Financial Contagion in the Laboratory: Does Network Structure Matter?

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1. Introduction

- The financial crisis of 2007-08 has reinforced the view that interbank network linkages are crucial to understanding the financial fragility of a country's banking system.
- For example, in the US, the collapse of Lehman Brothers was associated with a \$423 billion dollar contraction in the US dollar *interbank* lending market (Gorton, 2010), and this in turn pushed other banks to the brink requiring government bailouts (e.g. Morgan Stanley) or led them to be sold off (e.g., Merrill Lynch).
- The traditional view of financial crises as involving a run by bank depositors on their own bank has been modeled as a self-fulfilling equilibrium coordination game by Diamond and Dybvig (1983, *hereafter*, DD) where depositors' beliefs play a pivotal role.
- The more modern view of financial contagion as an equilibrium phenomena arising from the interbank network structure was first proposed by Allen and Gale (2000).

2. Contributions

- We explore the key implications of Allen and Gale's interbank model of financial crises, namely that network structure *matters* for the fragility of the banking system.
- We address the importance of network structure for financial fragility using the methodology of *experimental* economics, which provides us with precise control over the network structure of interbank connections as well as over the information that is available to depositors in that network.
- This control enables us to gather data that can be used to directly test the role played by network structure in the spread of a financial crisis.
- While there are many experimental studies of the DD model of bank runs, our paper provided the ***first experimental test*** of whether the ***interbank network structure*** matters for the likelihood of financial contagion.

3. Model

- 3 periods: $t = 0,1,2$
- 4 ex ante identical banks, labelled A, B, C and D.
- Each banks contains a continuum of ex ante identical depositors.
- Single consumption good that serves as the numeraire, which can also be invested in assets to produce future consumption.
- At $t = 0$, each depositor has an endowment equal to one unit deposited at the bank.
- The bank has 2 investment opportunities:

1. Liquid (or short) asset: acts as storage technology → at $t = 1$, the return is exactly equal to the amount invested
2. Illiquid (or long) asset: higher return but requires more time to mature → at $t = 2$, the return is an amount $R > 1$; however, premature liquidation of this asset has a cost, $0 < r < 1$

- Depositors to all banks have the usual DD preferences:

1. With probability w they are impatient and value consumption only at date 1
2. With probability $1 - w$ they are patient and value consumption only at date 2

→ 2 possible values of w_i: high value, w_H, and low value, w_L.

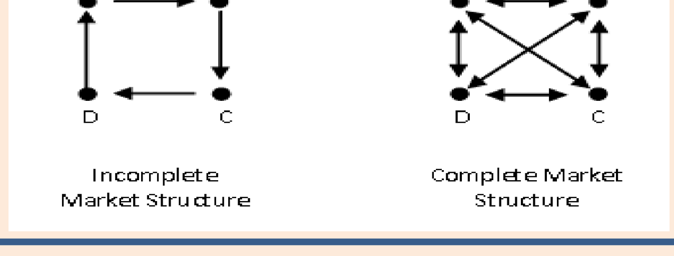
Table 1: Banks' liquidity shock

	A	B	C	D
S_1	w_H	w_L	w_H	w_L
S_2	w_L	w_H	w_L	w_H

- Banks know ex ante the average fraction of impatient depositors across all banks, $\gamma = \frac{w_H + w_L}{2}$ → invest amount $y = \gamma$ in short assets and $x = 1 - \gamma$ in long assets.

3.1. The Interbank Market

- Optimal allocation of risk is achieved by transferring resources among the different banks → introduce an interbank market of deposits.



3.2. Financial Fragility

- The "zero probability at date 0" perturbation state $\bar{S}$, in which the fraction of impatient depositors in (say) bank A is $\gamma + \varepsilon$.
- As this perturbed state is not known in advance, the continuation equilibrium is different from the normal state and depends on the network structure.

4. Experimental Design

- Our aim is to study the contagion of financial fragility, so we focus on the perturbation state.
- In our experimental setting, there are four banks: A, B, C and D.
- Each participants takes the role of a depositor.
- Payoffs have been estimated based on 4 depositors in each bank.
- We set $w_L = 1/4$ and $w_H = 3/4$. So, the average fraction of impatient depositors would be $\gamma = 0.5$.
- Bank A is the bank facing the financial fragility.
- The number of impatient depositor in bank A is $4 * \gamma = 2$ and in banks B, C and D, it is $4 * (\gamma + \varepsilon) = 3$.
- We implement a 2x2 between subjects design (four treatments):

Incomplete Network Structure	Complete Network Structure
r = 0.2	r = 0.2
r = 0.4	r = 0.4

- At the beginning of the experiment 8 participants are randomly divided into 4 groups of 2 and partners remain the same throughout the experiment (30 rounds).
- In each round, there are three periods (t = 0, 1 and 2).
- In period t =0, each group is assigned to each bank (and is informed about which bank it has been assigned to) and group members deposit 100 EP in their bank.
- In period $t = 1$, depositors in bank A learn whether or not they are forced to withdraw their deposit (if they are impatient or patient depositor, respectively).
- In each round, patient depositors have to make a single decision: whether to withdraw their deposit in $t = 1$ or wait until $t = 2$.
- Participants have full information about the perturbation, that is, that the shocked bank is always bank A and to which bank they are assigned in each round.

4.1. Hypotheses

1: *With LOW LR, in the INCOMPLETE Network, the original financial shock spreads to all banks as one after the other face bankruptcy.*

2: *With LOW LR, in the COMPLETE network, only the bank facing the financial shock should go bankrupt. The financial crisis does not become global in a fully integrated financial system.*

3: *With HIGH LR, in both the INCOMPLETE and the COMPLETE networks, only the bank facing the financial shock should go bankrupt. The HIGH liquidation cost becomes a substitute for market structure completeness.*

5. Results

Figure 1: Average Number of Bankrupted Banks

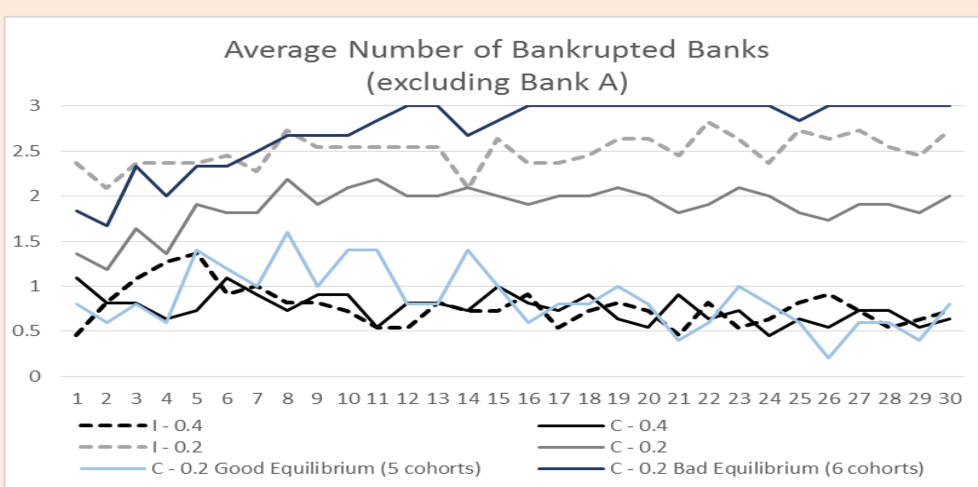


Figure 2: 5-Rounds Moving Average Number of Withdrawals

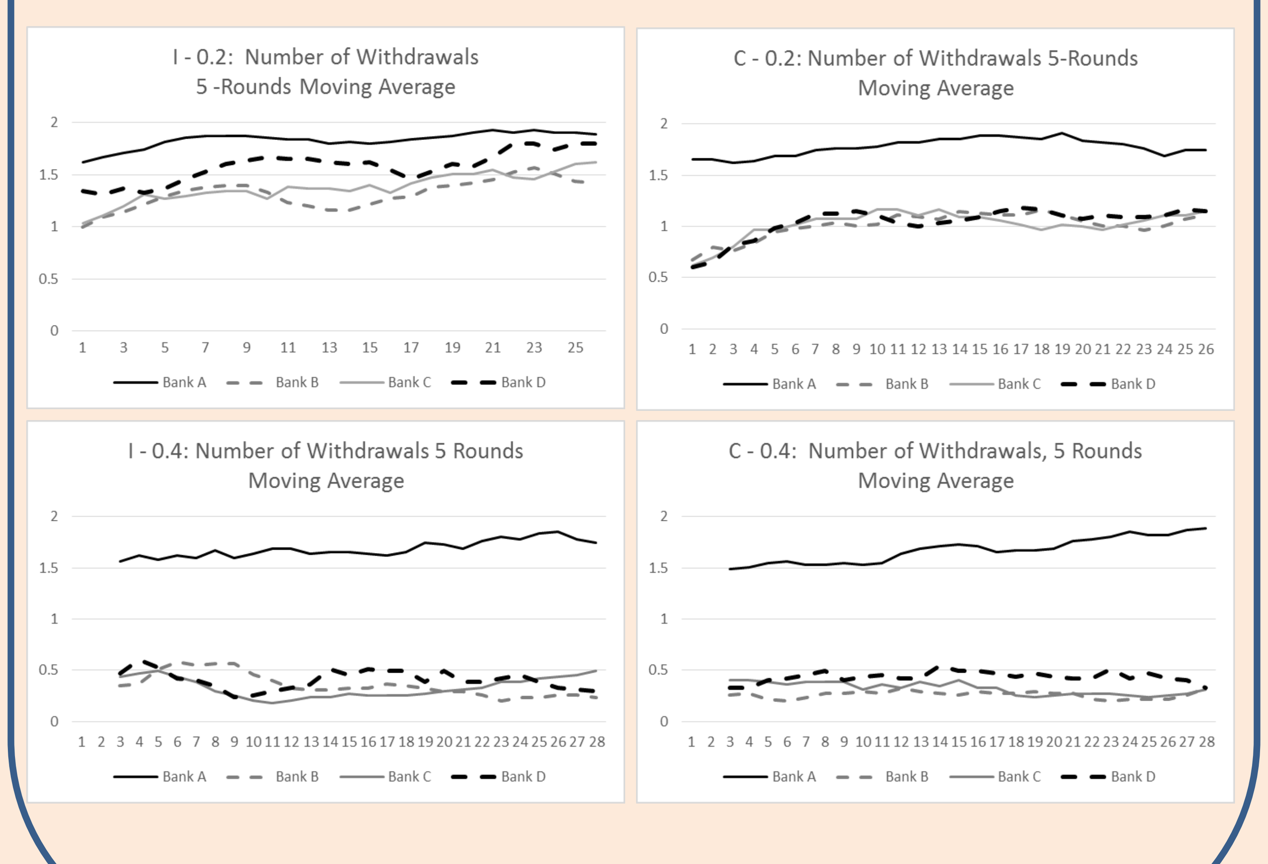


Figure 3: Average Efficiency

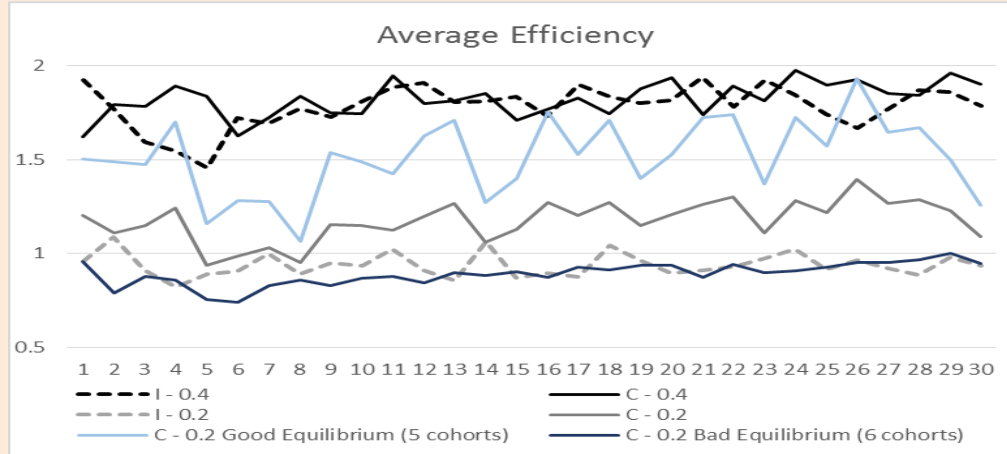


Table 2: Mixed effects Panel Logit Regression Analysis of Withdrawal Decisions

VARIABLES	(1) Odds ratio	(2) Odds ratio	(3) Odds ratio	(4) Odds ratio	(5) Odds ratio	(6) Odds ratio	(7) Odds ratio	(8) Odds ratio
Network Structure Incomplete = 1	3.498***	3.462***	3.279***	3.260***	3.137***	3.118***	2.790***	2.773***
	(1.657)	(1.629)	(1.457)	(1.438)	(1.343)	(1.325)	(1.071)	(1.056)
Liquidation Rate High (0.4) = 1	0.201***	0.202***	0.224***	0.226***	0.240***	0.241***	0.285***	0.287***
	(0.0950)	(0.0946)	(0.0992)	(0.0991)	(0.102)	(0.102)	(0.109)	(0.109)
Incomplete x Liquidation Rate High	0.293*	0.301*	0.310*	0.312*	0.324*	0.326*	0.356*	0.359*
	(0.196)	(0.200)	(0.194)	(0.194)	(0.196)	(0.196)	(0.193)	(0.193)
Withdraw (if not forced) in t-1			1.650***	1.650***	1.455***	1.456***	1.447***	1.448***
			(0.119)	(0.119)	(0.110)	(0.110)	(0.110)	(0.110)
Partner withdraw in t-1					1.504***	1.501***	1.569***	1.567***
					(0.113)	(0.112)	(0.118)	(0.118)
Number of withdrawals in connected banks in t-1 (normalized)							1.986***	1.985***
							(0.214)	(0.214)
if sex = Female		1.151		1.172		1.176		1.178
		(0.138)		(0.125)		(0.134)		(0.136)
Age (years)		0.985		0.987		0.986		0.987
		(0.0120)		(0.0107)		(0.0114)		(0.0116)
If native language not English		0.953		1.028		1.020		1.019
		(0.131)		(0.126)		(0.133)		(0.134)
Experience in DM Experiments		1.002		0.997		0.997		0.998
		(0.0154)		(0.0138)		(0.0146)		(0.0148)
Constant		1.504		1.192		1.022		0.660
		(0.638)		(0.464)		(0.400)		(0.249)
Observations	9,240	9,240	7,834	7,834	7,834	7,834	7,834	7,834
Number of groups (cohorts)	44	44	44	44	44	44	44	44

Notes: Dependant variable withdraw=1. Mixed-effects panel logistic regression, Three levels: Cohort (N=44)-group (N=176)-individual (N=362). Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

- β_1: The odds of withdrawal in the incomplete network structure are 3.5 times larger than in the complete network structure when the liquidation rate is low.
- β_2: The odds of withdrawal in the high liquidation rate treatment are 4.978 (=1/0.201) times lower than in the low liquidation rate treatment when the network structure is complete.
- β_3: The difference between the odd of withdrawal comparing incomplete *vs* complete network structures is about 3.4 times larger when the LR is low.
- $\beta_1 + \beta_3$: When the liquidation rate is high, the odds of withdrawal are similar between incomplete and complete network structure.
- $\beta_2 + \beta_3$: When the network structure is incomplete, the odds of withdrawal are 8.3 times smaller in the high LR than in the low LR treatment.
- $\beta_1 + \beta_2 + \beta_3$: the odds of withdrawal in the treatment with incomplete network and high liquidation rate are 4.855 smaller than in the complete network structure with low liquidation rate.

Table 3: Mixed effects Panel Logit, showing Odd Ratios for Banks (Baseline Bank A) by treatment, dependent variable "wait=1"

VARIABLES	Incomplete - Low LR	Complete - Low LR	Incomplete - High LR	Complete - High LR
Bank				
B	10.48***	20.64***	81.98***	81.02***
	(2.011)	(3.958)	(16.91)	(16.34)
C	7.433***	21.90***	87.62***	78.71***
	(1.406)	(4.208)	(18.11)	(15.83)
D	4.581***	20.59***	59.99***	63.29***
	(0.890)	(3.944)	(11.71)	(12.42)
Constant	0.0371***	0.0517***	0.111***	0.115***
	(0.0135)	(0.0254)	(0.0358)	(0.0327)
Observations	2640	2640	2,640	2,640
Number of groups (cohorts)	11	11	11	11

Note: Three levels: Cohort (N=44)-group (N=176)-individual (N=362). Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

- With LR low in the incomplete network structure, the odds of 'waiting' are lower the closer is the connection to Bank A. Consistent with a behavioural bias favouring early withdrawal the more directly connected the bank is to the source of the financial crisis.

6. Conclusion

- First experiment exploring the role of interbank network structure for the incidence of financial contagion.
- We find that:

1. When the premature liquidation cost is high, while more complete interbank network structures may reduce the incidence of financial contagions by facilitating more efficient risk sharing among banks, such complete network structures are not a *panacea* for preventing such contagions.
2. When the premature liquidation rate is reduced, we observe no significant difference in the probability of contagions in the incomplete and the complete network structures.
3. Low premature liquidation cost is a substitute for a more efficient risk sharing environment (i.e., complete network structure).