Financial Contagion in Interbank Networks
PhD Thesis

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Outline

- ❑ **Introduction**
- ❑ **Literature Review**
- ❑ **Uniform probabilistic network model**
- ❑ **Erdős-Rényi probabilistic network model**
- ❑ **Policy implications**

Introduction

“And the lessons from the global financial crisis are of course many and varied. But among the most important is also perhaps the simplest: to safeguard against systemic risk, the financial system needs to be managed as a system.”

in the speech “Rethinking the financial network” by Andrew G. Haldane, Executive Director of Financial Stability, Bank of England, at the Financial Student Association, Amsterdam, 28 April 2009.

Need for a Better Understanding of Contagion

Introduction

Literature Review

Uniform probabilistic network model

Erdős-Rényi probabilistic network model

Policy implications

Questions

- The financial crisis that began in 2007 and hit the U.S economy as well as the global financial system showed how a globally interconnected financial network can transmit shocks to financial centers all over the world.

- Even if an initial shock affects only a small number of institutions, the high connectivity of the financial system implies that a shock can be transmitted widely and can often cross international boundaries.

Systemic Risk and Interconnectedness

Systemic risk: Risk that failure of a participant to meet its contractual obligations, may in turn cause other participants to default with a chain reaction leading to broader spreads and instability throughout the whole financial system.

Channels of contagion :
- Direct interbank linkages (lending relationships)
- Indirect interbank linkages (identical assets, portfolio returns and overlapping portfolios)

Why does interconnectedness matter for financial stability?

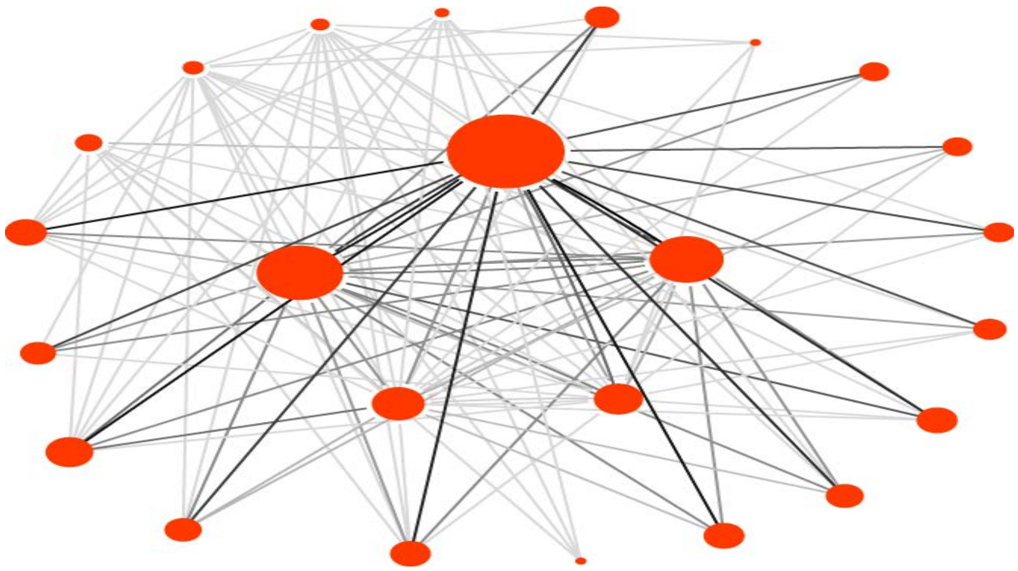
- **Interconnectedness or Connectivity in the interbank market can be** both a risk sharing and a risk amplification device. In normal times, interconnectedness may lead to an enhanced liquidity allocation and an increased risk sharing device between banks but in times of a crisis, interconnectedness can amplify shocks and propagate the crisis all over the network.

Thus, we have a global financial network system. How to model it?

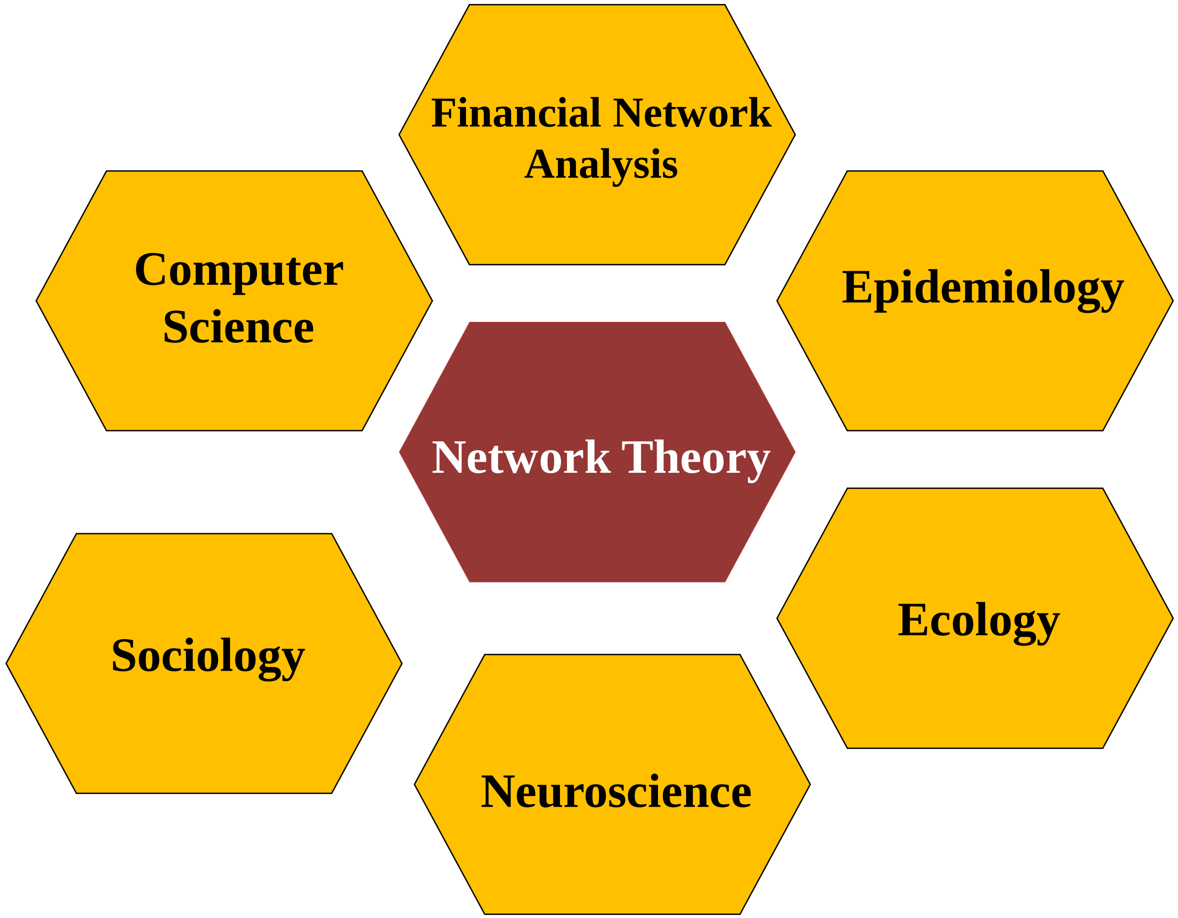
- Networks!

Why networks?

- Easy to model and visualize relations
- Easy to calculate major statistics
- The study of an interbank system as a network help us to understand how an initial shock can propagate within the system or find critical nodes (banks)



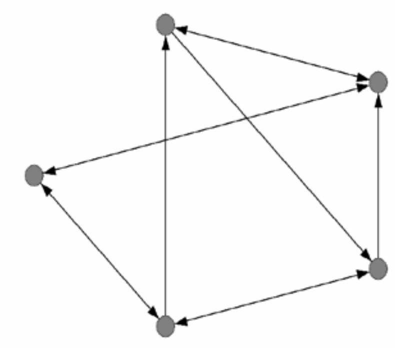
Network Theory and its applications



Network Structure

- An interbank network has n financial intermediaries (‘banks’)

- Each bank is a node, unsecured interbank assets and liabilities define links (weighted and directed)



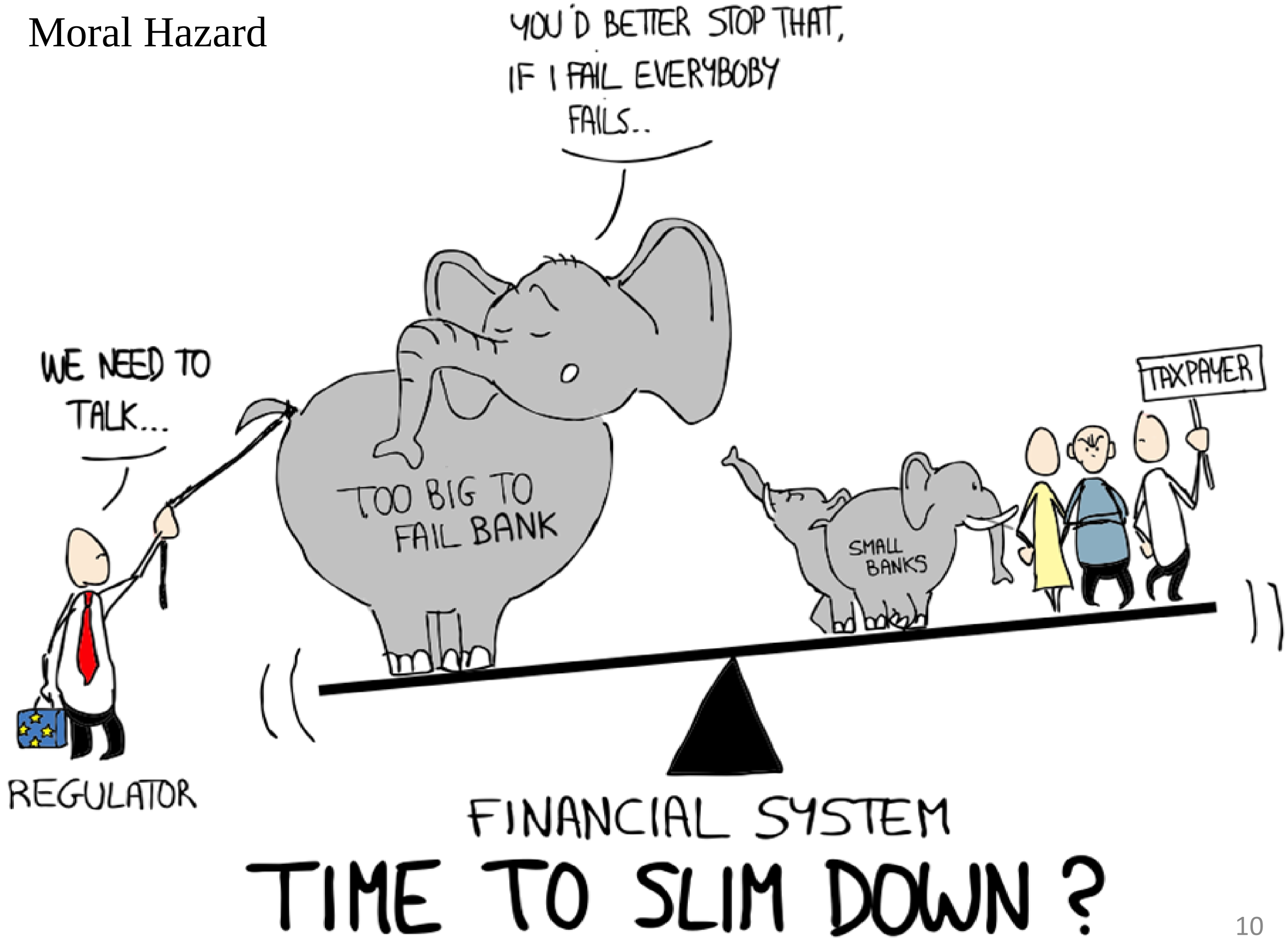
- Incoming (in-degree) and outgoing links (out-degree) define the degree distribution of the network.

Research Objectives & Research Questions

- Develop a better understanding of systemic risk in interbank markets
- Investigate how complexity and capital structure of an interbank network system affect interbank contagion.
- Focus on how an initial random shock can spread via the complex network of direct counterparty exposures.

Regulators' Dilemma: Let it fail or save it ?

- Too big or too connected to fail ?
- Bail-outs vs Bail-ins
- Moral Hazard



Complex Interbank Networks

The flourishing literature which ensued during the last few years has developed two distinct methodologies that use complex networks to analyze issues related to financial stability and shock propagation:

- ❑ methodology that applies **counterfactual simulations** to assess the danger of contagion in a range of national banking systems (Iori et al. (2008) for Italian banking system, Boss et al.(2004) for the Austrian interbank market and Wells (2002) for the UK interbank system.)
- ❑ methodology that analyses the **topological structure of interbank networks** in order to assess their stability.

Literature Review

❑ Counterfactual simulations

✓ Estimation of the **NxN exposure matrix**

Some sources of this information on bilateral exposures can be found:

- in reports provided by banks to their supervisors or credit registers or in balance sheet data.
- through payment data

$$E = \begin{bmatrix} 0 & a_{12} & a_{13} & a_{14} \\ a_{21} & 0 & a_{23} & a_{24} \\ a_{31} & a_{32} & 0 & a_{33} \\ a_{41} & a_{42} & a_{43} & 0 \end{bmatrix}$$

✓ Simulation process starts by assuming a bank is unable to repay its obligations in the interbank market.

✓ Losses and effects on other banks are calculated.

✓ Contagious defaults generally arise when the losses as a result of the exposures to the defaulting banks exceed the capital (Tier I capital) of a creditor bank.

❑ Topological structure of interbank networks

-Analyze the stability of various network formation models (network growth models, strategic network formation models etc)

Scale-free degree distribution: **networks characterized by the presence of hubs, that are nodes with a degree that is much higher than the mean degree of the other banks.** (Boss et al. (2004) for the Austrian interbank market, Inaoka et al. (2004) for the Japanese interbank market, Soramaki et al. (2007) for the US Fedwire system, Alves et al. (2013) for the European interbank market for large banks, while there exist divergent findings for the Italian interbank market (Iori et al. (2008), Lux et al. (2012))

Disassortative lending: networks where less connected nodes have a tendency to be connected with higher connected nodes. (Bech and Atalay (2010) and Soramäki et al.(2007))

Tiering in interbank market: networks operating in a hierarchical fashion, when few banks (core banks) intermediate between other banks (periphery banks) that do not transact with each other. (Crain and von Peter (2014) and Fricke and Lux (2015))

The role of heterogeneity in the interbank network structure

- Heterogeneity of connectivity, of exposures and the size heterogeneity of traders plays an important role on the stability of the financial system.

- Evidence is mixed and depends mainly on the initial shock, the bank that is initially distressed from the shock and how interconnected is with the other banks of the network system.

- Connectivity can act as both risk sharing and a risk amplification device.
  - "Robust-yet-fragile" systems (Haldane, 2009) (beyond a certain point, higher connectivity can harm the stability of financial system).

❑ Our Contribution:

- ✓ **Balance sheet and network based approach**

- ✓ **Direct Channel of contagion** (counterparty losses). A shock is diffused only via a direct channel of contagion. For example, once a bank is declared insolvent and goes bankrupt, its creditors suffer losses equivalent to the face value of their exposures with the defaulting bank. Furthermore, we assume zero recovery: i.e. when one's counterparty defaults, the creditor bank loses all of its interbank assets held against the defaulting bank.

- ✓ **Large set of simulated banking systems** (lack of bilateral data).

- ✓ **Examine how connectivity, heterogeneity of exposures and the size heterogeneity of traders affect contagion**

- ✓ **Find a relationship between contagion and various parameters that are introduced in our study**, e.g. :

  -how complexity (links) affect contagion,
  -how the relationship of interbank capital-interbank loans affect contagion,
  -how the variance of interbank capital-interbank loans affect contagion.
  -how leverage of the interbank system affect contagion

Definitions

- Unlike most papers in the recent literature (Nier et al.,2007; Gai and Kapadia,2010;Chinazzi et al.,2015; Amini Et al.,2016), we define **the term contagion** as the situation in which the initial failure of a bank leads to the failure of at least one other bank.

- The **extent of contagion is measured by the total capital loss in the banking system due to the failure of at least one bank**. In other words, we are mostly interested in detecting the magnitude of capital losses in the banking network rather than the number of banks that were adversely affected.

Uniform probabilistic network model

- A model has been developed with banks linked one another by their interbank claims and has been investigated by means of Monte Carlo simulations how complexity and capital structure of an interbank network affect interbank contagion under different scenarios tested.

- The constructed network systems are consisted of n=20, 50, 80, 100 nodes (banks) and link formation (degree distribution) between banks follows a uniform distribution.

- 9 independent Monte Carlo simulations have been employed, one for each interbank network size separately with k=2000 runs.

- The default procedure starts with an exogenous shock being simulated, typically by setting zero the equity of one randomly chosen bank *i* and the cascades of default proceeds on a step by step basis, assuming zero recovery.

- ✓ **Balance sheet allocation**
- ✓ **Link formation process**
- ✓ **Estimation of the NxN exposure matrix**

$$E = \begin{bmatrix} 0 & a_{12} & a_{13} & a_{14} \\ a_{21} & 0 & a_{23} & a_{24} \\ a_{31} & a_{32} & 0 & a_{33} \\ a_{41} & a_{42} & a_{43} & 0 \end{bmatrix}$$

- ✓ **Simulation process starts by assuming a bank is unable to repay its obligations in the interbank market.**
- ✓ **Losses and effects on other banks are calculated.**
- ✓ **Contagious defaults generally arise when the losses as a result of the exposures to the defaulting banks exceed the capital (Tier I capital) of a creditor bank.**

- The failure of a bank can affect other banks through their interbank connections

- The default procedure starts with an exogenous shock being simulated, typically by setting zero the equity of one randomly chosen bank i and the cascades of default proceeds on a step by step basis, assuming zero recovery.

- Therefore, the bank's default implies that it is unable to repay its interbank liabilities to its counterparties. Since these liabilities are other banks' assets, these banks get in trouble, thereby affecting also their counterparties.

- The interbank assets lost due to failure of a bank i is subtracted from the bank's j capital. Bank j fails if its exposure versus i exceeds its equity. Second round of bank failure occurs if the creditors of bank j cannot withstand the losses from the default of bank j.

- Eventually, contagion stops if no additional banks go bankrupt. Otherwise, third round of contagion takes place.

Interbank Networks Structure

Banking system:	**-small -medium -large**	**Connectivity :**	**-low -medium -high**	**Interbank Lending :**	**-low -medium -high**

- ❑ For each scenario tested and for each network size (n=20, 50, 80, 100) we have nine cases in which we let vary the number of outgoing links(l=2,3,4) and the weight of outgoing links (small, medium and large interbank claims) among banks.
- ❑ Each case gives us 2.000 realizations or -to put it differently, 2.000 banking crises. Thus, for each scenario tested and each network size we employ 2000 x 9= 18.000 realizations

Variables tested in each realization:

CATEND= Total loss of capital due to contagion as percentage of total capital of the system

CATIN1= Initial loss of capital by defaulting bank *i* as percentage of total capital of the system

CATIN2 = Loss of capital at the first stage (interbank loans that cannot be paid back) by defaulting bank i as percentage of total capital of the system

LEVIN= Leverage estimation of the interbank network

VARCAP = Variance of capital/equity (for the scenarios tested where we have heterogeneous bank sizes)

VARLOANS =Variance of interbank loans (for the scenarios tested where we have heterogeneous interbank loans)

NOUTGOING = Number of outgoing links of bank *i*

OLS regression models of the form:

CATEND=β1***CATIN1**+ β2 ***CATIN2**+ β3 ***LEVIN**+ β4 ***NOUTGOING** + β5***COUNT** +β6***VARLOANS/VARCAP**

Uniform probabilistic network model

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Simulation

Shock propagation & Contagion Dynamics

Scenarios tested

A. Heterogeneous Banks with homogeneous exposures.

B. Heterogeneous Banks with heterogeneous exposures

C. Homogeneous banks with heterogeneous exposures

D. Homogeneous banks with homogeneous exposures

Synopsis

Simulation algorithm:- Set up of the interbank network

- *Define the number of banks (n) in the interbank network system*
- *Define the complexity (number of outgoing links of each bank) of the network system*
- *Allocate Balance sheet components among banks (equity and interbank loans)*

Simulation algorithm:- Default procedure

for each of the T realizations

- *Set up the interbank network*
- *Estimate the leverage of the interbank network;(LEVIN)*
- *Estimate the variance of capital (VARCAP) for the scenarios tested where we have heterogeneous bank sizes or the variance of interbank loans (VARLOANS) for the scenarios tested where we have heterogeneous interbank loans ;*
- *Estimate the number of outgoing links of bank i (NOUTGOING) ;*
- *Shock the system with the exogenous default of bank i;*
- *Estimate the initial loss of capital by defaulting bank i as percentage of total capital of the system; (CATIN1)*
- *Estimate the loss of capital at the first stage (interbank loans that cannot be paid back) by defaulting bank i as percentage of total capital of the system; (CATIN2)*

while at least one bank defaulted do

for every bank i do

if counterparty losses occured then

update equity;

end

if equity < =0 then

default bank i;

end

end

end

-Estimate the total loss of capital due to contagion as percentage of total capital of the system; (CATEND) ;

-Estimate the shock propagation variable (COUNT) which measures the number of rounds until no further bank defaults;

end

We consider four different scenarios where we let vary the degree of heterogeneity of the system, the balance sheet composition, and connectivity among banks.

- *Scenario 1:* **Heterogeneous Banks with homogeneous exposures**. In this scenario, we construct network systems where banks have different equity size and interbank claims are evenly distributed among the outgoing links.

- *Scenario 2:* **Heterogeneous Banks with heterogeneous exposures**. In this scenario, we also allow for heterogeneous banks sizes and heterogeneous interbank claims among banks.

- *Scenario 3:* **Homogeneous banks with heterogeneous exposures**. In this scenario, we construct network systems where banks have the same equity size and unevenly distribute their exposure across creditor banks.

- *Scenario 4:* **Homogeneous banks with homogeneous exposures**. In this last scenario, we construct network systems where banks have the same equity size and interbank claims are evenly distributed among the outgoing links.

- *Scenario 1:* **Heterogeneous Banks with homogeneous exposures**. In this scenario, we construct network systems where banks have different equity size and interbank claims are evenly distributed among the outgoing links.

CATEND	**N=20 banks**	**N=50 banks**	**N=80 banks**	**N=100 banks**
CATIN1	0.080 (23.029)***	0.030 (7.671)***	0.024 (6.245)***	0.017 (4.591)***
CATIN2	0.208 (24.266)***	0.088 (9.191)***	0.020 (2.109)**	0.023 (2.568)**
LEVIN	0.078 (13.376***	0.131 (20.473)***	0.127 (19.898)***	0.160 (25.829)***
NOUTGOING	-0.147 (-25.061)***	-0.085 (-12.220)***	-0.023 (-3.212)***	-0.013 (-1.963)**
COUNT	0.721 (152.451)***	0.734 (147.324)***	0.762 (155.048)***	0.749 (158.296)***
VARCAP	-0.103 (-45.749)***	-0.063 (-39.920)***	-0.048 (-38.314)***	-0.042 (-39.818)***
Adjusted R-squared	0.760	0.717	0.716	0.745

The table presents the regression results for Scenario 1. The dependent variable is CATEND measured as the total loss of capital due to contagion as percentage of total capital in the network. Explanatory variables are CATIN1, CATIN2, LEVIN, NOUTGOING, COUNT and VARCAP. Each cell displays the OLS standardized coefficients along with the corresponding t-statistics (shown in parentheses). The sample comprises of 18,000 realizations (simulated banking crises). ** and *** denote significance at the 5 and 1 percent level, respectively.

CATEND=β1***CATIN1**+ β2 ***CATIN2**+ β3 ***LEVIN**+ β4 ***VARCAP** + β5***NOUTGOING** +β6***COUNT**

- *Scenario 2:* **Heterogeneous Banks with heterogeneous exposures**. In this scenario, we also allow for heterogeneous banks sizes and heterogeneous interbank claims among banks.

CATEND	N=20 banks	N=50 banks	N=80 banks	N=100 banks
CATIN1	0.670 (223.788)***	0.727 (271.376)***	0.640 (187.087)***	0.592 (177.760)***
CATIN2	0.121 (20.243)***	0.085 (15.635)***	0.064 (9.387)***	0.003 (0.524)
LEVIN	0.014 (2.616)***	-0.004 (-0.878)	0.068 (9.952)***	0.027 (4.186)***
NOUTGOING	-0.119 (-25.986)***	-0.081 (-18.756)***	-0.089 (-15.751)***	-0.060 (-11.101)***
COUNT	0.530 (145.530)***	0.541 (171.862)***	0.579 (147.590)***	0.674 (178.780)***
VARCAP	-0.101 (-53.995)***	-0.068 (-61.788)***	-0.061 (-50.322)***	-0.050 (-54.927)***
VARLOANS	-0.057 (-10.622)***	-0.023 (-4.303)***	-0.080 (-11.667)***	-0.034 (-5.396)***
Adjusted R-squared	0.823	0.865	0.782	0.796

The table presents the regression results for Scenario 2. The dependent variable is CATEND measured as the total loss of capital due to contagion as percentage of total capital in the network. Explanatory variables are CATIN1, CATIN2, LEVIN, NOUTGOING, COUNT, VARCAP and VARLOANS. Each cell displays the OLS standardized coefficients along with the corresponding *t*-statistics (shown in parentheses). The sample comprises of 18,000 realizations (simulated banking crises). *** denotes significance at the 1 percent level.

CATEND=β1***CATIN1**+ β2 ***CATIN2**+ β3 ***LEVIN**+ β4 ***VARCAP** + β5***VARLOANS** +β6***NOUTGOING**+β7***COUNT**

- *Scenario 3:* **Homogeneous banks with heterogeneous exposures**. In this last scenario, we construct network systems where banks have the same equity size and unevenly distribute their exposure across creditor banks.

CATEND	**N=20 banks**	**N=50 banks**	**N=80 banks**	**N=100 banks**
CATIN2	0.238 (51.837)***	0.166 (31.641)***	0.124 (21.978)***	0.085 (15.126)***
LEVIN	0.053 (11.723)***	0.080 (15.699)***	0.084 (15.145)***	0.089 (15.489)***
NOUTGOING	-0.186 (-61.481)***	-0.162 (-44.323)***	-0.147 (-37.350)***	-0.133 (-33.313)***
COUNT	0.875 (258.811)***	0.901 (247.480)***	0.911 (232.873)***	0.927 (241.892)***
VARLOANS	-0.199 (-41.960)***	-0.229 (-41.527)***	-0.235 (-39.356)***	-0.232 (-37.024)***
Adjusted R-squared	0.887	0.856	0.834	0.835

The table presents the regression results for Scenario 3. The dependent variable is CATEND measured as the total loss of capital due to contagion as percentage of total capital in the network. Explanatory variables are CATIN2, LEVIN, NOUTGOING, COUNT and VARLOANS. Each cell displays the OLS standardized coefficients along with the corresponding t-statistics (shown in parentheses). The sample comprises of 18,000 realizations (simulated banking crises). ** and *** denote significance at the 5 and 1 percent level, respectively.

$$\textbf{CATEND} = \beta1 * \textbf{CATIN2} + \beta2 * \textbf{LEVIN} + \beta3 * \textbf{VARLOANS} + \beta4 * \textbf{NOUTGOING} + \beta5 * \textbf{NOUTGOING} + \beta6 * \textbf{COUNT}$$

- *Scenario 4:* **Homogeneous banks with homogeneous exposures**. In this scenario, we construct network systems where banks have the same equity size and interbank claims are evenly distributed among the outgoing links.

CATEND	**N=20 banks**	**N=50 banks**	**N=80 banks**	**N=100 banks**
CATIN2	0.513 (136.409)***	0.484 (122.675)***	0.471 (122.258)***	0.465 (121.843)***
LEVIN	0.006 (2.250)***	0.021 (8.188)***	0.027 (11.317)***	0.024 (10.425)***
NOUTGOING	-0.340 (-143.844)***	-0.335 (-129.911)***	-0.331 (-129.930)***	-0.326 (-128.265)***
COUNT	0.652 (255.154)***	0.660 (246.926)***	0.668 (257.520)***	0.676 (262.331)***
Adjusted R-squared	0.933	0.929	0.932	0.934

The table presents the regression results for Scenario 4. The dependent variable is CATEND measured as the total loss of capital due to contagion as percentage of total capital in the network. Explanatory variables are CATIN2, LEVIN, NOUTGOING and COUNT. Each cell displays the OLS standardized coefficients along with the corresponding *t*-statistics (shown in parentheses). The sample comprises of 18,000 realizations (simulated banking crises). *** denotes significance at the 1 percent level.

CATEND=β1***CATIN2** + β2 ***LEVIN** + β3***NOUTGOING**+ β4***COUNT**

- ✓ **Heterogeneity plays a significant role on the stability of the financial system**

  - ❑ When heterogeneity is introduced with respect to the size of each bank, the system seems to be equipped with some sort of stabilization. An interbank network consisted of banks with different sizes can more easily withstand a random shock. Big banks can act as shock absorbers making contagion a less likely phenomenon.

  - ❑ When we allow for heterogeneous bank sizes and heterogeneous interbank exposure, additional resilience is observed to the interbank network system. The dispersion of interbank loans among creditor banks has also a stabilizing role for the financial system.

- ✓ **The importance of well capitalized banks on the stability of the financial system** (Scenario 3: Homogeneous banks with heterogeneous exposures)

- ✓ **Interconnectedness has a great impact on the resilience of the interbank network for all the scenarios tested**

  - ❑ Financial shocks will be absorbed more efficiently in relatively small and highly interconnected interbank networks, where as in larger systems increased connectivity will spread the shock into a large part of the system causing a cascade of defaults

- ✓ **Highly leveraged banks are more exposed to default risk and thus contribute more to systemic risk, especially to that of large interbank networks**

Erdős-Rényi probabilistic network model

- Each pair of nodes is equally likely to be connected, with probability p
- The degree distribution follows a binomial

$$p(k) = B(n;k;p) = \binom{n}{k} p^k (1-p)^{n-k}$$

- Assuming z=np is fixed, as n→∞, B(n,k,p) is approximated by a Poisson distribution

$$p(k) = P(k;z) = \frac{z^k}{k!} e^{-z}$$

- Highly concentrated around the mean, with a tail that drops exponentially

Evolution of an Erdős-Rényi graph

Erdős-Rényi probabilistic network model

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A. Heterogeneous Banks with homogeneous exposures

B. Heterogeneous Banks with heterogeneous exposures

C. Homogeneous banks with heterogeneous exposures

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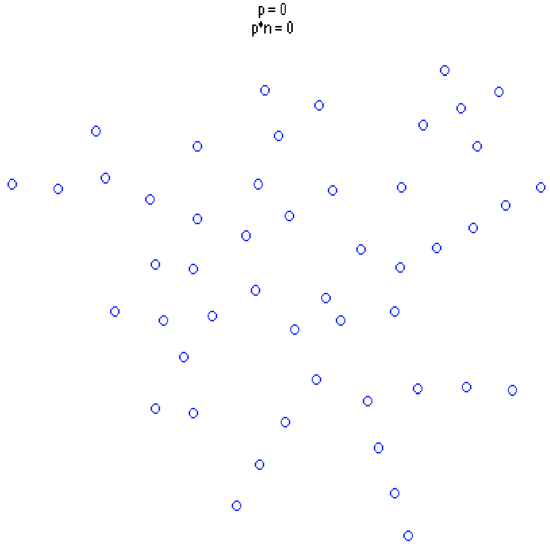
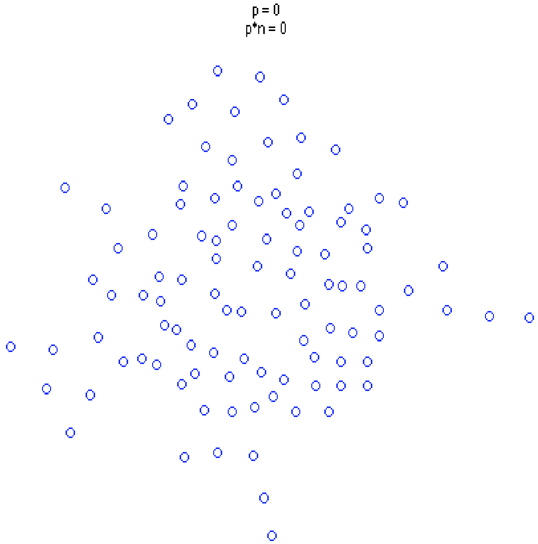
Synopsis



ER_50 nodes

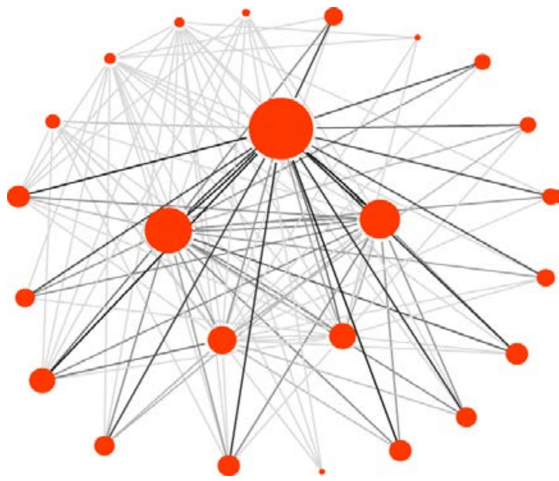


ER_100 nodes

- ✓ **Balance sheet allocation**
- ✓ **Link formation process**
- ✓ **Estimation of the NxN exposure matrix**

$$E = \begin{bmatrix} 0 & a_{12} & a_{13} & a_{14} \\ a_{21} & 0 & a_{23} & a_{24} \\ a_{31} & a_{32} & 0 & a_{33} \\ a_{41} & a_{42} & a_{43} & 0 \end{bmatrix}$$

- ✓ **Simulation process starts by assuming a bank is unable to repay its obligations in the interbank market.**
- ✓ **Losses and effects on other banks are calculated.**
- ✓ **Contagious defaults generally arise when the losses as a result of the exposures to the defaulting banks exceed the capital (Tier I capital) of a creditor bank.**



-

- The failure of a bank can affect other banks through their interbank connections

- The default procedure starts with an exogenous shock being simulated, typically by setting to zero the equity of one randomly chosen bank i and the cascades of default proceeds on a step by step basis, assuming zero recovery.

- Therefore, the bank's default implies that it is unable to repay its interbank liabilities to its counterparties. Since these liabilities are other banks' assets, these banks get in trouble, thereby affecting also their counterparties.

- The interbank assets lost due to failure of a bank i is subtracted from the bank's j capital. Bank j fails if its exposure versus i exceeds its equity. Second round of bank failure occurs if the creditors of bank j cannot withstand the losses from the default of bank j.

- Eventually, contagion stops if no additional banks go bankrupt. Otherwise, third round of contagion takes place.

Interbank Networks Structure

Banking system:	**-small -medium -large**	**Connectivity :**	**Vary with respect to the chosen probability p**	**Interbank Lending :**	**-low -medium -high**

- We consider a basic model that uses only two components from a bank's balance sheet, that is, equity and interbank loans–in the words of May and Arinaminpathy(2010) '*a caricature for banking ecosystems*'.

- For each scenario tested, we check a wide range of link probabilities, such that we can observe dense or sparse interbank network systems.

- For each scenario tested and for each network size we have three cases in which we allow the weight of outgoing links (small, medium and large interbank claims) to vary among banks. Each case gives us 6,000 realizations or, to put it differently, 6,000 banking crises. Thus, for each scenario tested and each network size we employ 6,000 x 3 =18,000.

Variables tested in each realization:

CATEND= Total loss of capital due to contagion as percentage of total capital of the system
CATIN1= Initial loss of capital by defaulting bank i as percentage of total capital of the system
CATIN2 = Loss of capital at the first stage (interbank loans that cannot be paid back) by defaulting bank i as percentage of total capital of the system
LEVIN= Leverage estimation of the interbank network

VARCAP = Variance of capital/equity (for the scenarios tested where we have heterogeneous bank sizes)
VARLOANS =Variance of interbank loans (for the scenarios tested where we have heterogeneous interbank loans)
NOUTGOING = Number of outgoing links of bank i, which corresponds to the number of creditors in the network.
COUNT= Shock propagation variable which measures the number of rounds needed until no further bank defaults

Erdős –Rényi probability= pij (p) that there is a lending/borrowing link between two nodes/banks

OLS regression models of the form:

CATEND=β1***CATIN1**+ β2 ***CATIN2**+ β3 ***LEVIN**+ β4 ***NOUTGOING** + β5***COUNT** +β6***VARLOANS/VARCAP** +β7***COUNT**+β8***p**

Erdős-Rényi probabilistic network model

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A. Heterogeneous Banks with homogeneous exposures

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C. Homogeneous banks with heterogeneous exposures

D. Homogeneous banks with homogeneous exposures

Synopsis

Simulation algorithm:- Set up of the interbank network

- *Define the number of banks (n) in the interbank network system*
- *Define the complexity (Erdős-Rényi prob) of the network system*
- *Allocate Balance sheet components among banks (equity and interbank loans)*

Simulation algorithm:- Default procedure

for each of the T realizations

- *Set up the interbank network*
- *Estimate the leverage of the interbank network;* ***(levin)***
- *Shock the system with the exogenous default of bank i*
- *Estimate the initial loss of capital by defaulting bank i as percentage of total capital of the system;* ***(catin1)***
- *Estimate the loss of capital at the first stage (interbank loans that cannot be paid back) by defaulting bank i as percentage of total capital of the system;* ***(catin2)***

while *at least one bank defaulted do*

for *every bank i do*

if *counterparty losses occured* ***then***

update equity;

end

if *equity < =0* ***then***

default bank i;

end

end

end

-Estimate the total loss of capital due to contagion as percentage of total capital of the system; ***(catend)***

end

We consider four different scenarios where we let vary the degree of heterogeneity of the system, the balance sheet composition, and connectivity among banks.

- *Scenario 1:* **Heterogeneous Banks with homogeneous exposures**. In this scenario, we construct network systems where banks have different equity size and interbank claims are evenly distributed among the outgoing links.

- *Scenario 2:* **Heterogeneous Banks with heterogeneous exposures**. In this scenario, we also allow for heterogeneous banks sizes and heterogeneous interbank claims among banks.

- *Scenario 3:* **Homogeneous banks with heterogeneous exposures**. In this scenario, we construct network systems where banks have the same equity size and unevenly distribute their exposure across creditor banks.

- *Scenario 4:* **Homogeneous banks with homogeneous exposures**. In this last scenario, we construct network systems where banks have the same equity size and interbank claims are evenly distributed among the outgoing links

- *Scenario 1:* **Heterogeneous Banks with homogeneous exposures**. In this scenario, we construct network systems where banks have different equity size and interbank claims are evenly distributed among the outgoing links.

CATEND	**N=20 banks**	**N=50 banks**	**N=80 banks**	**N=100banks**
CATIN1	0.051 (16.198)***	-0.002 (-0.459)	-0.001 (-0.347)	-0.007 (-2.044)**
CATIN2	0.098 (4.195)***	0.004 (0.170)	0.179 (8.073)***	0.104 (5.059)***
LEVIN	0.389 (17.018)***	0.413 (19.043)***	0.260 (12.205)***	0.315 (15.935)***
NOUTGOING	-0.080 (-3.915)***	0.097 (2.773)***	-0.170 (-4.933)***	-0.053 (-1.534)
COUNT	0.602 (138.571)***	0.572 (134.093)***	0.576 (136.735)***	0.540 (124.326)***
VARCAP	-0.088 (-53.348)***	-0.075 (-61.005)***	-0.053 (-53.890)***	-0.054 (-57.165)***
P	-0.101 (-5.089)***	-0.080 (-2.338)**	0.165 (4.885)***	0.107 (3.148)***
Adjusted R-squared	0.800	0.763	0.756	0.749

The table presents the regression results for Scenario 1. The dependent variable is CATEND measured as the total loss of capital due to contagion as percentage of total capital in the network. Explanatory variables are, CATIN1, CATIN2, LEVIN, NOUTGOING, COUNT, VARCAP and P, the probability for a link to exist between two nodes. Each cell displays the OLS standardized coefficients along with the corresponding *t*-statistics (shown in parentheses). The sample comprises of 18,000 realizations (simulated banking crises).*, ** and *** denote significance at the 10, 5 and 1 percent level, respectively.

CATEND=β1***CATIN1**+ β2 ***CATIN2**+ β3 ***LEVIN**+ β4 ***VARCAP** + β5***NOUTGOING** +β6***COUNT**

- *Scenario 2:* **Heterogeneous Banks with heterogeneous exposures**. In this scenario, we also allow for heterogeneous banks sizes and heterogeneous interbank claims among banks.

CATEND	N=20 banks	N=50 banks	N=80 banks	N=100 banks
CATIN1	0.070 (23.660)***	0.007 (2.024)**	0.000 (0.047)	-0.001 (-0.283)
CATIN2	0.201 (19.541)***	0.113 (11.183)***	0.106 (9.669)***	0.071 (6.015)***
LEVIN	0.653 (58.484)***	0.346 (30.847)***	0.321 (26.320)***	0.399 (30.132)***
NOUTGOING	-0.136 (-11.540)***	-0.150 (-6.539)***	-0.052 (-2.253)**	0.038 (1.575)
COUNT	0.456 (111.687)***	0.630 (156.274)***	0.577 (141.939)***	0.573 (131.397)***
VARCAP	-0.032 (-18.897)***	-0.067 (-50.848)***	-0.053 (-52.027)***	-0.041 (-40.597)***
VARLOANS	-0.246 (-45.472)***	-0.091 (-14.882)***	-0.018 (-3.113)***	-0.082 (-12.307)***
P	-0.254 (-21.462)***	0.038 (1.620)	0.064 (2.678)***	-0.110 (-4.311)***
Adjusted R-squared	0.830	0.796	0.776	0.751

The table presents the regression results for Scenario 2. The dependent variable is CATEND measured as the total loss of capital due to contagion as percentage of total capital in the network. Explanatory variables are the constant term CATIN1, CATIN2, LEVIN, NOUTGOING, COUNT, VARCAP, VARLOANS and P, the probability for a link to exist between two nodes. Each cell displays the OLS standardized coefficients along with the corresponding *t*-statistics (shown in parentheses). The sample comprises of 18,000 realizations (simulated banking crises). *, ** and *** denote significance at the 10, 5 and 1 percent level, respectively.

CATEND=β1***CATIN1**+ β2 ***CATIN2**+ β3 ***LEVIN**+ β4 ***VARCAP** + β5***VARLOANS** +β6***NOUTGOING**+β7***COUNT**

- *Scenario 3:* **Homogeneous banks with heterogeneous exposures**. In this last scenario, we construct network systems where banks have the same equity size and unevenly distribute their exposure across creditor banks.

CATEND	**N=20 banks**	**N=50 banks**	**N=80 banks**	**N=100 banks**
CATIN2	0.196 (25.178)***	0.143 (16.422)***	0.125 (15.232)***	0.088 (9.806)***
LEVIN	0.324 (39.268)***	0.298 (32.475)***	0.275 (31.619)***	0.279 (30.578)***
NOUTGOING	-0.163 (-15.308)***	-0.168 (-10.438)***	-0.126 (-8.707)***	-0.087 (-5.561)***
COUNT	0.736 (191.690)***	0.761 (175.841)***	0.790 (195.383)***	0.793 (186.247)***
VARLOANS	-0.175 (-43.977)***	-0.190 (-44.390)***	-0.180 (-46.723)***	-0.167 (-41.937)***
P	-0.253 (-24.270)***	-0.313 (-19.153)***	-0.322 (-21.833)***	-0.339 (-21.575)***
Adjusted R-squared	0.860	0.823	0.845	0.809

The table presents the regression results for Scenario 3. The dependent variable is CATEND measured as the total loss of capital due to contagion as percentage of total capital in the network. Explanatory variables are the constant term CATIN2, LEVIN, NOUTGOING, COUNT, VARLOANS and P, the probability for a link to exist between two nodes. Each cell displays the OLS standardized coefficients along with the corresponding *t*-statistics (shown in parentheses). The sample comprises of 18,000 realizations (simulated banking crises). *, ** and *** denote significance at the 10, 5 and 1 percent level, respectively.

CATEND=β1***CATIN2** + β2 ***LEVIN** + β3***VARLOANS**+ β4***NOUTGOING** + β5***NOUTGOING** +β6***COUNT**

Erdős-Rényi probabilistic network model

Introduction

Simulation

Shock propagation & Contagion Dynamics

Scenarios tested

A. Heterogeneous Banks with homogeneous exposures

B. Heterogeneous Banks with heterogeneous exposures

C. Homogeneous banks with heterogeneous exposures

D. Homogeneous banks with homogeneous exposures

Synopsis

- *Scenario 4:* **Homogeneous banks with homogeneous exposures**. In this scenario, we construct network systems where banks have the same equity size and interbank claims are evenly distributed among the outgoing links

CATEND	**N=20 banks**	**N=50 banks**	**N=80 banks**	**N=100 banks**
CATIN2	0.228 (21.978)***	0.153 (14.098)***	0.137 (12.902)***	0.105 (9.426)***
LEVIN	0.137 (14.890)***	0.268 (28.512)***	0.352 (37.106)***	0.352 (37.707)***
NOUTGOING	-0.257 (-15.906)***	-0.146 (-9.715)***	-0.130 (-8.719)***	-0.095 (-6.262)***
COUNT	0.645 (198.356)***	0.617 (172.925)***	0.568 (150.736)***	0.573 (148.381)***
P	-0.156 (-10.231)***	-0.304 (-21.593)***	-0.378 (-26.723)***	-0.379 (-27.197)***
Adjusted R-squared	0.834	0.806	0.817	0.779

The table presents the regression results for Scenario 4. The dependent variable is CATEND measured as the total loss of capital due to contagion as percentage of total capital in the network. Explanatory variables are the constant term CATIN2, LEVIN, NOUTGOING, COUNT and P, the probability for a link to exist between two nodes.. Each cell displays the OLS standardized coefficients along with the corresponding *t*-statistics (shown in parentheses). The sample comprises of 18,000 realizations (simulated banking crises). *, ** and *** denote significance at the 10, 5 and 1 percent level, respectively.

CATEND=β1***CATIN2** + β2 ***LEVIN** + β3***NOUTGOING**+ β4***COUNT**

- ✓ **Non-monotonic relation between diversification and interbank contagion across the different sizes of interbank networks for all scenarios tested**

  - ❑ While for small or medium interbank networks, connectivity can act as an absorbing barrier, such that interbank systems of these sizes can withstand the initial shock, for large network systems connectivity does not seem to provide an effective shield against capital losses.

- ✓ **Small and thus more concentrated interbank network systems are more prone to contagion**

  - ❑ In these cases, there is observed that the size of total capital losses is, in most cases, larger than that documented in medium and large sized systems, which is in line with the findings of Nier et al.(2007).

✓ **Heterogeneity plays a significant role on the stability of the financial system**.

❑ Similar to Leventides et al. (2019), we still find that when heterogeneity is introduced with respect to the size of each bank, the system's shock absorption capacity is enhanced. In addition, when we allow for heterogeneity on interbank exposures in our model, we observe additional resilience to the interbank network as an initial shock dissipates more easily than in the case of homogeneous interbank claims.

✓ **The importance of well capitalized banks on the stability of the financial system** (Scenario 3: Homogeneous banks with heterogeneous exposures)

✓ **Highly leveraged banks are more exposed to default risk and thus contribute more to systemic risk, especially to that of small and medium interbank networks.**

Policy implications

- Attention is needed to the **interaction structure among banks and financial institutions** in the propagation of an initial shock that hits the system.
- Our research proposes network models that give **the ability on the supervisor to quantify the possibility of contagion** given various measurable variables that has at his disposal.
- The crucial thing is to **limit systemic risk and the contagion effect by preventing banks from failing in the first place**, placing particular emphasis on the systemic banks, being these banks with few connections but large risk exposure each or these banks with many connections and low risk exposure each.
- Once the initial shock spread in the system, **the extent to which the propagation will stop is primarily associated with the network structure of interbank exposure in the system and the total capital adequacy of the system**. Capital adequacy of the system plays a prominent role whether the interbank network system withstands an initial shock or incur contagious breakdowns with detrimental consequences to the entire economy.

Supervisor- Passive intervention

- ❑ Monitor measurable variables and check if the stability of the system improves or deteriorates
- ❑ Compare different network structures as far as contagion is concerned
- ❑ Detect possible weaknesses of the system or the systemic bank
- ❑ Suggest corrective actions
- ❑ Ring the alarm bells for immediate actions should the conditions deteriorates.

Possible Weaknesses

- Highly leveraged network
- Highly leveraged bank or cluster of banks
- High degree of risk concentration caused by large exposures to specific banks or to a cluster of banks
- Insufficient capital buffers to absorb losses

Corrective Actions

- Limit banks' exposures
- Increase capital buffers
- Use Credit Default Swaps (CDS)

Supervisor- Active intervention

- Monitor measurable variables and check if the stability of the system or deteriorates

- Compare different network structures as far as contagion is concerned

- Set parameters' boundaries concerning contagion and systemic risk, ranging from low to medium or high risk. These boundaries can be interpreted as limits to the independent variables that supervisor can measure.

- Every time the supervisor observes that contagion has entered into a danger zone or has the propensity to enter, he will have to take corrective actions with regards to the variables of the model.

Policy implications

- Our results also suggest that it would be **wiser and more prudent policy to set capital requirements from a system-wide angle** rather than imposing a common threshold to all financial institutions. In other words, capital requirements should be set to each bank according to its systemic importance within the system. This notion is in line with the suggestions of Haldane and May (2011) and Alter et al. (2015).

- Our suggested analysis is **easily explainable, reproducible and can be carried out for all banks in a banking system for a certain point in time**. Repeating this exercise periodically for a range of parameters concerning contagion and systemic risk makes it possible to judge how the stability of the financial system evolves over time. This could give regulators important information on how e.g. certain regulatory actions affect the stability of the financial system.

- **Regulators should review periodically the parameters of their model they have decided to work with, respond quickly to fast-evolving market conditions and adapt their policies**. Early regulatory intervention is of crucial importance, since it paves the way to tackling the undesirable developments contributing to contagion or systemic collapse.

Further Research

Avenues for future research can include:

- the study of non-performing loans (NPLs) in relation to contagion risk in a unified framework.

- test how asset devaluations and haircuts depicted on bank balance sheets can affect interbank contagion.

Under such setting various weaknesses of network systems can be identified and additionally, the role systemic banks play in causing market-wide effects can be further explored. This be comes extremely relevant to the case of the European sovereign debt crisis whose aftermath is still fresh in the financial system.

Thank You !!

Questions/ Comments are welcome