<th>CP 15</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All data</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full info</td>
<td>911</td>
<td>791</td>
<td>946</td>
<td>742</td>
</tr>
<tr>
<td>No info</td>
<td>894</td>
<td>804</td>
<td>937</td>
<td>657</td>
</tr>
<tr>
<td><strong>Last half data</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full info</td>
<td>905</td>
<td>758</td>
<td>948</td>
<td>646</td>
</tr>
<tr>
<td>No info</td>
<td>883</td>
<td>748</td>
<td>942</td>
<td>543</td>
</tr>
</tbody>
</table>

- Network structure and size matter in price formation.
- Information effect on price formation appears less notable.
Price Formation: CP 15 vs. Circle 15 with full information

Price dynamics with small shock

Price dynamics with medium shock

Price dynamics with large shock
Price Formation: CP 15 vs. Circle 15 with no information
Network and Information Effects on Price Formation

Network structure

- Under full information,
  - (Circle 6) >*** (Core-periphery 6)
  - (Circle 15) >*** (Core-periphery 15)

- Under no information
  - (Circle 6) >*** (Core-periphery 6)
  - (Circle 15) >*** (Core-periphery 15)

Information

- In the circle networks,
  - (Circle 6 under full info) >* (Circle 6 under no info)
  - (Circle 15 under full info) = (Circle 15 under no info)

- In the core-periphery networks,
  - (CP 6 under full info) = (CP 6 under no info)
  - (CP 15 under full info) >*** (CP 15 under no info)
Network and Information Effects on Price Formation

Network size

• In the circle networks,
  • (Circle 6 under full info) = (Circle 15 under full info)
  • (Circle 6 under no info) <*** (Circle 15 under no info)

• In the core-periphery networks,
  • (CP 6 under full info) >*(CP 15 under full info)
  • (CP 6 under no info) >*** (CP 15 under no info)
Conclusion

• We offer an experimental tool to study the roles of network and information structure on contagion and price formation.

  • Network structure and size effects are strong for systemic risks
  • Information plays relatively minor role

• Further extensions:

  • Richer variations in network topology
  • Network formation in the presence of systemic risks
  • Spillovers across markets
Price Dynamics: Circle 15 with full info

Price

CloseTimeCumulative

shock = 50

shock = 1200

shock = 5000
Price Dynamics: CP 15 with full info

**shock = 50**

**shock = 1200**

**shock = 5000**

Price vs CloseTimeCumulative
Price Dynamics: Circle 15 with no info

- shock = 50
- shock = 1200
- shock = 5000

Price vs. CloseTimeCumulative
Price Dynamics: CP 15 with no info

![Graph showing price dynamics with different shocks.]