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

- Haldane, A.G. (2009). *Rethinking the Financial Network*. Bank of England.

  "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"

- Financial Stability Report (2009). Bank of England, Issue 25.

  "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

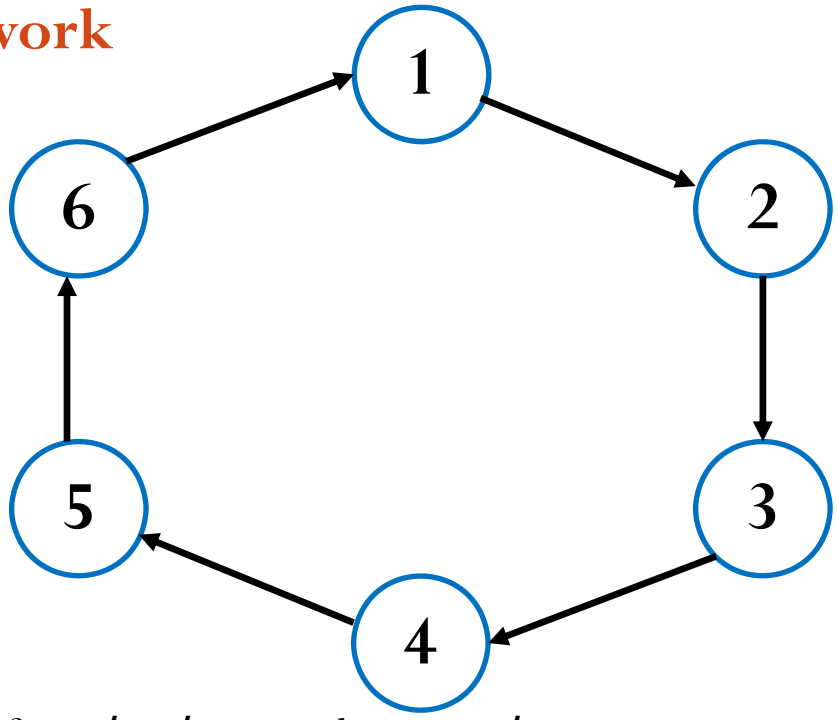
- N number of financial agents, each of whom (agent n) are endowed with
  - One unit of a (long-term) asset
  - A per-unit value of the long-term asset, R_n
  - Cross-holdings of short-term debt (financial network)

Initial balance sheet of an agent n

Assets	Liabilities
• Short-term debt claim with face value y_n • One unit of a (long-term) asset	• Short-term debt claim with face value y_n

Financial Linkages

Circle 6 network

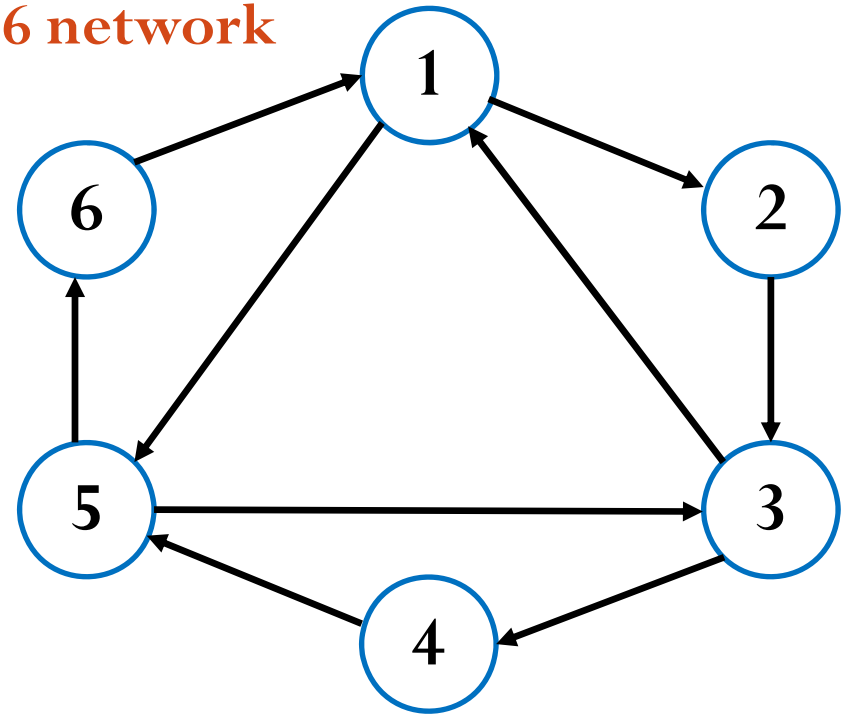


- A directed edge from j to i means that agent j owes y amount of cash via short-term debt to agent i.

- 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



Timeline

Period 0 (trading decision)

- Agents learn that one agent will become distressed and need θ 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

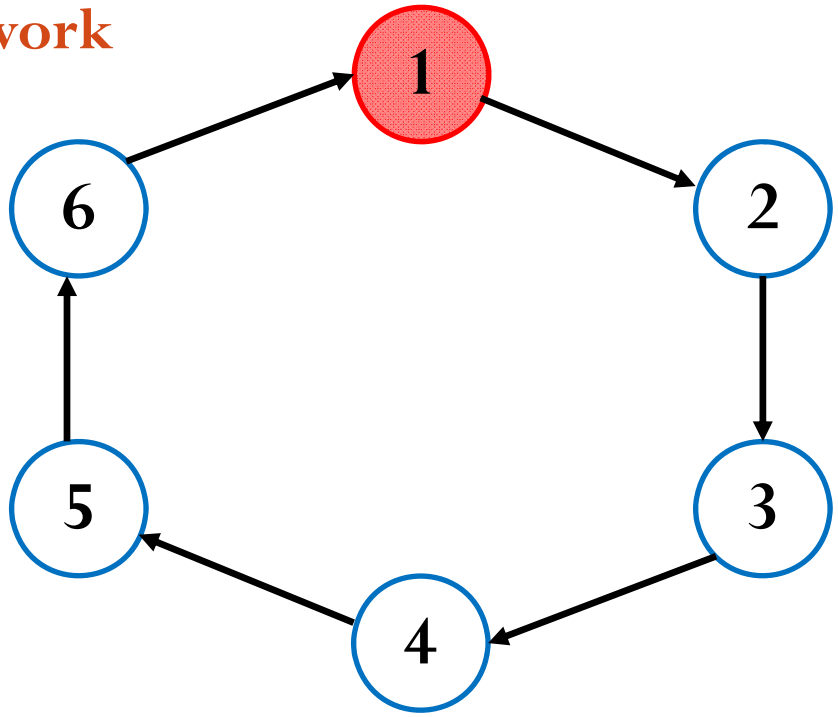
- Cross-debt claims are cleared.
- Agents who are unable to pay fully the short-term debt go bankrupt.

Period 2

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

Two Information Structures

Circle 6 network



- Under full information, agents know that one agent (agent 1) is hit by a shock of size θ.
- 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 $p = (p_1, \ldots, p_N)$ 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:

$$\theta_L(=50) < \theta_M(=1200) < \theta_H(=3000\ or\ 5000)$$

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)

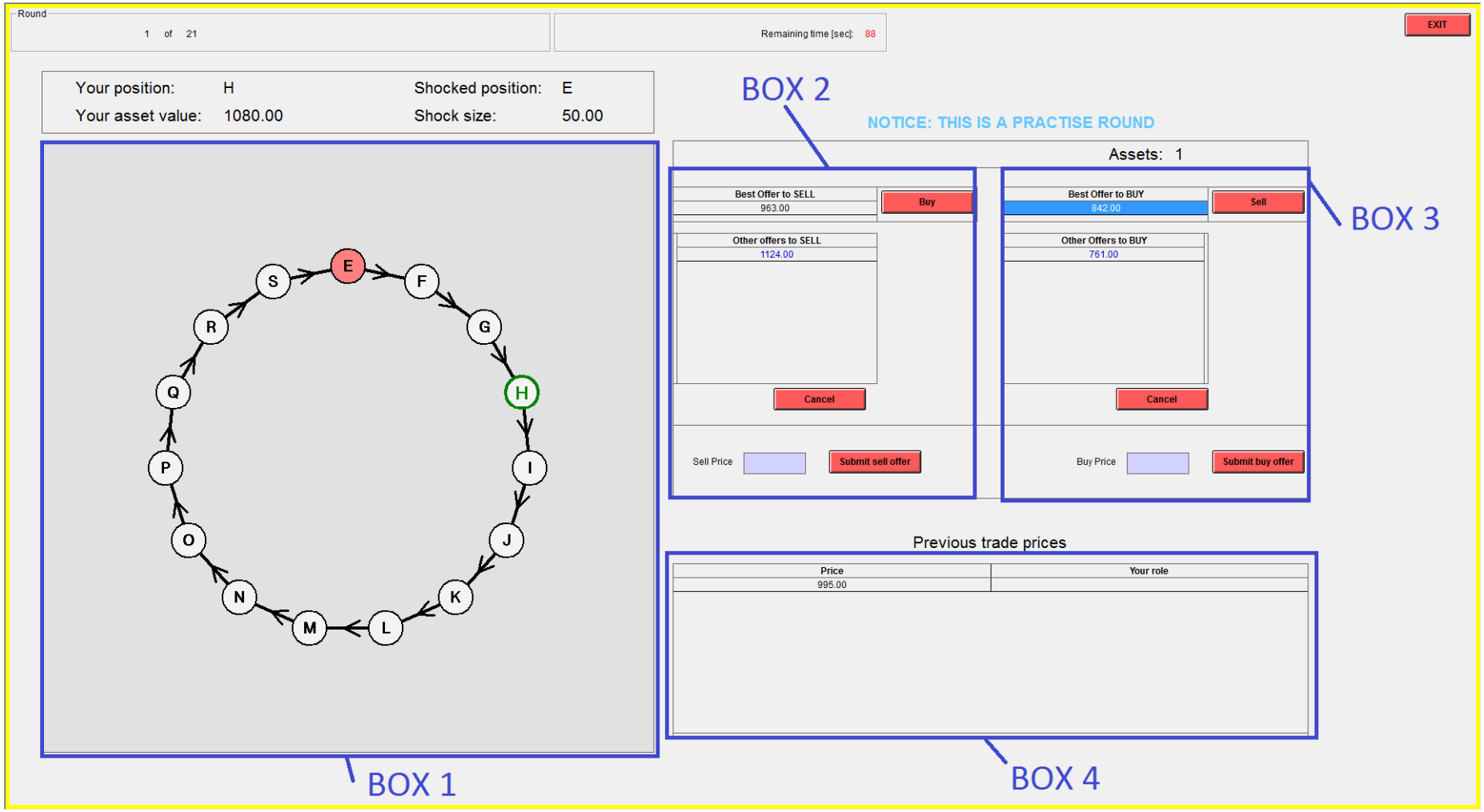
Selling the asset

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

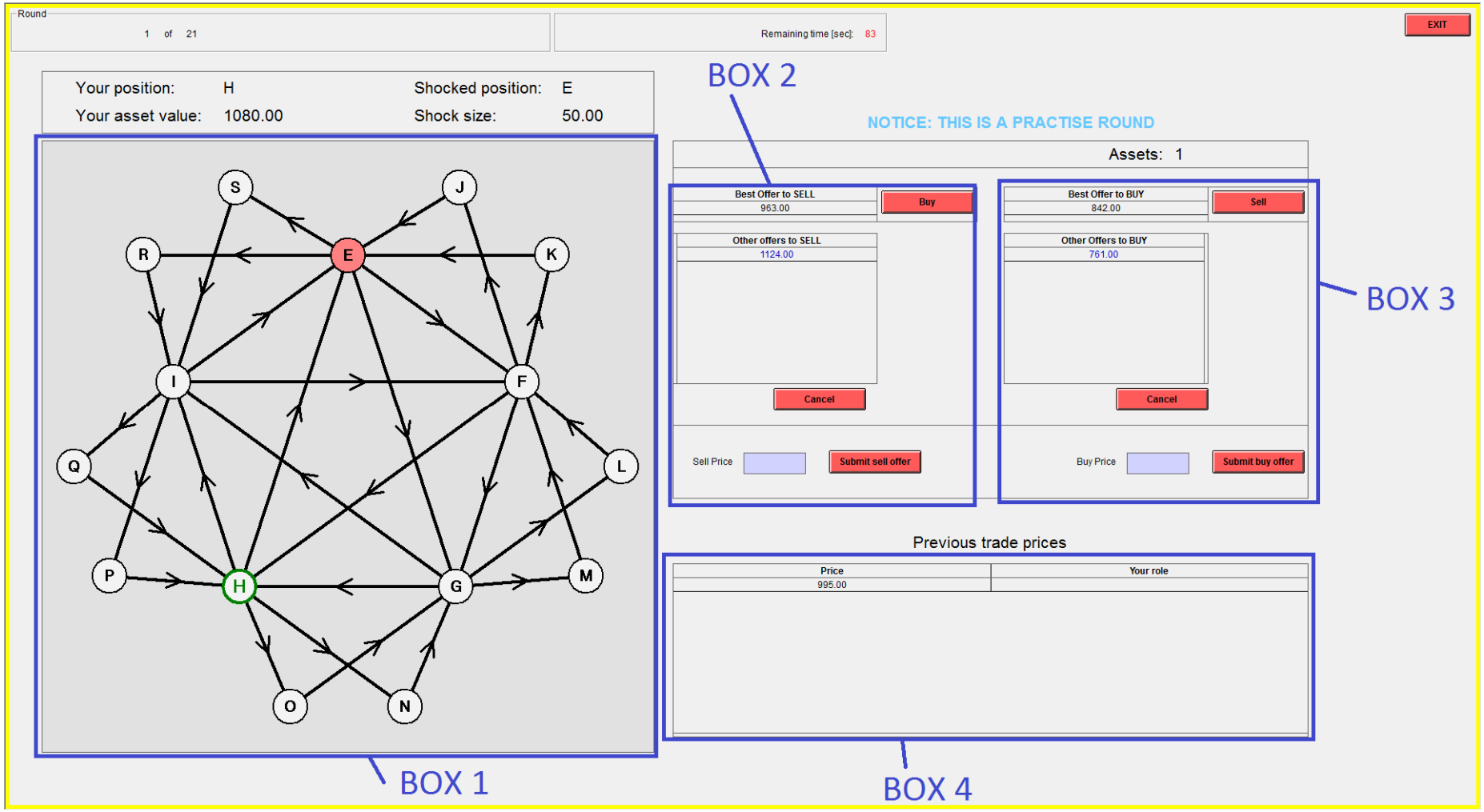
Buying the asset

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

Experimental Screen: Decision



Experimental Screen: Decision



Experimental Screen: Results

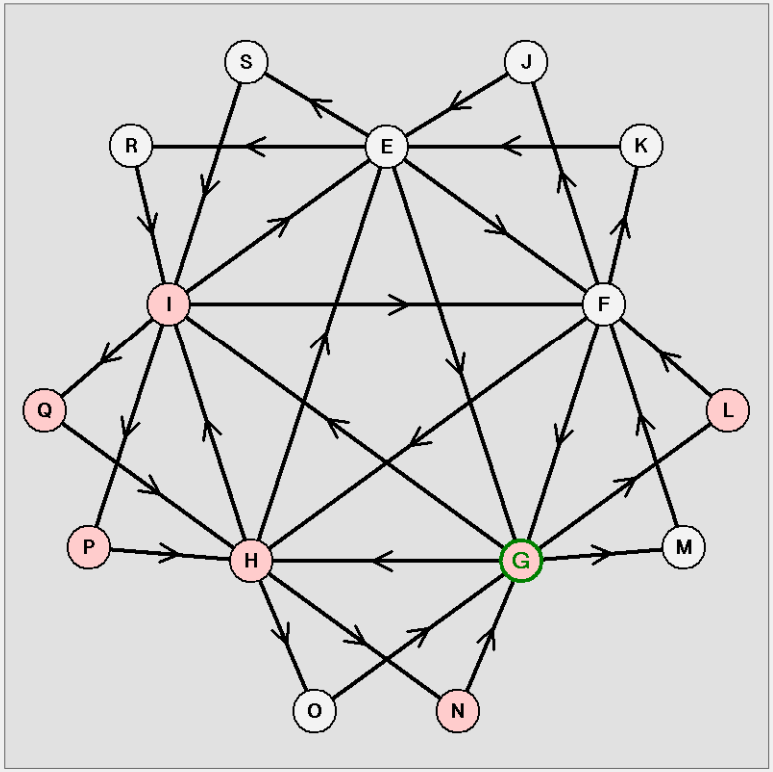
Round

2 of 21

Remaining time [sec]: 28

EXIT

Your position:	G	Shocked position:	G
Your asset value:	1060.00	Shock size:	5000.00



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

STAGE 1

BALANCE SHEET

CREDITS		DEBITS	
Debt paid from E	1000.00	Debt paid to H	0.00
Debt paid from F	1000.00	Debt paid to I	0.00
Debt paid from N	721.43	Debt paid to L	0.00
Debt paid from O	1000.00	Debt paid to M	0.00
		Direct loss from Shock	5000.00
Cash received from selling 1 asset:	1100.00		
Total cash credits	4821.43	Total cash debits	5000.00
		Total unpaid debt	4000.00

YOU ARE BANKRUPT

Stage 1 earnings: -4178.57 tokens

Earnings

Earnings from round = Stage 1 earnings

= -4178.57 tokens

OK

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.

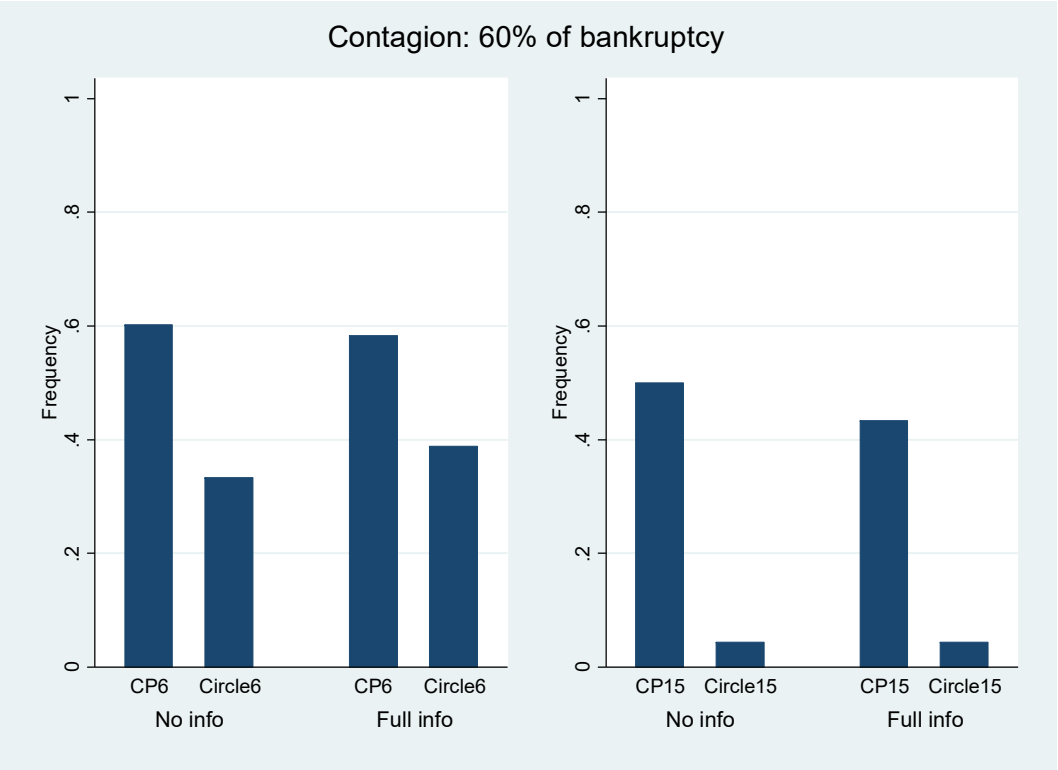
3. Benchmark II: competitive equilibrium with the assumption that the shocked person always sells its asset.

   – Network effects with endogenous price response.

Financial Contagion

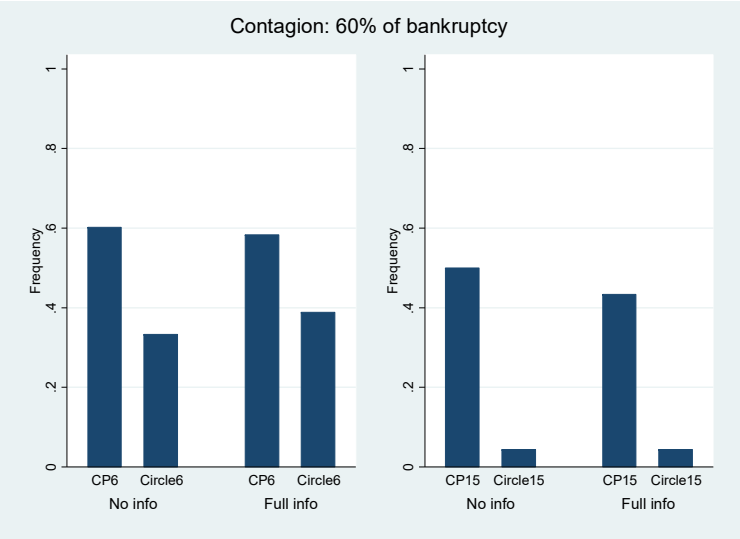
- Financial contagion with $x\%$ is defined to occur if $x\%$ of agents go bankrupt.

Contagion with 60%

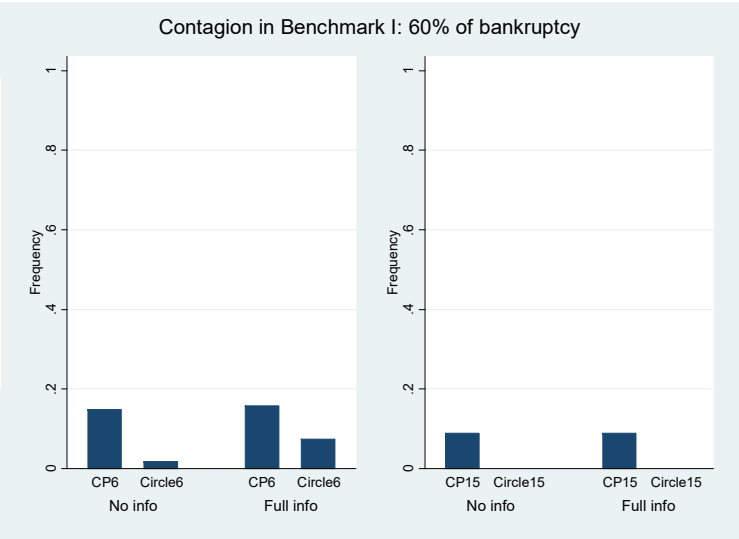


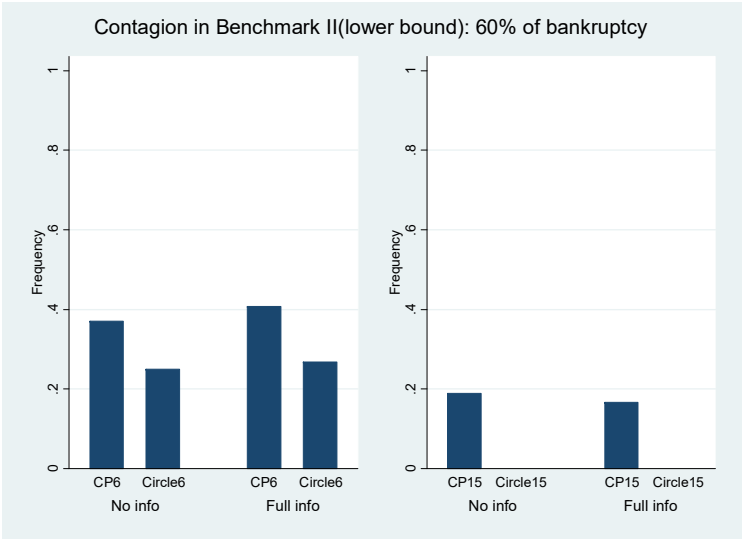
Contagion: Data vs. Benchmarks

Data



Benchmark I





Benchmark II

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

	All networks		Core-periphery networks	
	(1)	(2)	(3)	(4)
Networks and shocks				
shock recipient	0.307***	0.306***	0.370***	0.367***
	(0.077)	(0.076)	(0.110)	(0.109)
shock size: medium	1.550***	1.574***	1.541***	1.562***
	(0.065)	(0.067)	(0.081)	(0.082)
shock size: large	2.109***	2.142***	2.097***	2.127***
	(0.067)	(0.069)	(0.086)	(0.088)
distance from shock	-0.498***	-0.505***	-0.394***	-0.402***
	(0.017)	(0.017)	(0.028)	(0.028)
periphery shocked			-0.204***	-0.204***
			(0.060)	(0.060)
Asset value				
ln(asset value)		1.750***		1.838***
		(0.221)		(0.293)
Behavioral characteristics				
Fraction of correct answers in Part		-0.270**		-0.552**
		(0.118)		(0.229)
# of safe choices: gain		-0.013		0.009
		(0.017)		(0.026)
# of safe choices: loss		-0.010		-0.025
		(0.015)		(0.022)
Constant	-0.080	-11.851***	-0.478***	-12.669***
	(0.137)	(1.530)	(0.145)	(2.041)
Treatment & period dummies	Yes	Yes	Yes	Yes
Log likelihood	-3094.17	-3054.46	-1884.27	-1857.09
Observations	7,992	7,992	3,996	3,996
Number of subjects	444	444	222	222

- Shock matters for bankruptcy.
  - Shock receipient
  - Shock size
  - Distance from shock
- Comprehension task matters for bankruptcy: the smarter the individual is, the less likely he goes bankrupt.

Buy & Sell Decisions

	Buy		Sell	
	(1)	(2)	(3)	(4)
Asset value				
ln(asset value)	6.009***	6.004***	-6.270***	-6.269***
	(0.358)	(0.358)	(0.379)	(0.379)
ln(asset value) * CP networks	-3.117***	-3.116***	3.222***	3.227***
	(0.463)	(0.463)	(0.469)	(0.470)
Networks and shock				
shock recipient	-0.314***	-0.315***	0.357***	0.357***
	(0.074)	(0.074)	(0.069)	(0.069)
shock size: medium	-0.037	-0.037	-0.039	-0.039
	(0.045)	(0.045)	(0.043)	(0.043)
shock size: large	-0.046	-0.046	-0.058	-0.058
	(0.046)	(0.046)	(0.044)	(0.044)
distance from shock	0.078***	0.078***	-0.075***	-0.074***
	(0.016)	(0.016)	(0.016)	(0.016)
distance * CP networks	0.064**	0.063**	-0.023	-0.022
	(0.029)	(0.029)	(0.027)	(0.027)
Behavioral characteristics				
Fraction of correct answers in Part 2		0.005		0.429***
		(0.157)		(0.148)
# of safe choices: gain		-0.023		0.032
		(0.020)		(0.024)
# of safe choices: loss		-0.026		0.004
		(0.017)		(0.019)
Constant	-42.081***	-41.793***	42.949***	42.468***
	(2.473)	(2.488)	(2.597)	(2.591)
Treatment & period dummies included	Yes	Yes	Yes	Yes
Log likelihood	-4611.43	-4608.47	-4548.99	-4543.88
Observations	7,992	7,992	7,992	7,992
Number of subjects	444	444	444	444

- Structural factors matters for trading.
  - Asset value
  - Shock receipient
  - Distance from shock
- Comprehension task matters for trading: the smarter the individual is, the more likely he sells his asset.

Takeaway Points

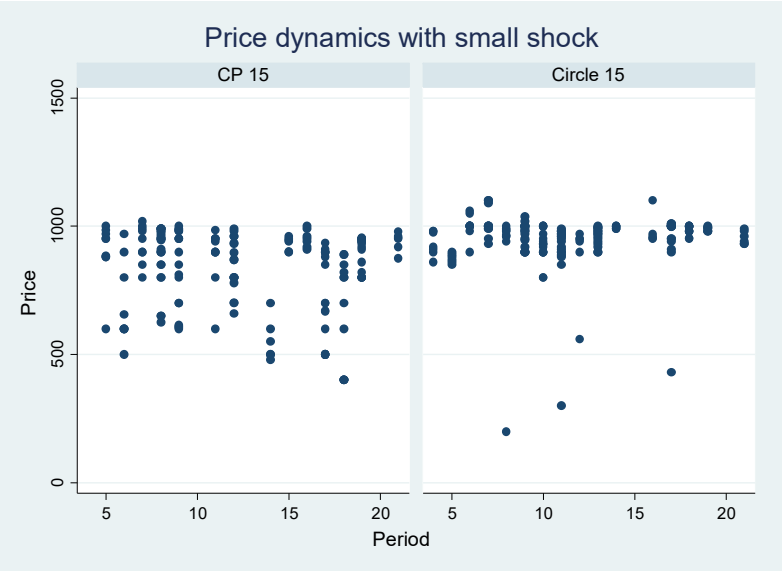
- We find strong impacts of network topology on contagion and bankruptcy.
- There is little impact of information on contagion.
  - We thus find little evidence on the amplification of contagion through such informational channel as Caballero and Simsek (2013).
- Structural and behavioural factors matter for bankruptcy and trading decisions.

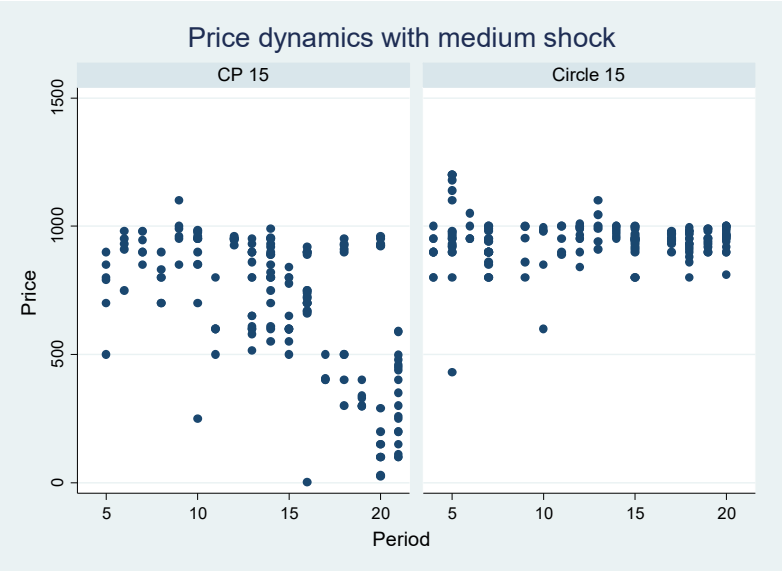
Price Formation

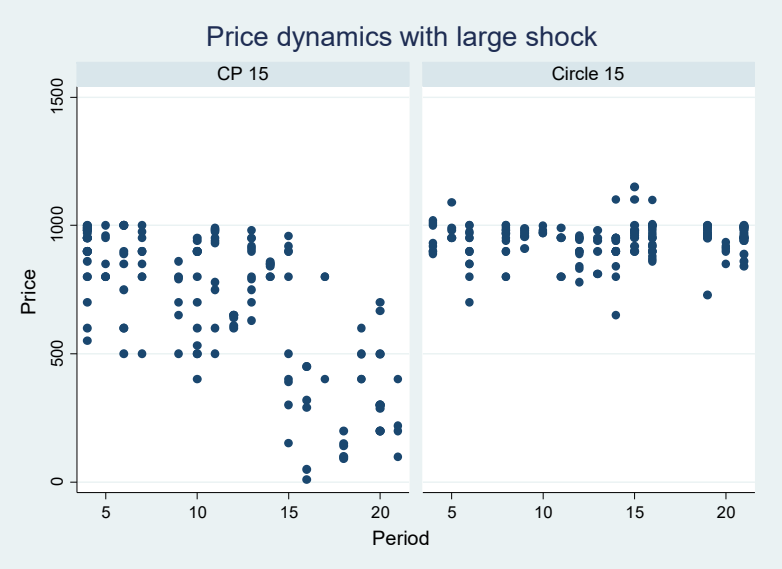
	Circle 6		CP 6		Circle 15		CP 15	
	Full info	No info	Full info	No info	Full info	No info	Full info	No info
All data	911	894	791	804	946	937	742	657
Last half data	905	883	758	748	948	942	646	543

- Network structure and size matter in price formation.
- Information effect on price formation appears less notable.

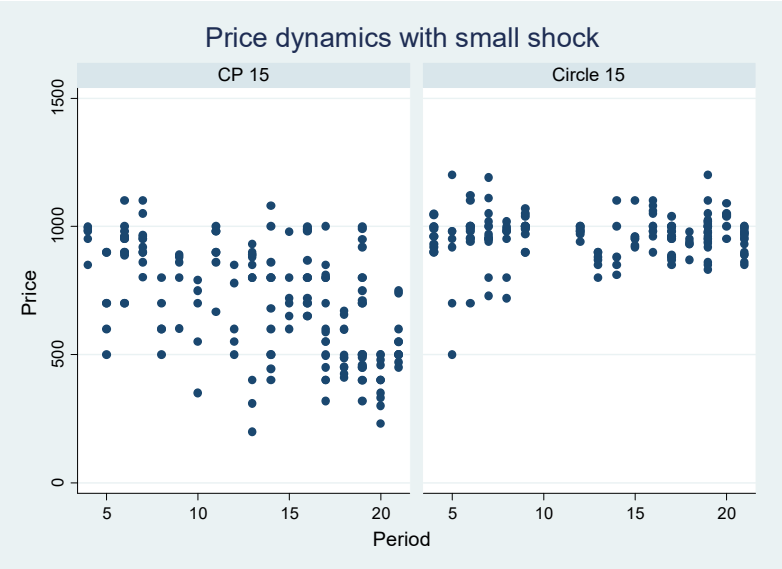
Price Formation: CP 15 vs. Circle 15 with full information

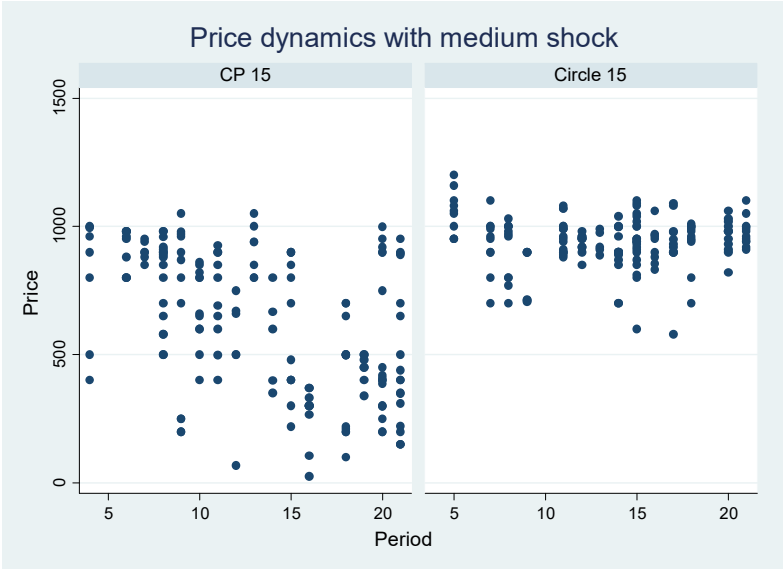


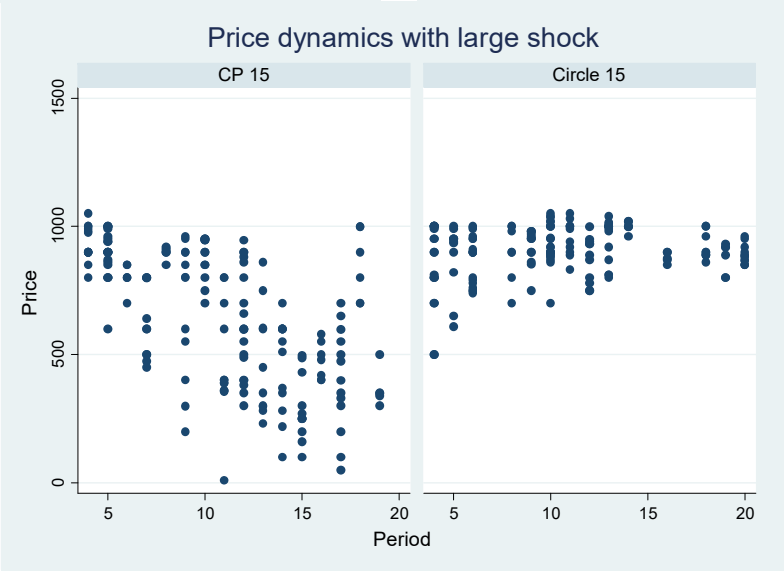




Price Formation: CP 15 vs. Circle 15 with no information







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

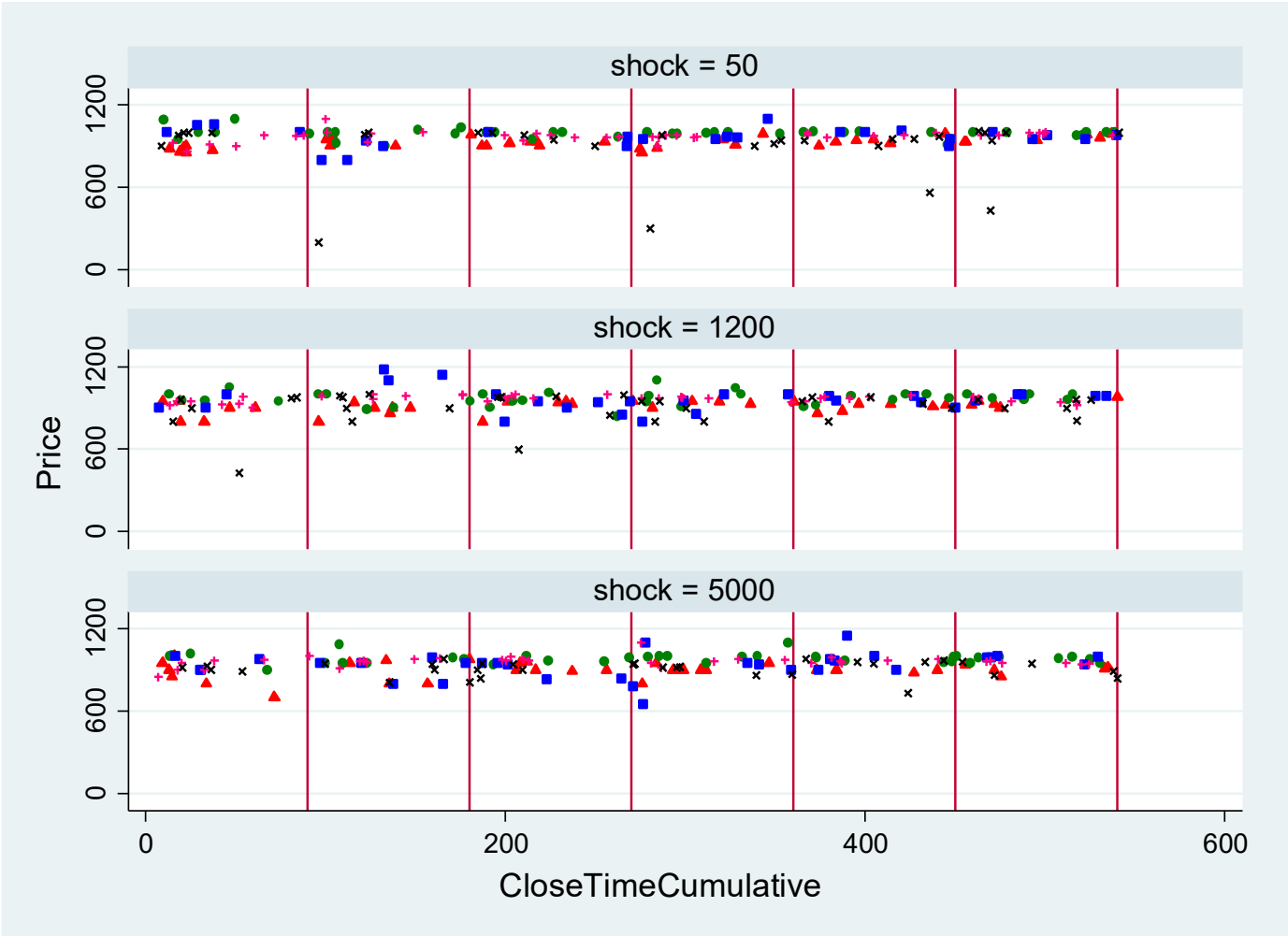
- In the circle networks,
  - (Circle 6 under full info) $=$ (Circle 15 under full info)
  - (Circle 6 under no info) $<^{***}$ (Circle 15 under no info)

- 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)

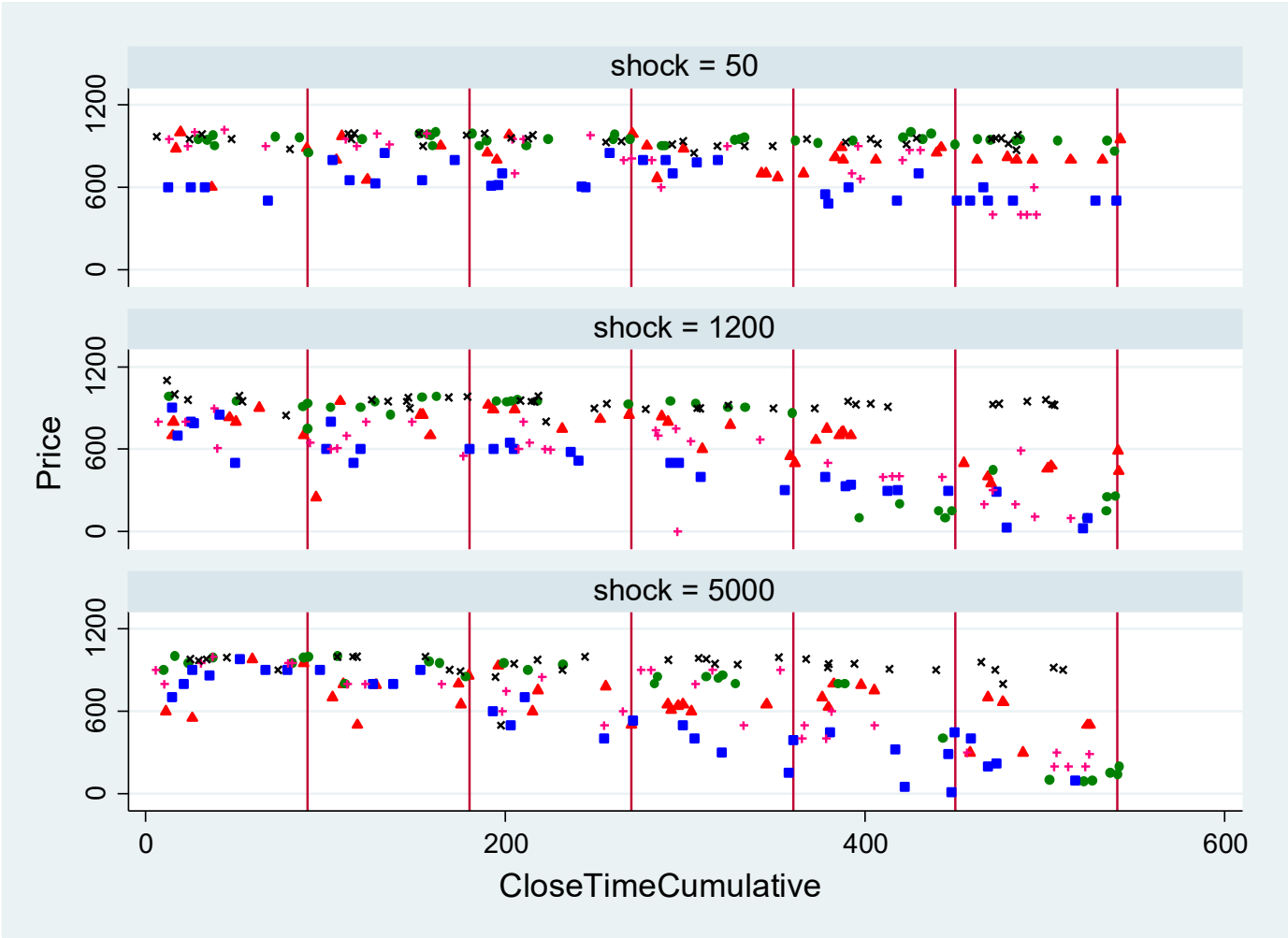
Conclusion

- 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

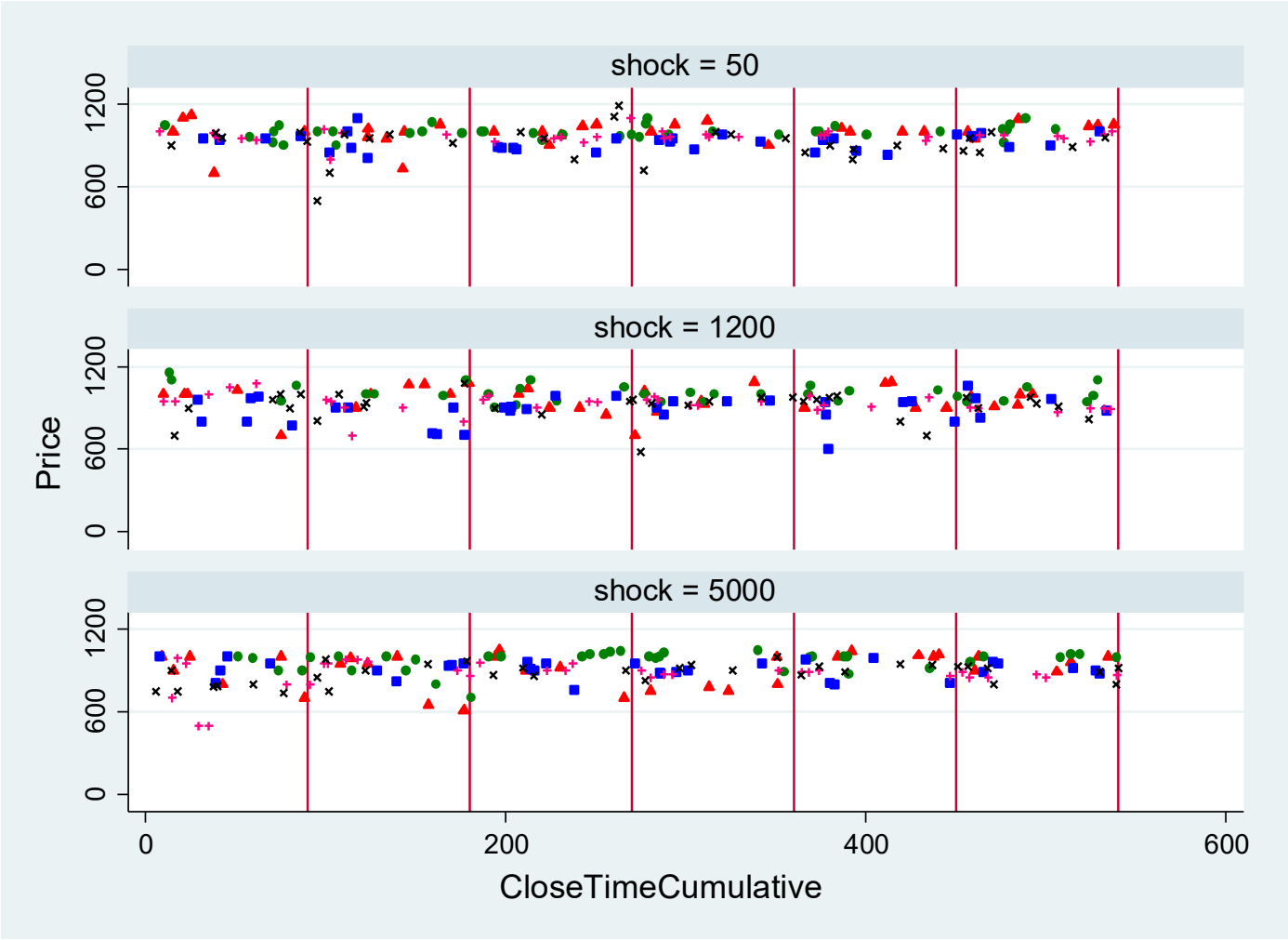
Price Dynamics: Circle 15 with full info



Price Dynamics: CP 15 with full info



Price Dynamics: Circle 15 with no info



Price Dynamics: CP 15 with no info