Beware of topology! An analysis of contagion in banking networks

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Outline

New trends...

"Before 1997, the term "contagion" usually referred to the spread of a medical disease"

"A Lexis-Nexis search of major newspapers since mid 1997 finds that almost all articles using the term contagion referred to the spread of financial market turmoil across countries"

International Financial Contagion
Claessens and Forbes, 2001

Related literature

Empirical literature: study the main properties of complex structure (interconnectedness, clusters, hub, concentration)

- International financial system (Garratt et al. (2011), Minoiu and Reyes (2011), Von Peter (2007))
- National interbank markets (Bech et al (2011), Boss et al (2003), Soramaki et al. (2007))

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Theoretical literature: models of financial system as a network among banks and analysis of contagion dynamics

- Dynamic models (Iori et al. (2006), Ladley (2011), Lenzu and Tedeschi (2012))
- Static models (Allen and Gale (2000), Nier et al. (2007), Gai et al. (2011))

Empirical

Stylized facts on banking networks

- low density (below 1%)
- low average path length (2-3 degrees of separation)
- power-law degree distributions
- communities and tiered structure (small-bank-large-bank dichotomy)
- disassortativity

Theoretical

Systemic risk and channels of contagion

- Information: poor performances of one bank increase borrowing costs of other banks
- Liquidity: "fire selling" of assets and falling prices due to idiosyncratic shock to a bank. Strong (specific asset type) and weak (general loss of confidence)
- Common shock: crisis as part of business cycle
- Interlocking credit exposure:
  - Financial contagion: the large scale breakdown of financial intermediation due to domino effects of insolvency
  - Bank run: liquidity hoarding by banks, which cascades and generate systemic liquidity crisis

Main questions

What kind of interbank network structure is more or less prone to systemic collapse?

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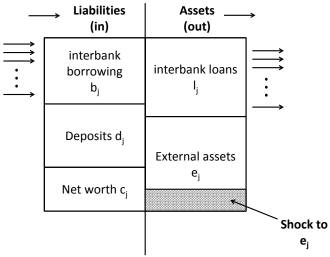
What kind of interbank network structure is more or less prone to systemic collapse?

1. Financial contagion in Erdos-Renyi, small-world (Watts and Strogatz 1998) and scale-free (Barabasi and Albert 1999) networks
2. Probability and extent of financial contagion and systemic hoarding in a tiered banking network

Outline

Bank balance sheet and shocks

Credit shock → financial contagion



$$c_j = (e_j + i_j) - (d_j + b_j) \geq 0$$

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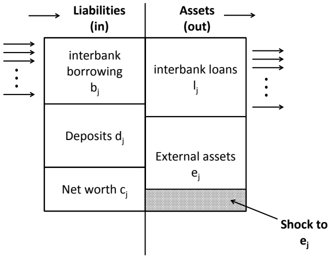
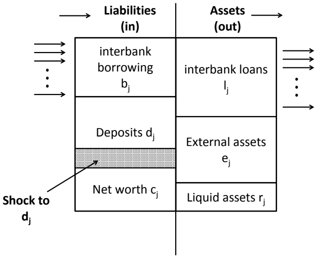


$$c_j = (e_j + i_j) - (d_j + b_j) \geq 0$$

Funding shock → bank run

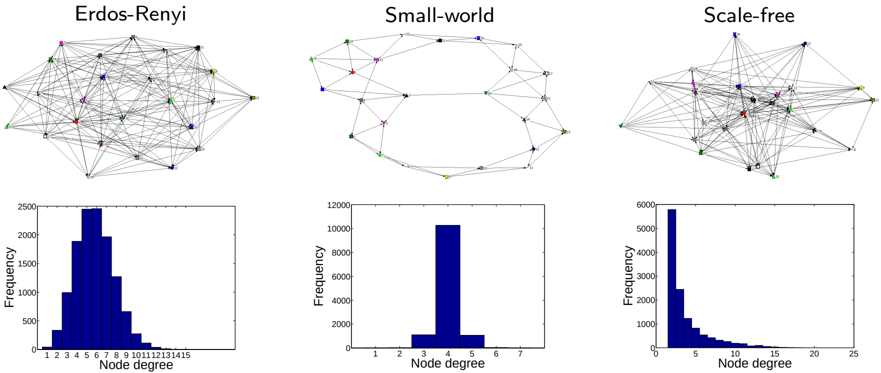


$$r_j = (d_j + b_j + c_j) - (e_j + i_j) \geq 0$$

Interbank network models 1

Parameter	Network type	Description	Benchmark value
E	All	Total external assets	100000
N	All	Number of banks in the network	25
γ	All	Percentage of net worth to total assets	0.05
θ	All	Percentage of interbank assets to total assets	0.2
p	Erdos-Renyi	Probability of connection between any two nodes	0.2
r	Small-world	Number of nearest-neighbours to connect	2
p	Small-world	Rewiring probability	0.05
d	Scale-free	Minimum node degree	2

Interbank network models 2

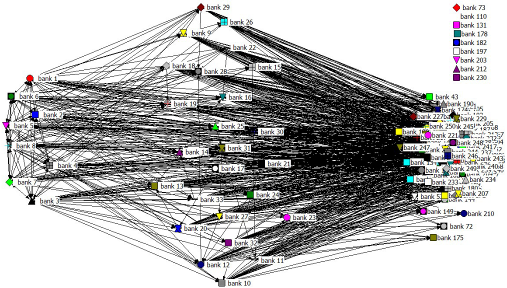


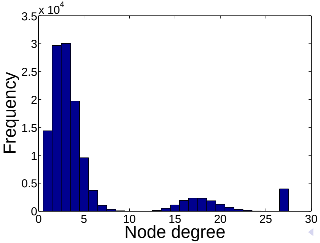
Tiered network 1

$$A = \begin{pmatrix} C-C & C-SP & C-P \\ SP-C & SP-SP & SP-P \\ P-C & P-SP & P-P \end{pmatrix} = \begin{pmatrix} 1 & 4\times p & 0.5\times p \\ 2\times p & 0.5\times p & 0.5\times p \\ 0.1\times p & 0.1\times p & 0 \end{pmatrix}$$

Adjacency matrix defining the tiered network: A_{ij} is 1 if bank i borrows from bank j and 0 otherwise

Tiered network 1





Tiered network 2

"Core-periphery structure could be seen as a new stylized fact of modern banking systems" *Fricke and Lux*, 2012

Feature	Erdos-Renyi	Tiered Model	Real world	Sources
Density	0.01	0.01	< 0.01	Bech et al. (2010), Craig and Von Peter (2010) Soramaki et al. (2007)
Average path length	4.2	3.0	$2 - 3$	Boss et al. (2003), Soramaki et al. (2007)
Clustering	0.01	0.1	$0.12 - 0.28$	Boss et al. (2003), Bech et al. (2010)
Out-degree/in-degree correlation	0	-0.37	~ -0.3	Bech et al. (2010), Boss et al. (2003), Soramaki et al. (2007)
Degree distribution	normal	tiered	power-law/tiered	Bech et al. (2010), Boss et al. (2003)

Tiered network 2

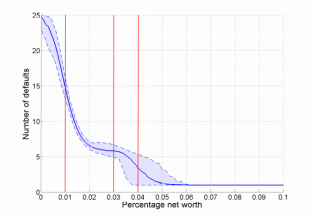
Many small creditor banks and a few large borrowing banks

Connectivity	$p = 0$	$p = 0.1$	$p = 0.2$	$p = 0.3$	$p = 0.4$	$p = 0.5$	$p = 0.6$	$p = 0.7$	$p = 0.8$
Average total degree									
Large	14	42	70	94	111	129	142	155	168
Medium	0	20	41	60	76	93	109	124	139
Small	0	2	4	6	8	10	12	14	16
Average net position									
Large	0	-14	-28	-36	-39	-43	-52	-61	-70
Medium	0	-7	-15	-23	-32	-43	-52	-61	-70
Small	0	1	3	4	5	7	8	9	11

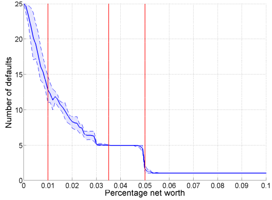
Outline

A "Representative cascade"

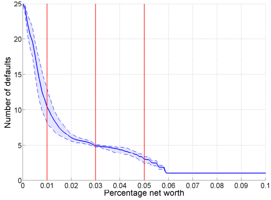
Erdos-Renyi



Small-world

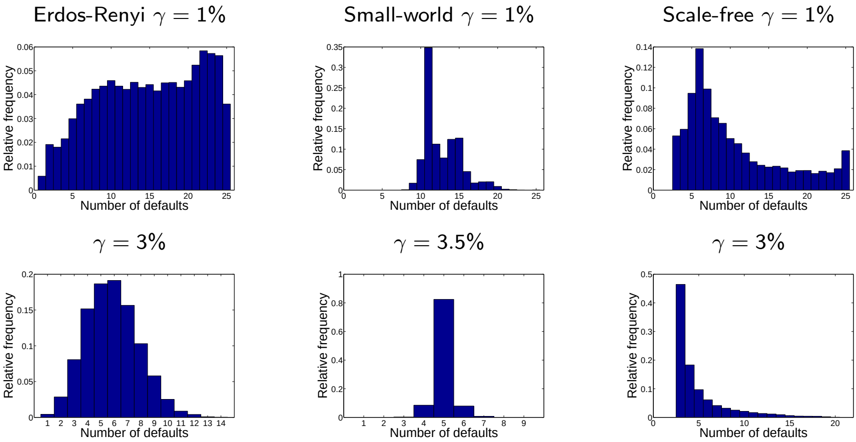


Scale-free



Non-linear relation between capitalization and contagion

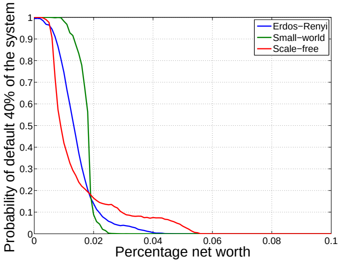
A closer look at the distributions of defaults



A map between degree distribution and default distribution?

Policy implications

Extreme event



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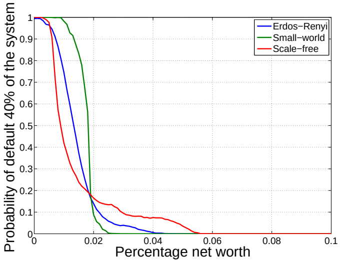
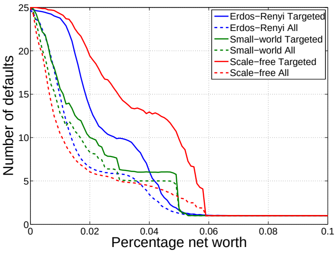


Targeted shock



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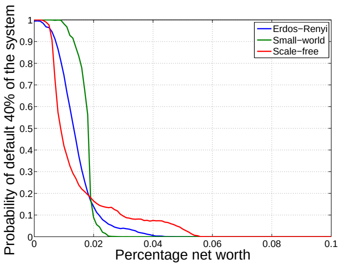

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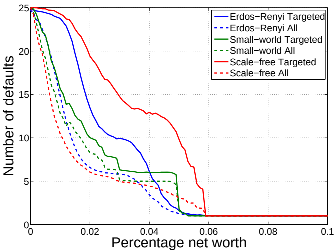
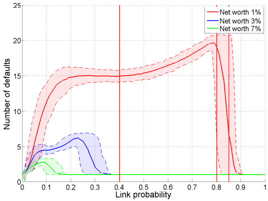


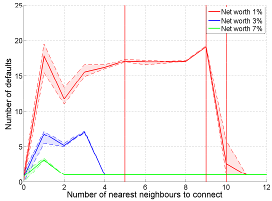
- Erdos-Renyi network in-between the small-world and scale-free networks
- Role played by heterogeneity → homogeneous capital requirements may work well in a small-world banking network, targeted ratio for most connected banks in scale-free

Links as “shock-absorbers” or “shock-transmitters”?

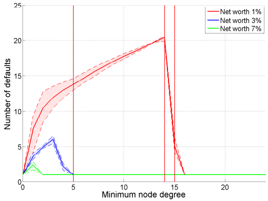
Erdos-Renyi



Small-world



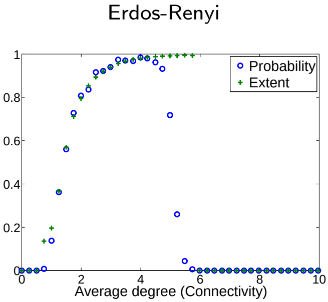
Scale-free



- Non-monotonic effect of connectivity on contagion
- M-shape relation is Erdos-Renyi and small-world. Different dynamic in scale-free
- Better capitalized systems $\rightarrow$ connections more likely to act as “shock-absorbers”

Outline

Random credit shock



- Probability of contagion non-monotonic in connectivity, extent monotonically increasing inside the contagion window = "robust-yet-fragile" (as in Gai and Kapadia, 2010)

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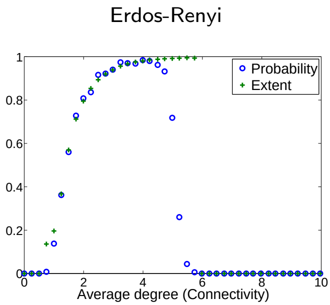
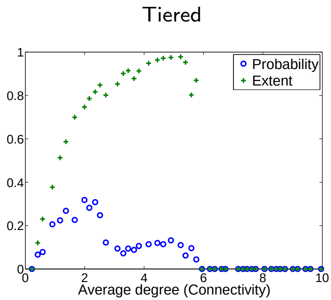
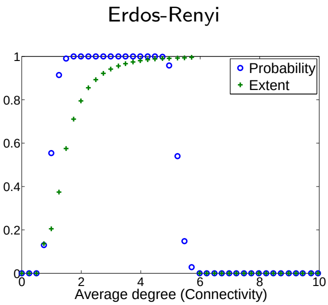




- Probability of contagion non-monotonic in connectivity, extent monotonically increasing inside the contagion window = "robust-yet-fragile" (as in Gai and Kapadia, 2010)
- Tiered structure more robust to random idiosyncratic shock (lower probability of contagion), but accentuates "robust-yet-fragile" tendency

Targeted credit shock



- No major changes in Erdos-Renyi network

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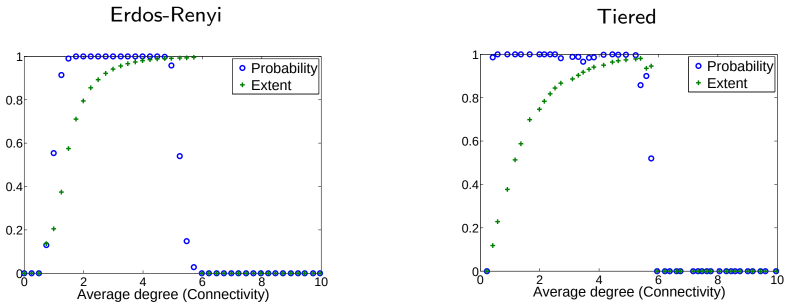
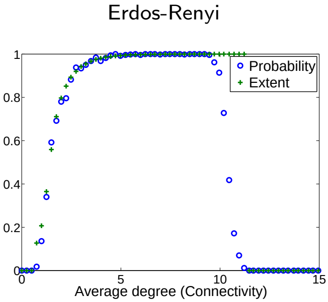


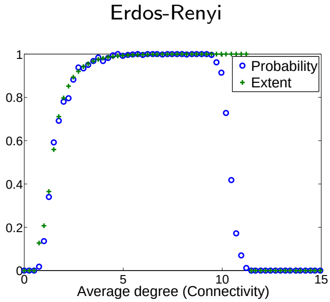
- No major changes in Erdos-Renyi network
- In tiered structure almost sure to observe contagion when the shock hits the most connected borrower

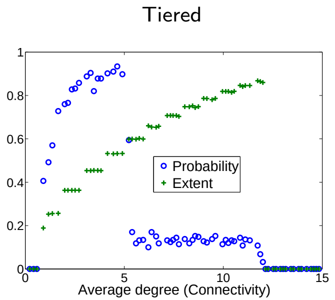
Random funding shock



- Probability and extent of bank run $\sim$ financial contagion

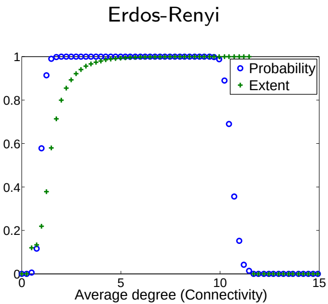
Random funding shock





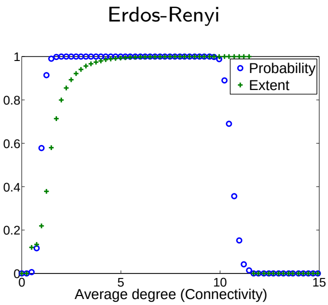
- Probability and extent of bank run $\sim$ financial contagion
- Rise in probability and then drop. Stepwise increase in the number of hoarding banks
- Combination of probability and magnitude opposite to "robust-yet-fragile" for density close to real banking networks

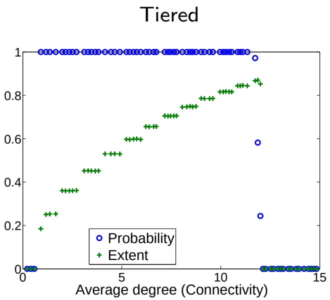
Targeted funding shock



- Again no big differences in Erdos-Renyi case

Targeted funding shock





- Again no big differences in Erdos-Renyi case
- In tiered structure along all the contagion window we are almost sure to observe systemic hoarding if a withdrawal affects a central lender

Outline

Main results

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- Erdos-Renyi network in-between small-world and scale-free networks
- Relation between degree distribution and default distribution

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Real banking networks

- Tiered system more "robust" to random shocks, "yet fragile" to targeted shocks than Erdos-Renyi networks
- Diversities between financial contagion due to a random failure and systemic hoarding due to a random initial withdrawal

Future research

Next steps...

- Weighted network (i.e. introduce links' magnitude)
- Robustness with respect to the size of the network (i.e. vary the number of banks)

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What lies ahead?

- Merge theoretical models with empirical stylized facts of real banking systems
- Introduce behavioural considerations and closer-to-reality rules in dynamic models to study the endogenous build-up of systemic risk

Thank you for your attention!