CITY UNIVERSITY LONDON

Modeling interbank lending and credit to the real Economy

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Complexity Science Group Seminar

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Introduction

- Banks operate by issuing liquid liabilities, such as chequing accounts and investing the funds in illiquid assets, such as mortgages and business loans.
- For this reason individual banks may not always be able to meet all their liquidity needs from their own reserves and the interbank market is a source from which banks facing liquidity shortages can borrow funds from other, liquid banks.

- In normal times, interbank markets are among the most liquid in the financial sector and the financial literature has historically devoted a relatively low consideration to the interbank market due to the short term nature of the exchanged deposits.
- During the 2007-2008 financial crisis though liquidity in the interbank market has considerably dried up, even at short maturities, and an increasing dispersion in the credit conditions of different banks has emerged.
- These events have triggered a new interest in interbank markets.

Characteristics of Interbank lending

Interbank lending:

- very short term,
- mainly overnight,
- allows banks facing liquidity shortages to cover their obligations and reserve requirements by borrowing from surplus banks.

Interbank lending represents one form of safety net for the banking system.
At the same time it has the potential to create knock-on effects from the failure of debtor banks.
Thus, there is a tradeoff between mutual insurance and systemic risk.

ABM Approach

We focus on *microstructure* rather than on microeconomics:

- Conventional microeconomic models stress forward looking behaviour by far-sighted and rational, often representative, agents at the expense of the 'plumbing' (i.e. the inter-connections) of an actual economy.
- ABMs have the advantage of simplifying behavior at the individual level by assuming that agents follow given but evolving rules-of-thumb, and this allows them to explore the multiplicity of agent types and their set of inter-connections in far greater detail.
- In particular ABMs can follow the behaviour of agents in rapidly evolving dynamic settings and see how this both determines and is determined by the emergence of crises and collapses.

Iori, Jafarey Padilla Model (2006)[1]

Main assumptions

- The strategies and prices are imposed exogenously.
- Vary the risk characteristics of constituent banks and the degree of interbank activity and see how this affects the stability of the overall system

Justifications (valid before the crisis!!)

- nature of interbank market and very short time horizons allow limited opportunities for strategic behaviour
- Focus on the role of connectivity patterns and nodes heterogenenity: analogy between financial contagion and biological epidemics.

[1] Iori, Jafarey Padilla, Systemic Risk on the Interbank market, Journal of Economic Behaviour and Organization, Vol. 61, No. 4, 525-542 (2006)

The Banks

The agents in our model are commercial banks who hold accounts for their customers. The various activities engaged by a bank through a day (tracked by the overall liquidity held by the bank) are:

- Random deposits and withdroawls
- Receipt of investment income
- Interest payments to depositors
- Settlement of previous loans
- Receive new investments opportunities which arise randomly (risk-free but illiquid)
- Maintenance of target reserves (loose constraint)

The interbank market

- If banks overestimate their liquidity needs they will end up with excess reserves which can be lent.
- If banks underestimate their liquidity needs, they will need to borrow the shortfalls.
- we assume that banks do not have access to central bank intraday or overnight credit but can lend or borrow from each other on an interbank market.
- Interbank lending is overnight and at an exogenous constant interest rate.

- With no interbank market, the mere inability to settle payments especially to depositors, would trigger off a bank's failure.
- If interbank lending is possible, an illiquid bank might seek funds not just to pay depositors but also to repay past creditor banks.
- If despite such efforts, a bank ends up with insufficient funds, we assume for simplicity that it is removed from the system (it could potentially return at a later date).

The interbank market connectivity

- Interbank credit linkages are defined by a connectivity matrix, J_{ij}.
- J_{ij} is either one or zero; a value of one indicates that a credit linkage exists between banks i and j and zero indicates no relationship.
- J_{ij} are randomly chosen at the beginning of the simulation.
- c represents the probability that J_{ij} is one for any two banks.
- At one extreme, $c = 0\%$ represents the case of no interbank lending, while $c = 100\%$ represents a situation in which all banks can potentially borrow and lend from each other.

Simulation Analysis: Homogeneous case

In the initial set of simulations, we assumed that 400 banks are identical in the stochastic sense:

- Each bank holds initial deposits, $A_0^k = \bar{A}$.
- Each bank faces normal shocks to deposits and investment opportunities with variances σ_A and σ_ω
- investment opportunities can be undertaken only if sufficient liquidity is available

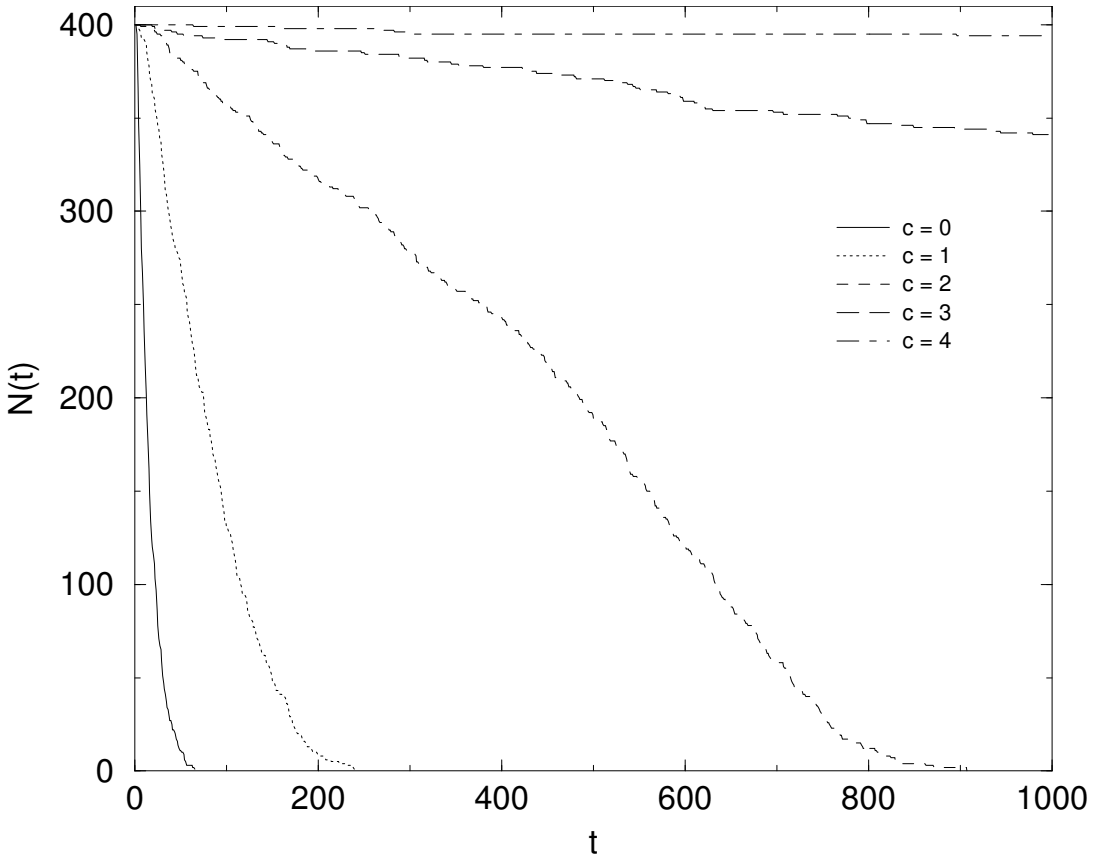


Figure: Surviving homogeneous banks with $\sigma_A = 0.5$, $\sigma_\omega = 0.5$, $\beta = 20\%$ and different interbank linkages. No single bank became a significant debtor in this case.

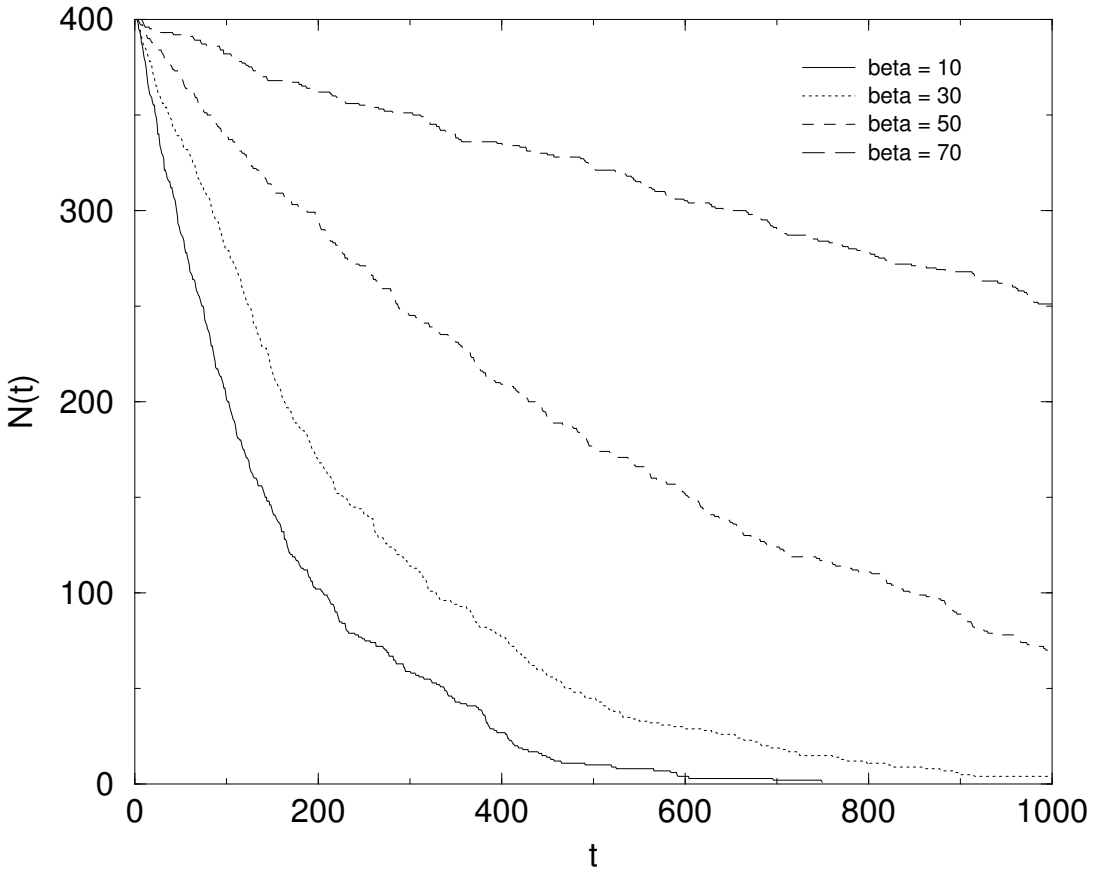


Figure: Surviving homogeneous banks with $\sigma_A = 0.25$, $\sigma_\omega = 0.5$, different reserves and no interbank linkage.

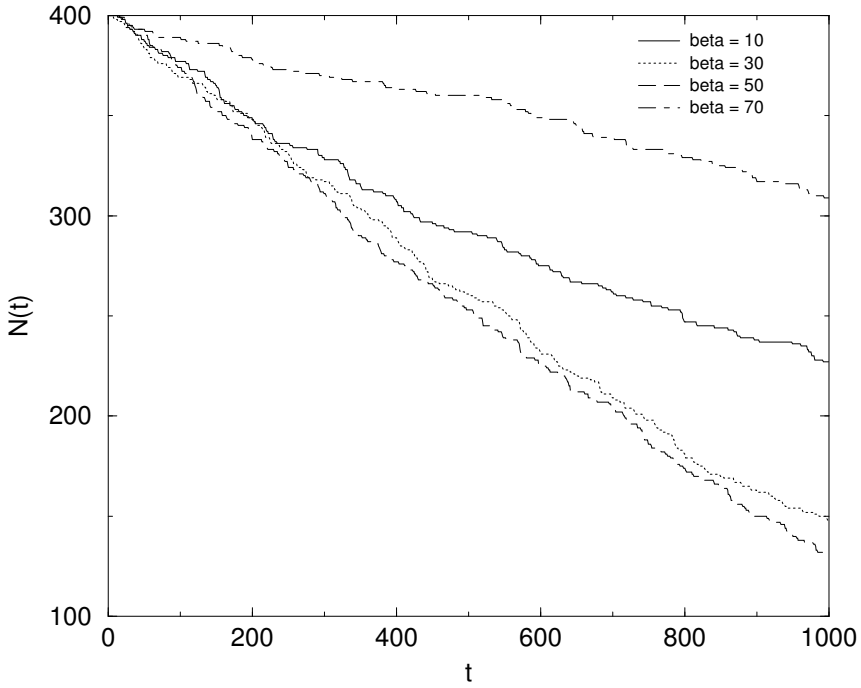


Figure: Surviving homogeneous banks with $\sigma_A = 0.25$, $\sigma_\omega = 0.5$, different reserves and 1% interbank linkage. Higher reserve increase individual liquidity BUT reduce systemic liquidity. Increasing β initially leads to an increase in the incidence of bank failures, but if β crosses a critical level, increasing it further results in fewer bank failures.

Heterogeneous case

Banks differ in the distribution of investment opportunities,

$$A_t^k = |\bar{A}(1 + \sigma_A \epsilon_t)|$$

$$\omega_t^k = |i^k + \sigma_\omega \eta_t|$$

with $i_k \sim |N(\bar{\omega}, \sigma_i^2)|$.

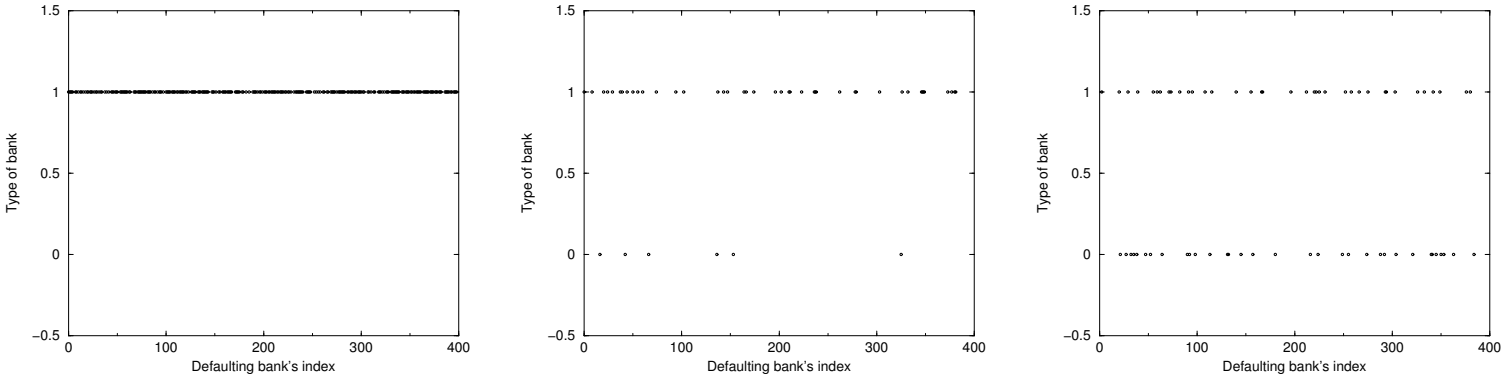


Figure: Incidence of bank failures by bank type with (a) no interbank linkage, (b) 1% linkage, (c) 5% linkage. The *overall* incidence of bank failures remaines lower with interbank lending than without. This illustrates the trade-off between the insurance role of interbank credit and the possibility that it will result in 'knock-on' effects.

General case

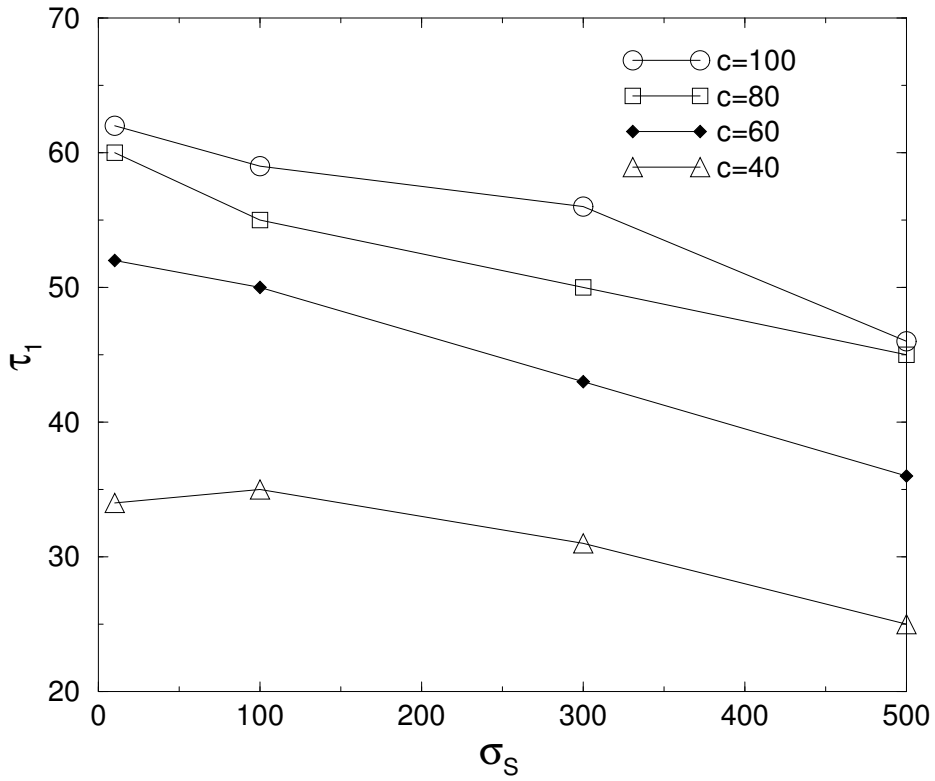
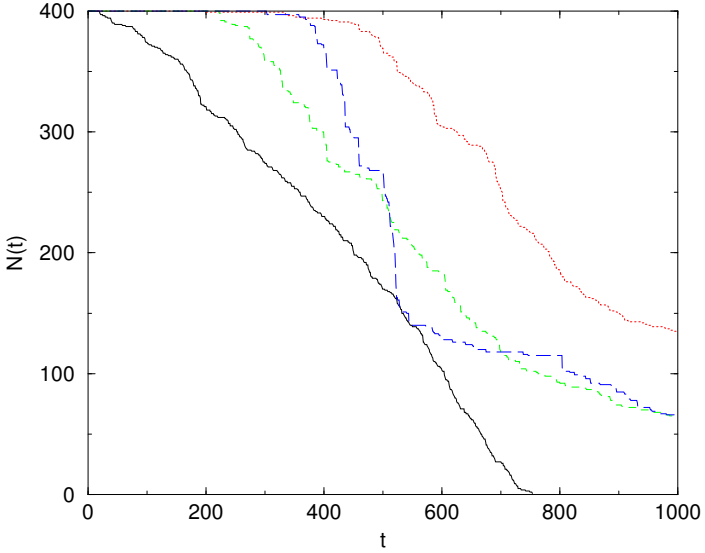


Figure: First default time τ_1 versus σ_i at differenet level of connectividness, with $\sigma_A = 0.4$ and $\sigma_\omega = 0.2$.



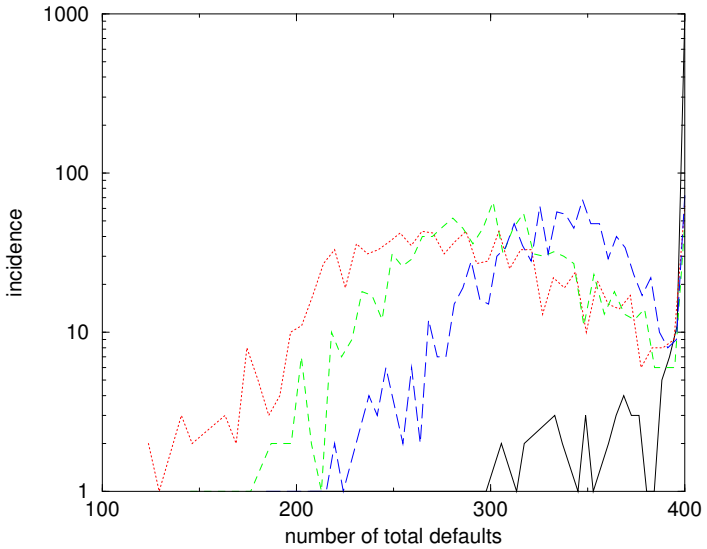


Figure: (a) Number of surviving banks over time for a representative simulation. (b) Incidence of total banks failing over the entire period for 1000 simulations. In both cases $\sigma_A = 0.4$, $\sigma_\omega = 0.2$, $\sigma_I = 0.5$. Connectivity varies from $c = 10\%$ (black-full line), $c = 20\%$ (red-dotted line), $c = 30\%$ (green-dashed line), to $c = 60\%$ (blue-long-dashed line). The average rate of failure goes down as c increases from 10 to 20, but then goes up beyond that. Interestingly, the variance in the number of failures becomes lower as c increases from 20 to 30 to 60 percent, implying that connectivity beyond the optimal point tends to invariably lead to more overall failures in the system.

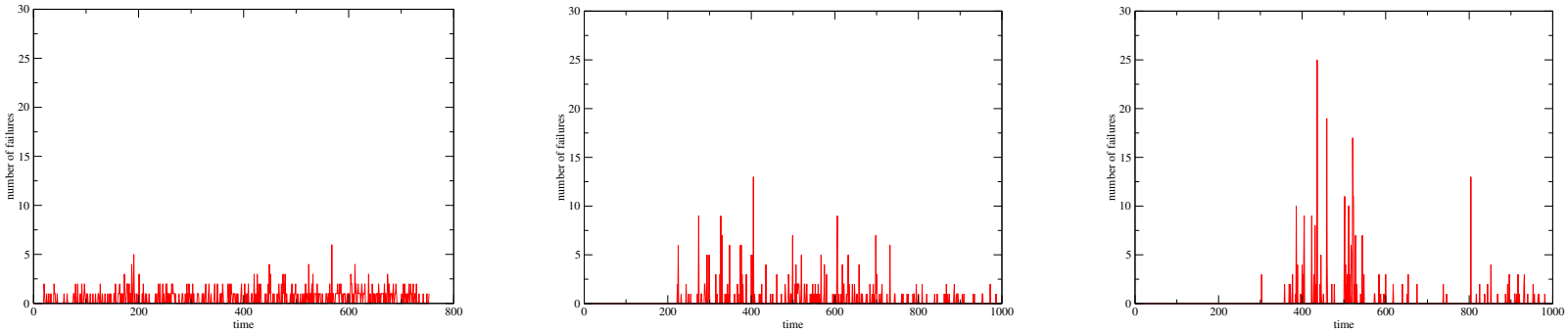


Figure: Effects of increasing linkages on avalanches: $\sigma_A = 0.4, \sigma_\omega = 0.2, \sigma_I = 0.5$ and $c = 10\%$ (left), $c = 30\%$(center) and $c = 60\%$ (right).

Avalanches or Contagion?

- To go from the mere existence of avalanches to a more rigorous proof of contagion, we have to control for the effect that past failed loans have on a creditor bank's failure.
- We thus narrow the definition of direct contagion to focus on the number of banks that fail at some time given that they had lost funds due to defaults by their debtors in the period just before

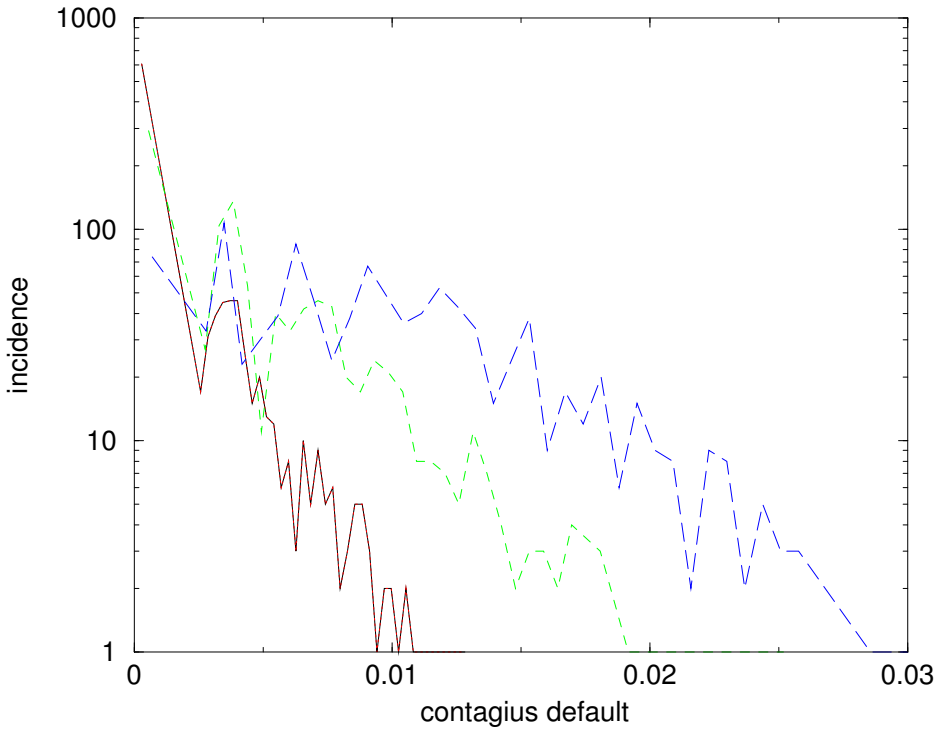


Figure: Contagious default for $\sigma_A = 0.4$, $\sigma_\omega = 0.2$ and $\sigma_I = 0.5$. Connectivity varies from $c = 20\%$ (red full line), $c = 30\%$ (green dashed line), to $c = 60\%$ (blue long-dashed line). Direct contagion effects become more important as connectivity increases.

Indirect Contagion

- Contagion while clearly increasing with connectivity, only explains a small percentage of the overall failures.
- Simultaneous defaults can arise spontaneously as the consequence of the system reaching a critical state by its own intrinsic dynamics.
- One intuitive explanation is that of indirect contagion, i.e. as the system looses funds it becomes more fragile. Thus instabilities builds up over time leading to clusters of avalanches happening over brief periods of time.
- This phenomenon resembles self-organized criticality in physical systems (Bak). Critical states of the system are typically signaled by a power-law distribution of avalanches size

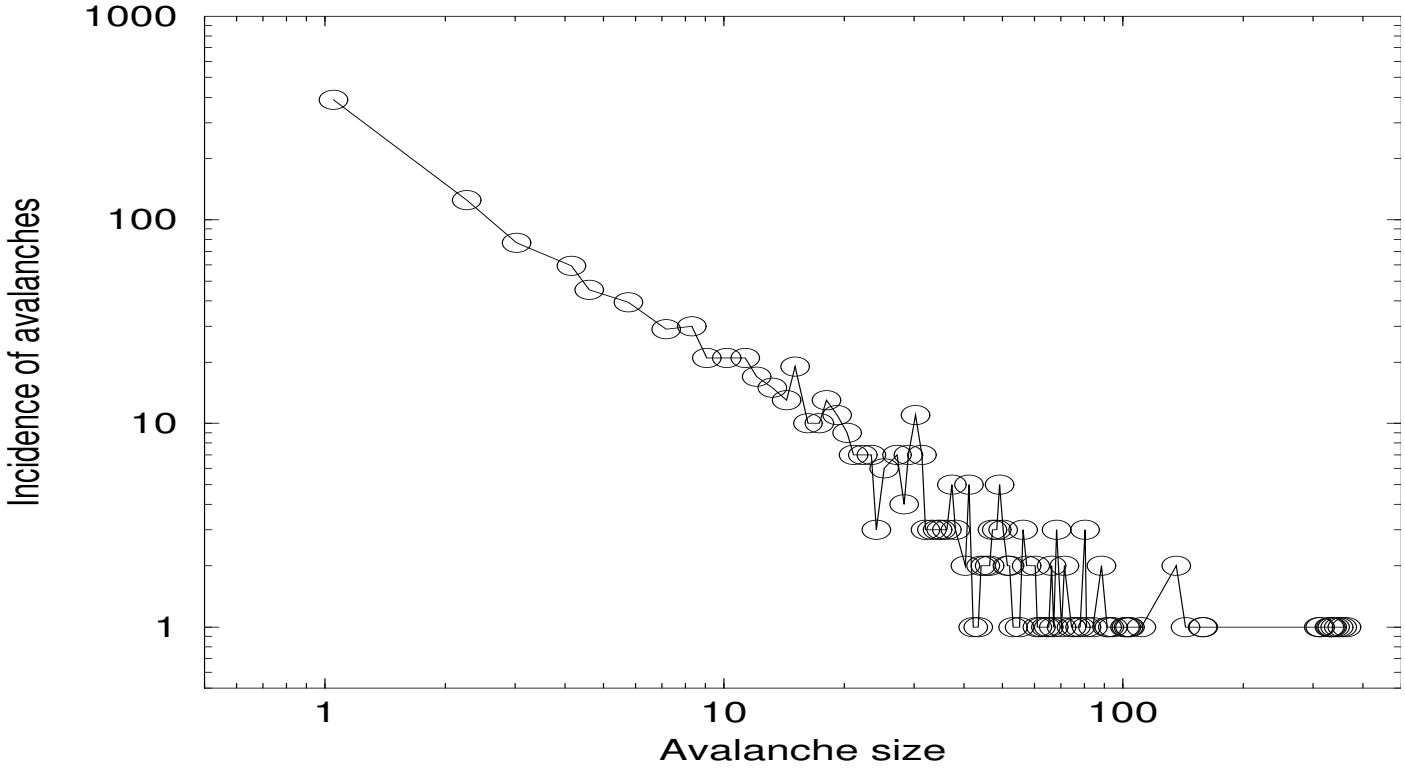


Figure: Log-log plot of the statistical distribution of avalanche size.

Questions

- Is this model realistic?
- How are real interbank markets organized?
- Do banks lend on the same terms to each other?
- Do stable interbank lending networks exist (as opposed to random matching)?

Papers addressing these questions:

- Vasilis Hatzopoulos, Giulia Iori, Rosario N. Mantegna, Salvatore Micciche', Michele Tumminello, *Quantifying preferential trading in the e-MID interbank market*, Quantitative Finance (forthcoming)
- Burcu Kapar, Giulia Iori and Jose Olmo *Bank Characteristics and the Interbank Money Market: A Distributional Approach*, Studies in Nonlinear Dynamics & Econometrics (forthcoming)
- G. Iori, B. Kapar, V. Hatzopoulos, G. Germano, M. Politi and G. Gabbi, *Market microstructure, banks' behaviour, and interbank spreads*' (submitted).
- A. Temiszoy, G. Iori and G. Montes-Rojas, *TThe role of bank relationships in the e-Mid interbank market* (submitted)
- A. Temiszoy, G. Iori and G. Montes-Rojas, The role of network location on credit spreads in the e-Mid market

European liquidity management framework

Credit institutions in the euro area are required to hold minimum reserve balances with NCBs.

- These reserves are remunerated at the main refinancing rate.
- They have to be fulfilled only on average over a one-month maintenance period that runs from the 24th of a month to the 23rd of the following month.
- Banks can exchange reserves on the interbank market with the objective to minimize the reserve implicit costs.
- The overnight rate is bounded above and below by the official rates corridor fixed by the ECB: banks may borrow against collateral at the rate on the marginal lending facility (the ceiling) or deposit funds at the rate on the overnight deposit facility (the floor).

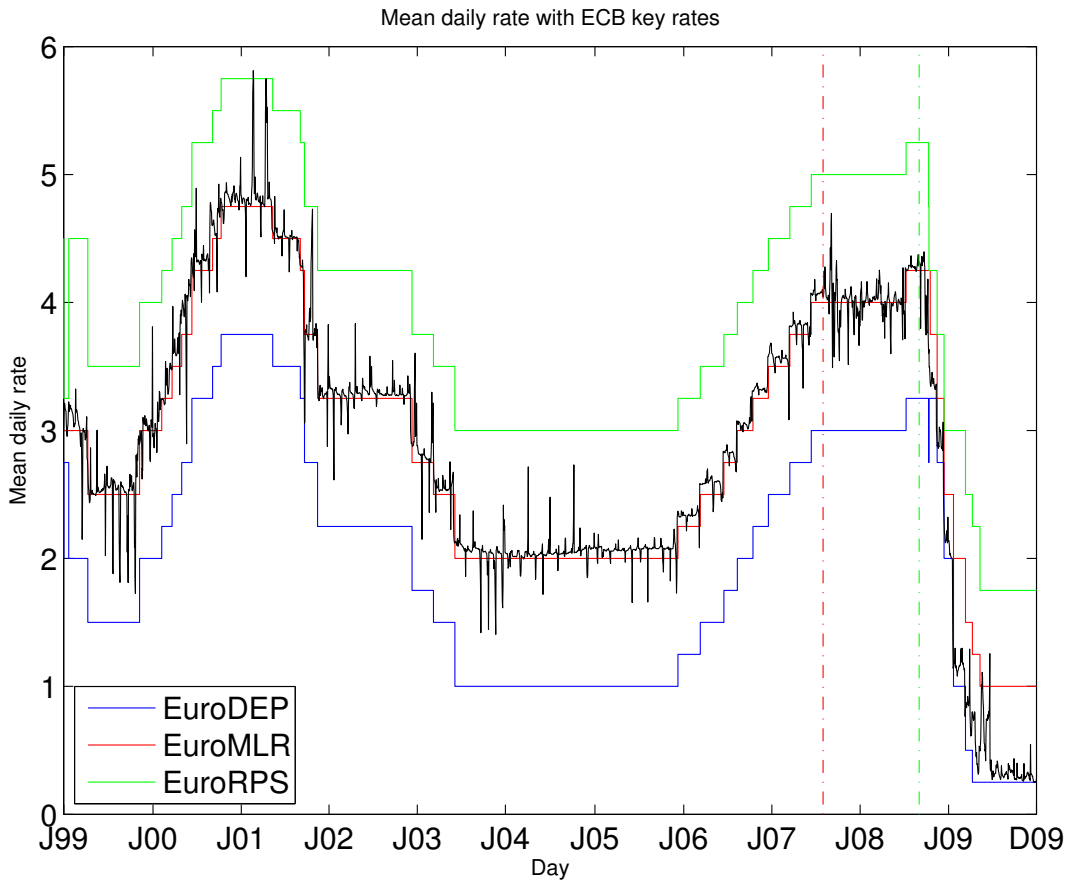


Figure: Mean daily rate with the ECB key rates. Here we added two vertical lines. The first marks the subprime crisis of August 2007 and the second the collapse of Lehman Brothers of September 2008.

Effect of the crisis (e-Mid): market freeze

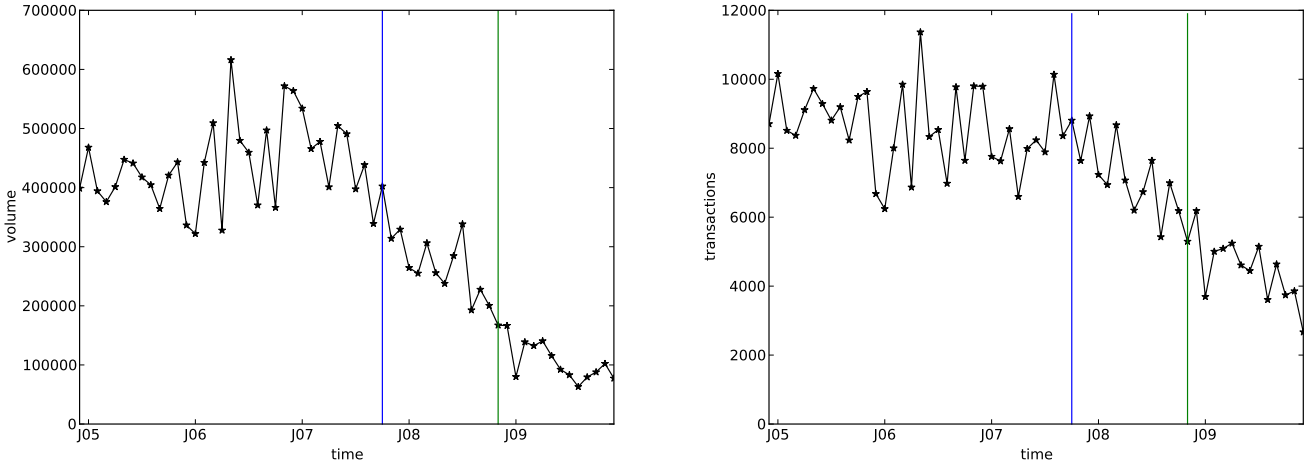


Figure: Left: monthly sum of volumes. Right: monthly sum of transactions

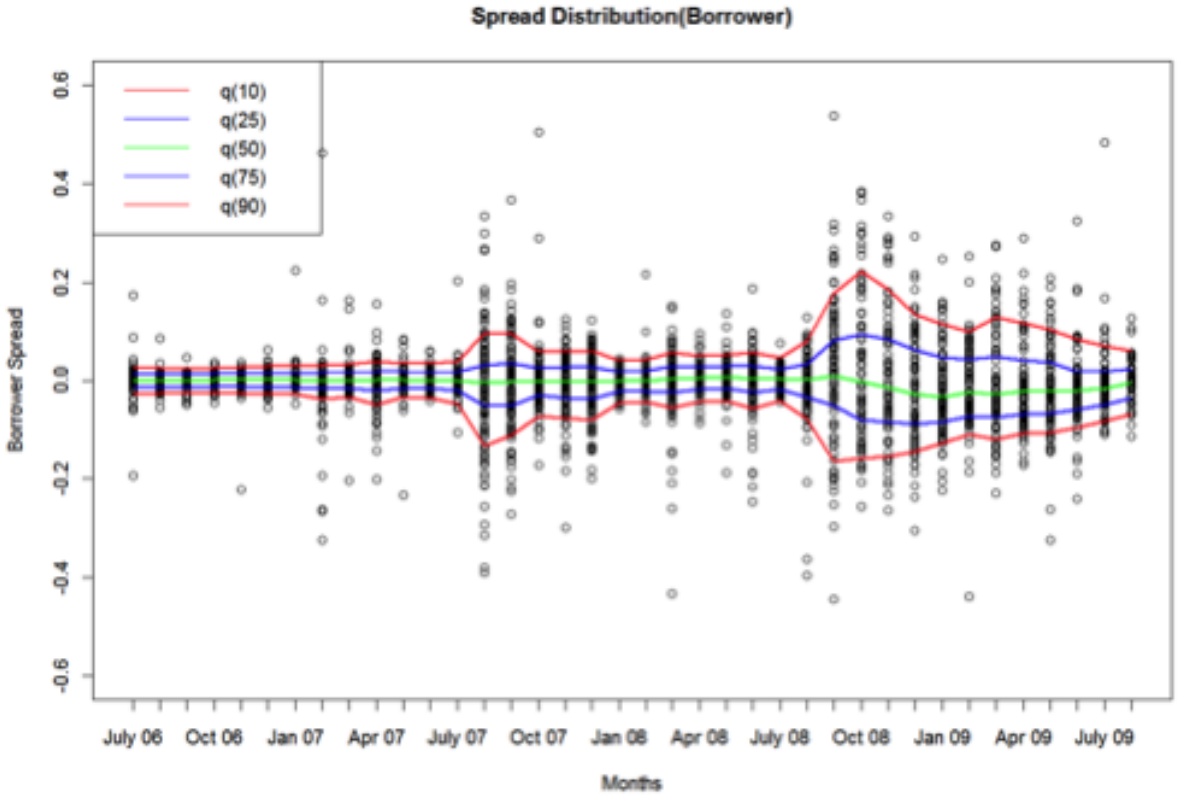


Figure: Montly evolution of the quantiles of estimated cross-sectional distributions of borrower spreads

Effect of the subprime crisis on interbank lending: dispertion of credit spreads volatility(e-MID)

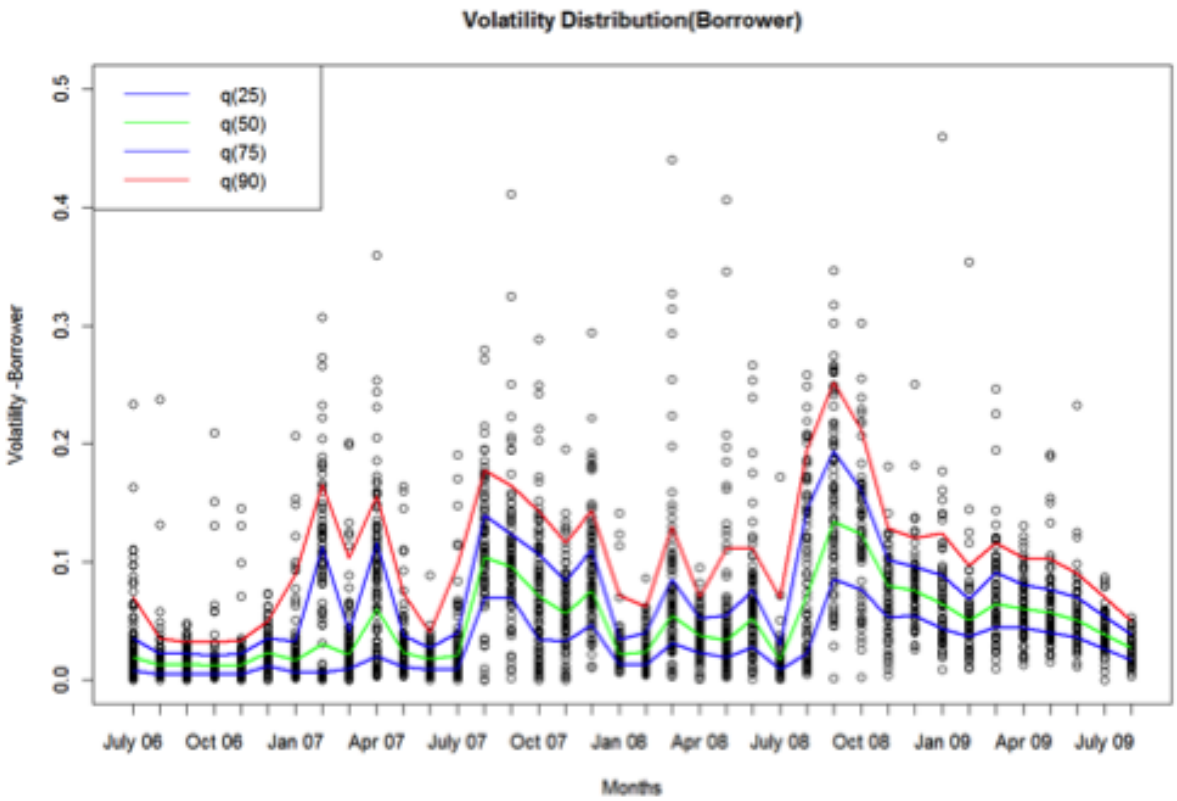


Figure: Montly evolution of the quantiles of estimated cross-sectional distributions of borrower spreads volatility

The literature has presented two main explanations for the volume collapse (or freeze) in the money market and for the raise in spreads during the recent turmoil:

- **liquidity hoarding:** banks were hoarding liquidity in order to anticipate additional money demand, both for internal needs, and from external operators.
- **Trust evaporation:** banks, rationally or irrationally, perceive an increase in the counterparty-risk and became reluctant to lend.

Our analysis is an attempt to quantify the second effect by looking at the network of transactions (without information on the credit quality of market participants).

e-MID: electronic Market for Interbank Deposits

A transparent Market

- This market is unique in the Euro area in being a screen based fully electronic interbank market. Outside Italy interbank trades are largely bilateral or undertaken via voice brokers.
- The central system is located in the office of the SIA and the peripherals on the premises of the member participants.
- The names of quoting banks are visible next to their quotes to facilitate credit line checking. A transaction is finalized if the ordering bank accepts a listed bid/offer.

A European Market

Both italian banks and foreign banks can exchange funds. Market players are 246 members from 29 EU countries and the US, of which:

- 30 central banks acting as market observers
- 2 Ministries of Finance
- 108 domestic banks
- 106 international banks

Average exposure of about 5.5 million euros per transaction. According to European Central Bank (2007) e-MID accounted, before the crisis, for 17% of total turnover in unsecured money market in the Euro Area. In the report on money markets (European Central Bank, 2010), it recorded 12% of the total overnight turnovers.

e-MID

ON and longer maturities

- Overnight (O/N): Trades for a transfer of funds to be effected on the day of the trade and to return on the subsequent Business Day;
- Tomorrow next (T/N): Trades for a transfer of funds on the first Business Day following the day of the trade and to return on the second Business Day following that of the trade;
- Spot next (S/N): Trades for a transfer of funds on the second Business Day following the day of the trade and to return on the third Business Day following that of the trade;

e-MID

- Time Deposits: Trades for an initial transfer of funds and to return at a predetermined maturity (from 1 week to 12 months);
- Broken Date Deposit: Trades with freely agreed Initial Value Date and Final Value Date between parties without standardization obligations provided that both dates do not coincide with the previous ones and that the two days are not separated by a period superior to a calendar year

We only look at ON and ONL transactions!!

Dataset

- The data base is composed by the records of all transactions registered in the period 01/1999–12/2009 for a total of 1.523.510 transactions.
- For each contract we have information about the date and time of the trade, the quantity, the interest rate and the encoded name of the quoting and ordering bank.
- The banks are reported together with a code representing their country and, when the bank is Italian, a final label that indicates the class of capitalization (major, large, medium, small, minor)
- The aggregate characteristics of the entire set of transactions can thus be studied in terms of the statistical and topological properties of this HIGHLY HETEROGENEOUS network.

System Heterogeneity: nationality

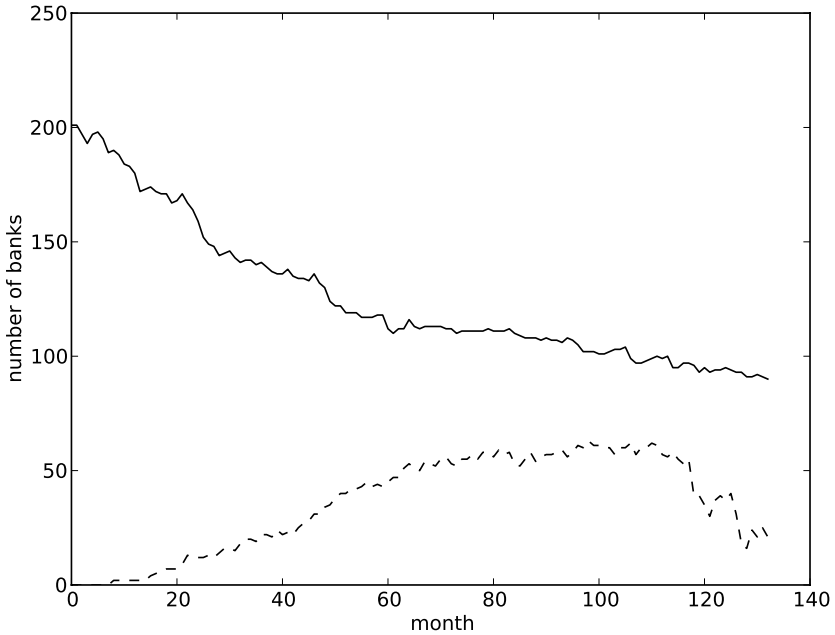


Figure: Number of Italian and non-Italian banks as a function of time.

System Heterogeneity: volume per group

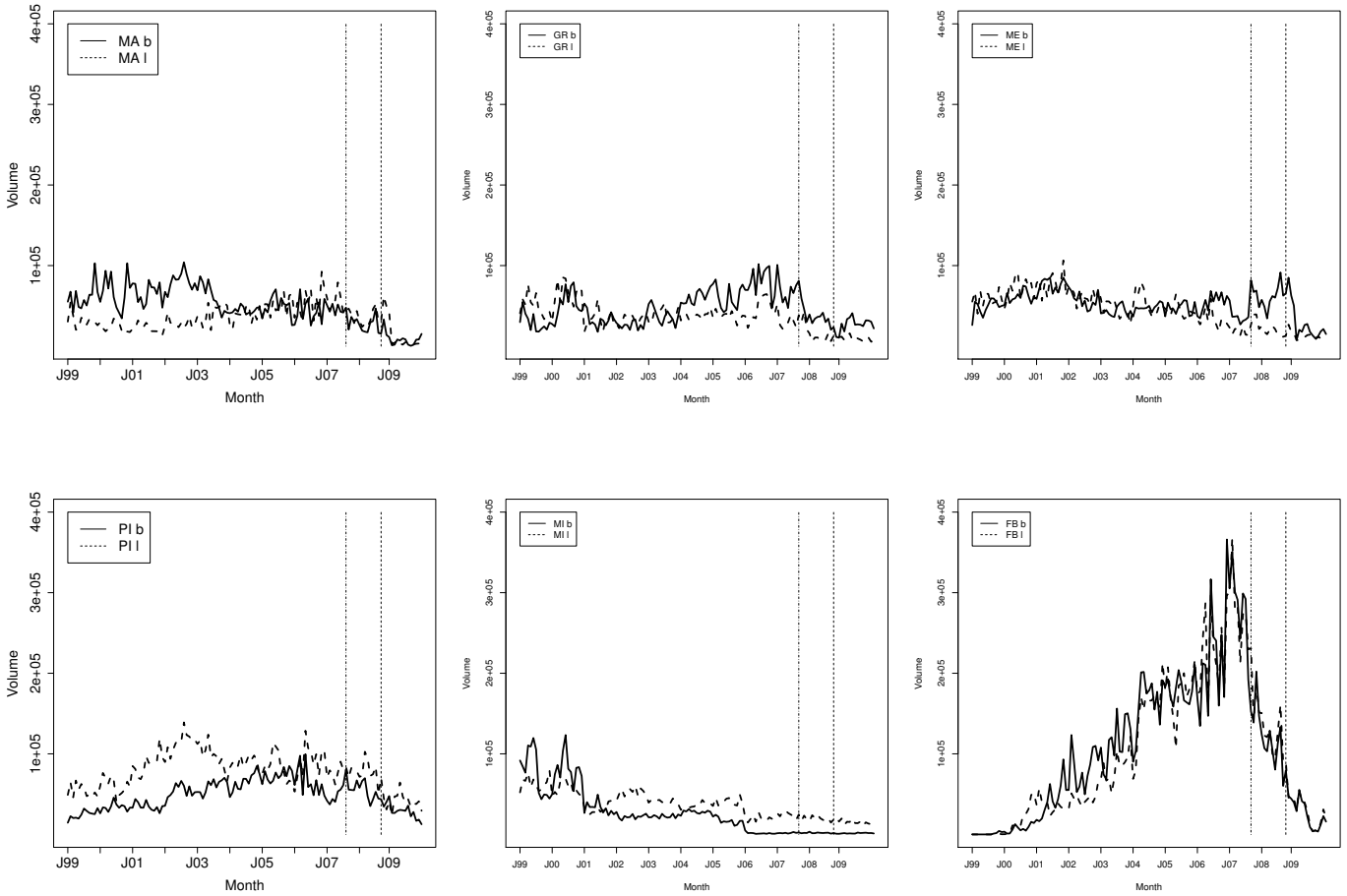


Figure: Average daily volume per maintenance period per group as lender (dashed line) and borrower (continuous line).

System Heterogeneity: net volume per group

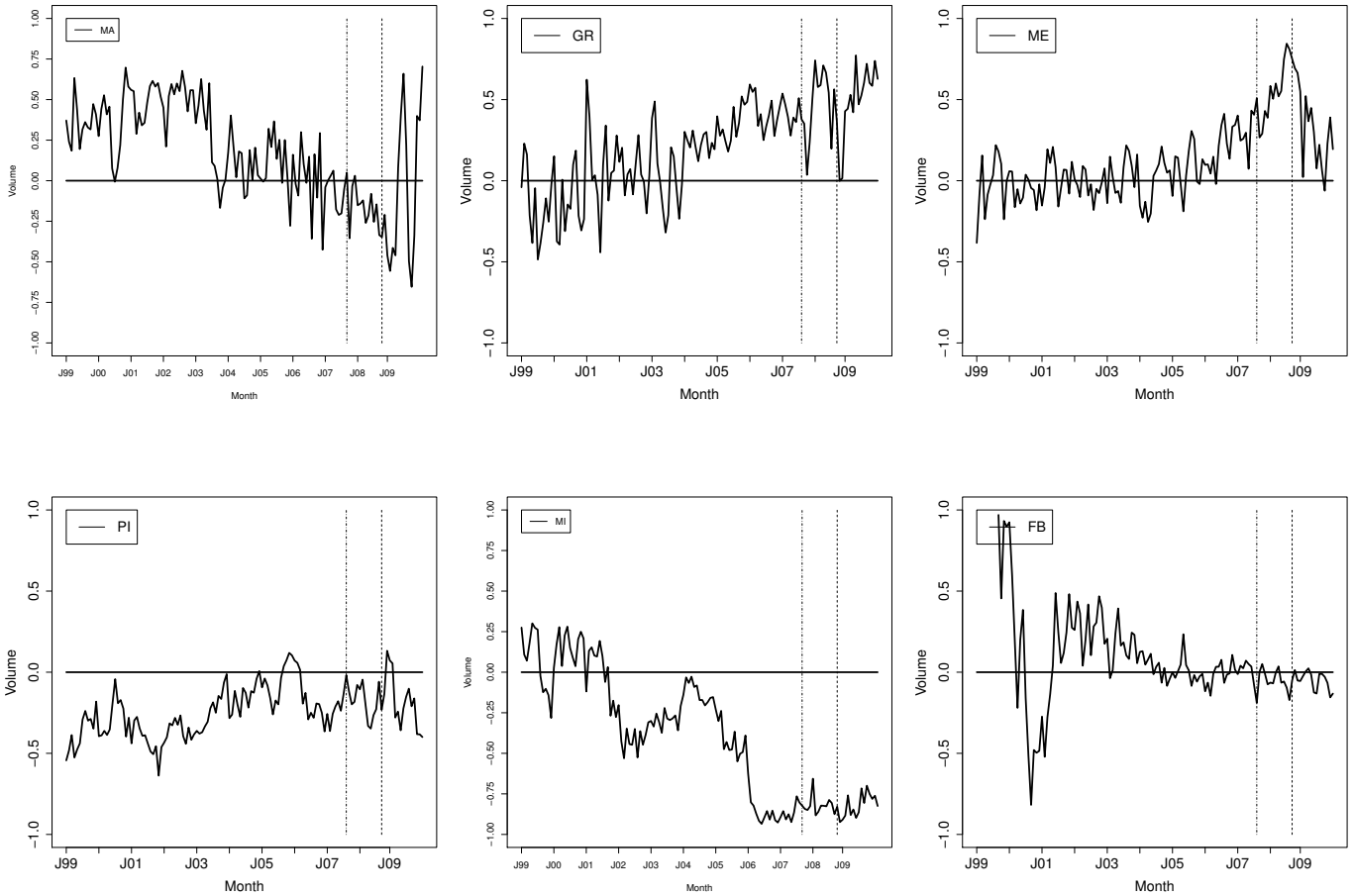


Figure: Net percentage traded volume per group as (borrowed - lent).

System Heterogeneity

To summarize:

- Highly heterogenous system: larger banks trade more often and larger volumes
- Composition of the system changes over time

Network construction:

Two natural timescales in the system

- daily:maturity of the interbank loans
- monthly: around 23 business days-known as a maintenance period

We perform the analysis at the monthly (or 3 months) time scale as want to monitor the frequency of exchanges between counter parties and compare it with a random null hypothesis that preserves bank's heterogeneity in strengths (number of trades).

Choice of weights:

- Volume
- Number of transactions

We choose number of transactions

Example Monthly Networks in p_1

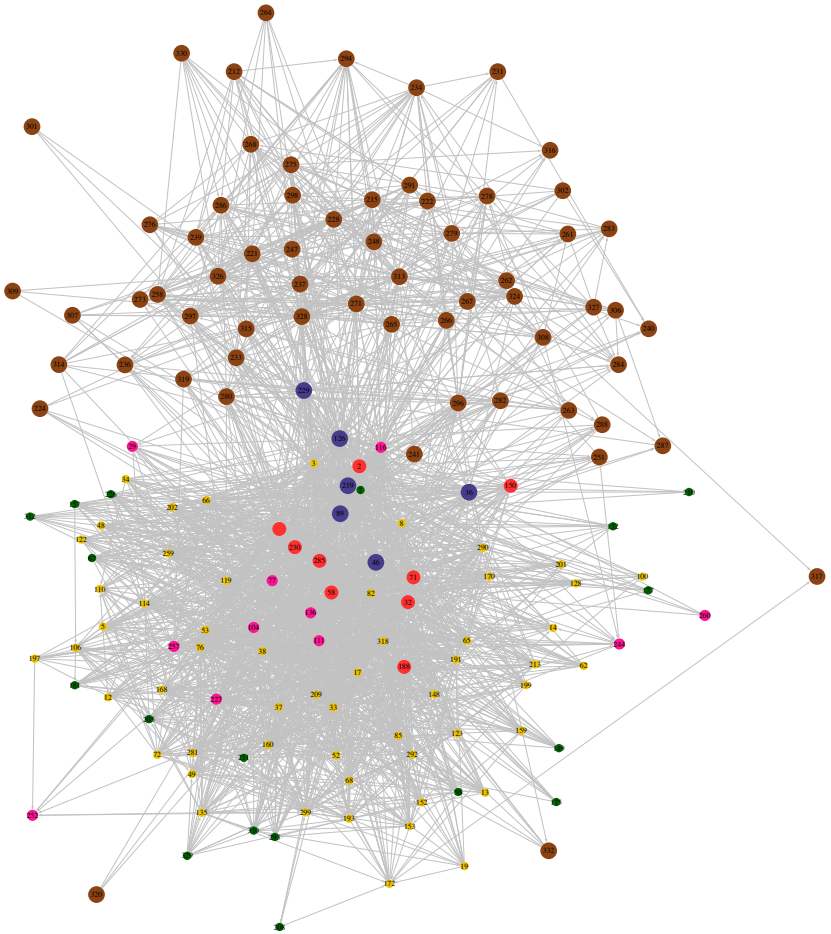


Figure: eMid bank Network in maintenance period 14-Feb-2007 to 13-Mar-2007

Example Monthly Networks in p_2

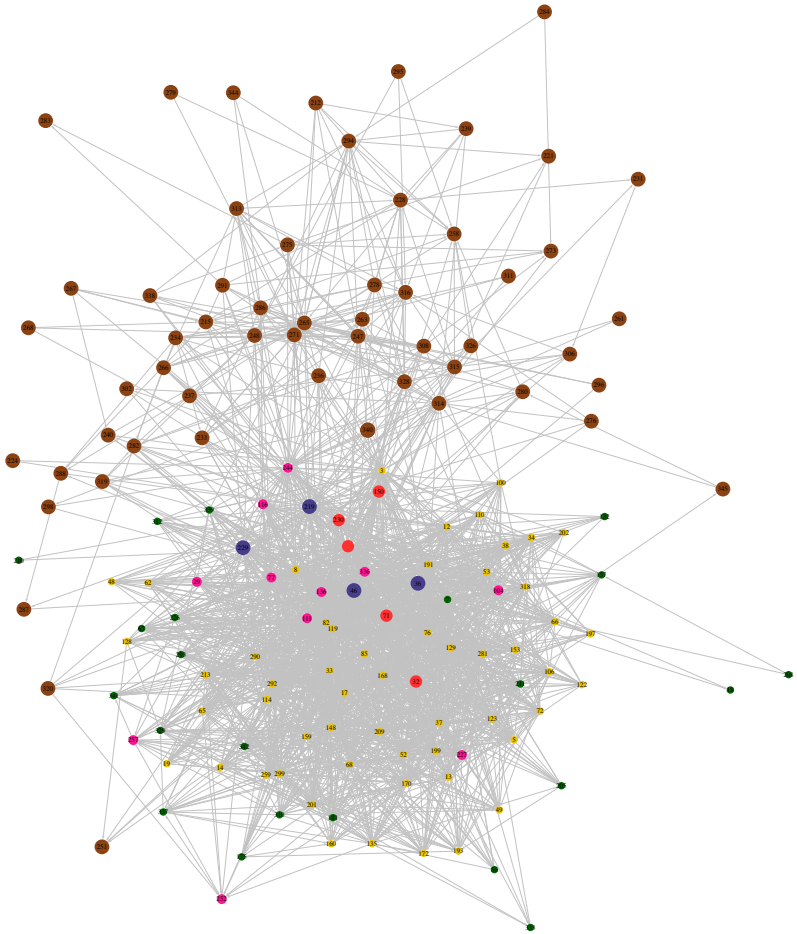


Figure: eMid bank Network in maintenance period 11-Jun-2008 to 08-Jul-2008

Example Monthly Networks in p_3

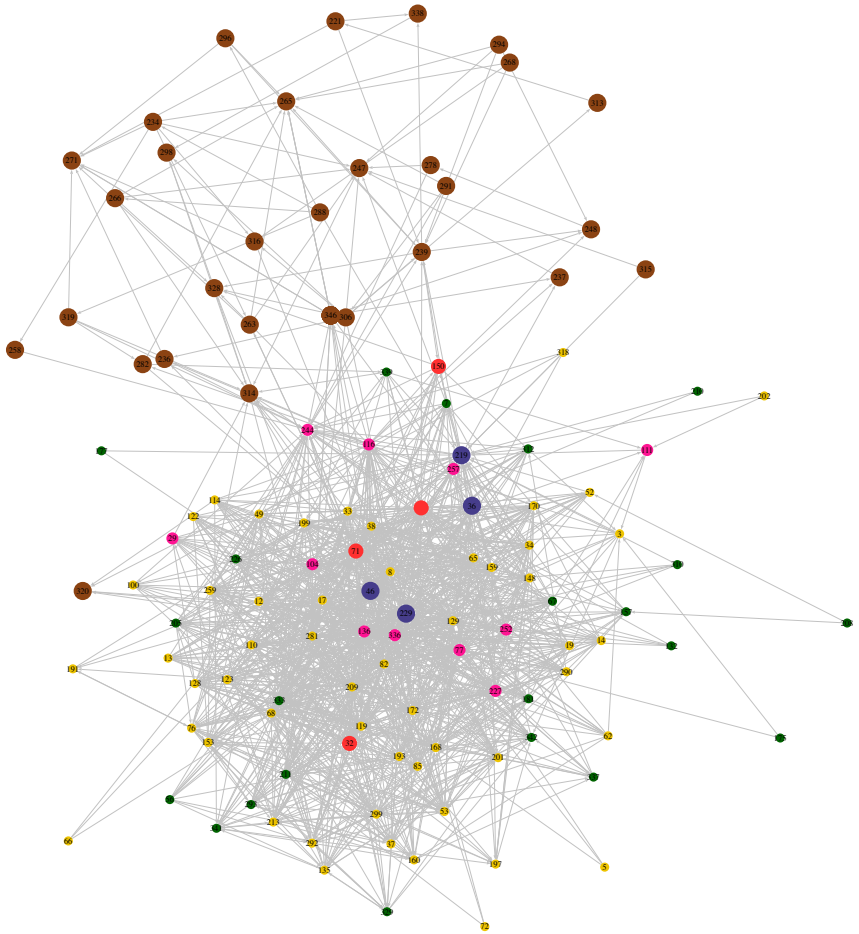
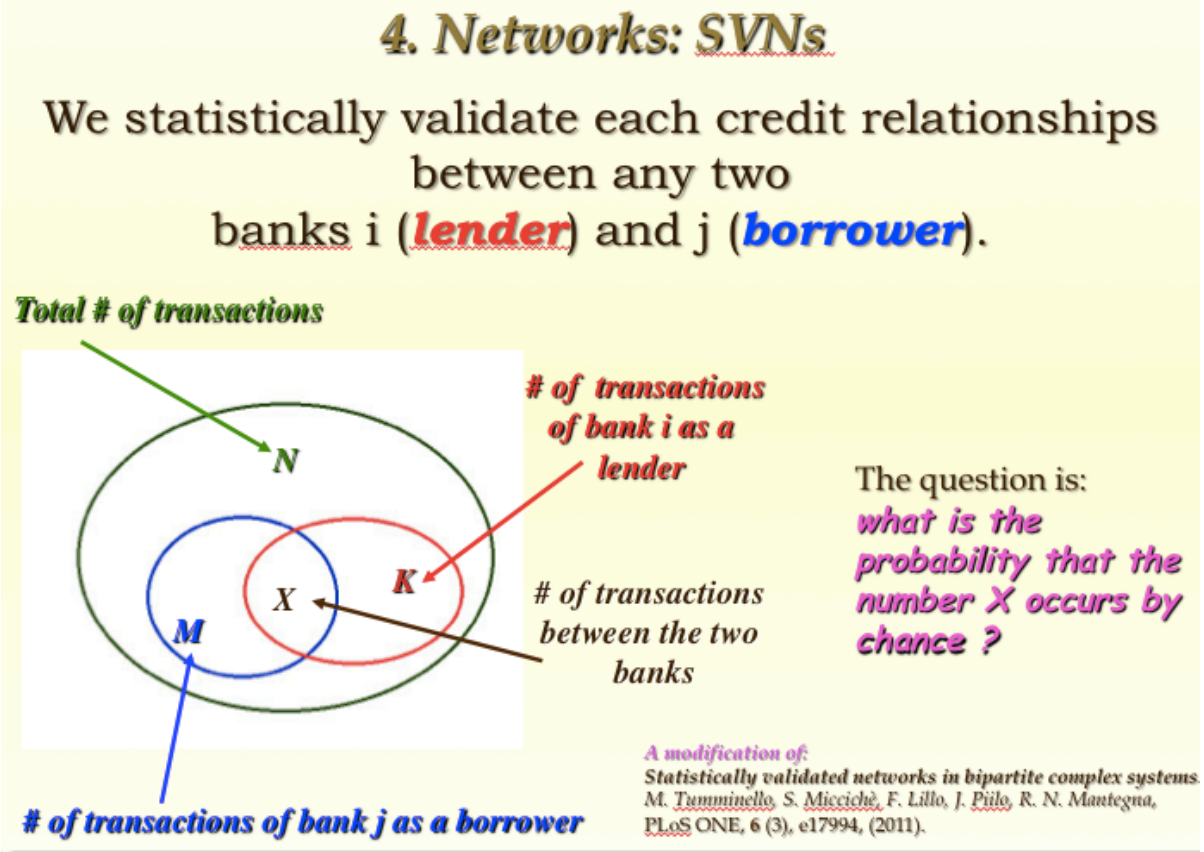


Figure: eMid bank Network in maintenance period 08-Oct-2008 to 11-Nov-2008

Randomness in matching and Trust Evaporation

- The question we address is whether banks behaviour regarding the choice of counter parties in a trade changed before and during the subprime crisis.
- In particular we try and quantify the level of randomness (given bank heterogeneity) in the weights distribution across the links of the credit network.
- We interpret this randomness as a proxy of the level of trust among credit institution.

SVN method[2]



[2] Vasilis Hatzopoulos, Giulia Iori, Rosario N. Mantegna, Salvatore Micciche', Mich Tumminello, *Quantifying preferential trading in the e-MID interbank market*, Quantita Finance (forthcoming)

SVN method

4. Networks: SVNs

In other words: if I randomly pick K transactions in the set of N available transactions and count how many of them are intersecting with the M transactions of the other banks category F, what is the probability of having exactly X transactions in the intersection ?

Hypergeometric distribution

$$P(X \mid N, M, K) = \frac{\binom{M}{X}\binom{N-M}{K-X}}{\binom{N}{K}}$$

p-value

OVER-expression

$$p = 1 - \sum_{i=0}^{X-1} \frac{\binom{M}{i}\binom{N-M}{K-i}}{\binom{N}{i}}$$

UNDER-expression

$$p = \sum_{i=0}^{X} \frac{\binom{M}{i}\binom{N-M}{K-i}}{\binom{N}{i}}$$

threshold t: 5%, 1%, ...: $p_i < t$

Multiple test comparison

in order to control false positives expected in multiple comparisons

Bonferroni

The threshold t must be divided by the number R of populated terms: $p_i < t/R$

False Discovery Rate

$P_i < t/R$
$P_2 < 2\,t/R$
$P_3 < 3\,t/R$
...

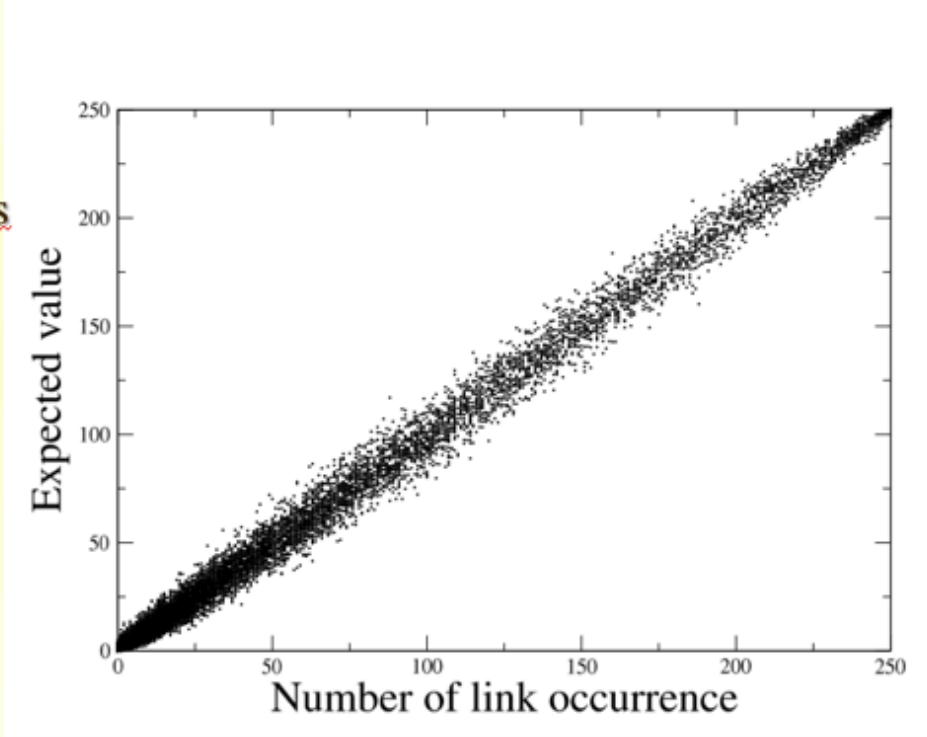
SVN versus reshuffling

4. Networks: re-shufflings

N_S=250

maintenance periods

$$E(n_{lb})$$



This indicates that the links predicted by the model and those obtained in the re-shufflings are in agreement.

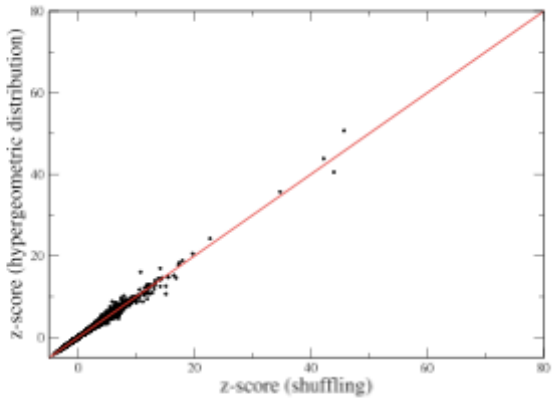
re-shufflings

SVN versus reshuffling

4. Networks: Z-scores

There is even more!!

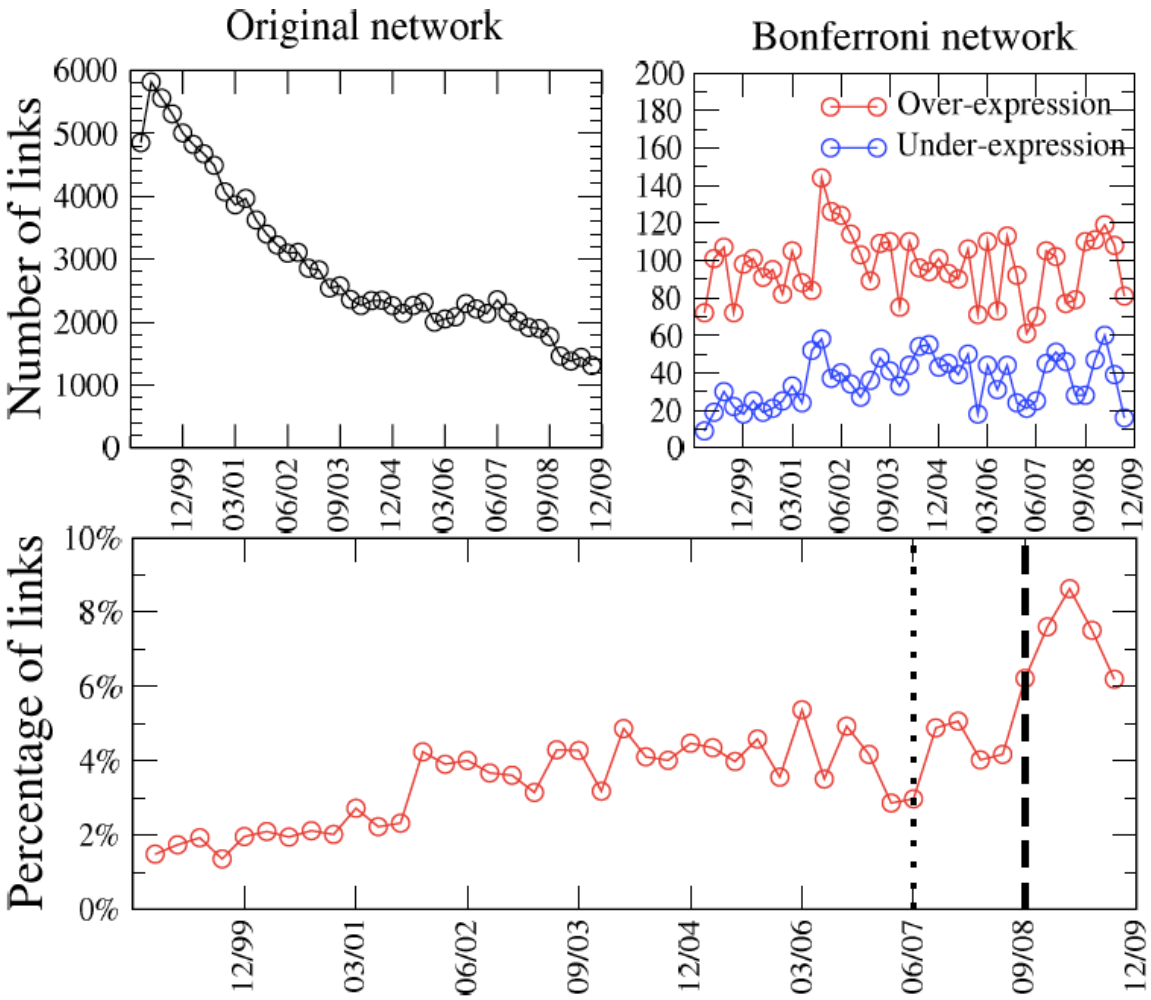
$$Z_{lb} = \frac{n_{lb} - E(n_{lb})}{sd(n_{lb})} \qquad Z_{lb} = \sqrt{T}\rho_{lb}$$



This indicates that the weights predicted by the model and those obtained in the re-shufflings are in agreement.

$$\rho_{lb} = \frac{\langle LB\rangle - \langle L\rangle\langle B\rangle}{\sqrt{\left(L-\langle L\rangle\right)^2}\sqrt{\left(B-\langle B\rangle\right)^2}} = \frac{\frac{n_{lb}}{N_T} - \frac{n_l n_b}{N_T^2}}{\sqrt{\frac{n_l}{N_T}\left(1-\frac{n_l}{N_T}\right)}\sqrt{\frac{n_b}{N_T}\left(1-\frac{n_b}{N_T}\right)}}$$

Over expressed and under expressed links



Do relationships and network position matter?[3]

Aim of study

Econometric Analysis of e-MID aggregated daily transaction data to identify:

- Effect of bank preference in terms of choosing counter-party on borrowing rates.
- Dependency of rates on lenders' and borrowers' degrees, affinity, clustering, centrality
- Periodic impact: pre-, during- and post-crisis.

[3] A. Temiszoy, G. Iori and G. Montes-Rojas, The role of bank relationships in the e-Mid interbank market (working paper)

We show that

- trading with preferred counterparts leads to more favourable rates for both lenders and borrowers, and carries larger volumes.
- Our interpretation is that lenders are willing to provide a discount to borrowers for taking funding risk, in return for better monitoring opportunity, while borrower are willing to pay a premium to lender for taking non diversification risk, in return for preferential access to liquidity.
- The results point to a peer monitoring role of relationship lending in the e-MID market. Private information acquired through frequent transactions, by improving the ability of banks to assess the creditworthiness of their counter parties, supported liquidity reallocation in the e-MID market during the crisis.

- Relationship lending thus played a positive role for financial stability and the default, or exit from the market, of banks that are important relationship lenders or borrowers may lead to a deterioration of the interbank credit market.
- The policy implication is that when establishing if a bank is too connected to fail, regulators should not only look at how connected a bank is, but also at how preferentially connected it is to other key players.

Other determinants of credit spreads

- Size
- Nationality
- Currency (Euro/non Euro)
- Time of trade (Morning/Afternoon)
- Side of trade (Quoter/Aggressor)
- Centrality

Back to Iori, Jafarey, Padilla (2006)

Our 2006 model captures

- System heterogeneity
- stable relationships

but has a number of shortcoming

- Bank's risk profile does not affect their ability to borrow in the interbank market.
  - Banks lend on the basis of a first come first serve principle
  - Interbank rate is the same for all banks
- Banks risk profile is imposed exogeneously and is constant over time
- There is no central bank

Gabbi, Iori, Jafarey, Porter (2014)[4]

The model builds on Iori, Jafarey and Padilla (2006) by introducing some microfoundation:

1. learning and strategic behavior of banks;
2. endogenous fund allocation between real sector-loans, inter-bank loans, or holding cash reserves;
3. counter-party rating schemes and interest adjustment models;
4. bank decisions dependent on counter-party credit risk;
5. bank decisions also conditional on liquidity and inter-bank exposure.

[4] Giampaolo Gabbi, Giulia Iori, Saqib Jafarey, James Porter
Financial regulations and bank credit to the real economy
Journal of Economic Dynamics and Control (forthcoming)

Main goals of the paper

- Model Credit market: bank-firm and inter-bank
- Understand the propagation of financial fluctuations into the real economy.
- Test the impact of regulatory schemes
- Understand systemic risk, originating from inter-bank credit relations; in particular the relation between interbank contagion, network topology and leverage.

The model assumptions

- The financial sector is comprised of a set of banks and a Central Bank.
- The central bank sets the rates of the discount window, provides central bank deposit facilities to banks (r_L, r_H), and provides liquidity to banks.
- Banks are risk neutral and aim at maximising profits.
  - Choose the leverage target: $\lambda = L/E$
    - $L = L^f + L^b$ = total lending
    - E = equity.
  - Set lending rates to firms
  - Set interbank lending/borrowing rates

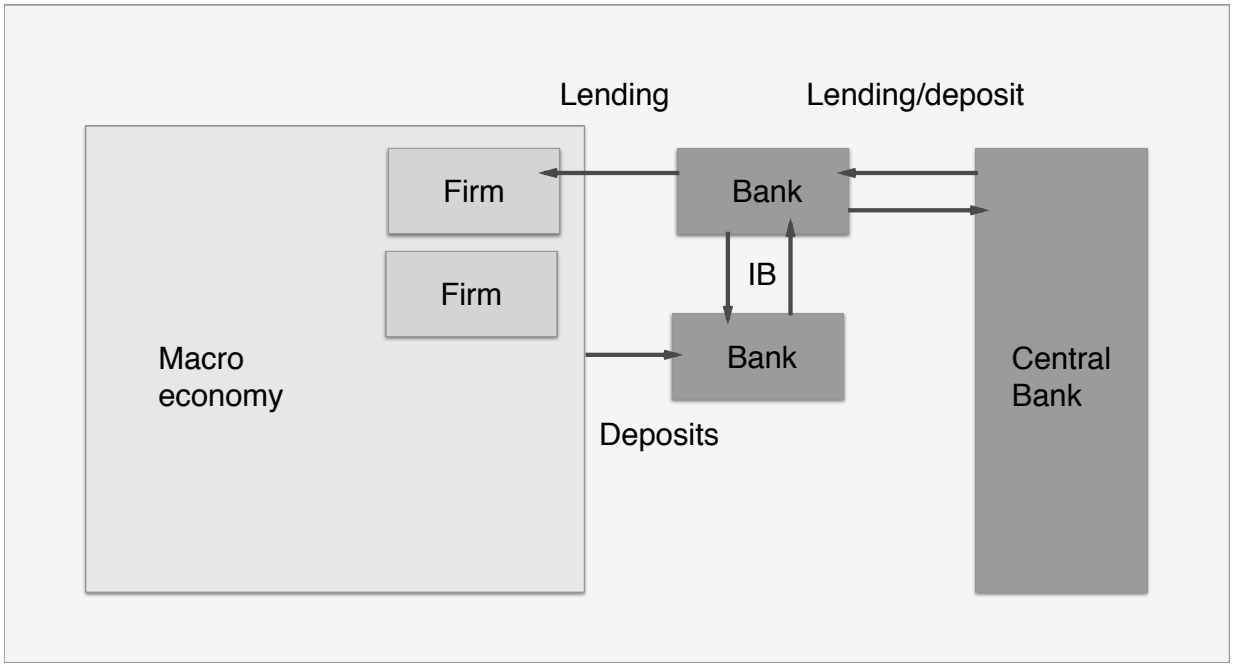


Figure: A schematic overview of the economy.

Quantities

- Banks receive demand for loans from firms.
- Firms can only borrow from banks with which they are connected.
- Firms demand is random but the average size $\bar{d}$ is constant.
- With exogenous probability ρ each firm will default on its loans. This is the same for all firms.
- Banks offers loans to firms for a total of $\hat{L}_j^f(t) = \lambda_j(t)E_j(t)$.
- Interbank lending is a residual.
- Bank lending to firms is the source of both risk and reward in the banking sector.

Rates

- Each bank takes into account its own financing costs and the firm probability of default when determining their lending rates to firms.
- Since each firm has the same probability of default the minimum rate at which a bank will lend to any firm is the same for all firms and depends on the bank's own costs.

$$\underline{r}^f_{ji}(t) = \frac{1 + c_j(t)}{1 - \rho} - 1 \tag{1}$$

where $c_j(t)$ is the expected cost of funds

$$c_j(t) = \omega^D_j(t) r^D + \omega^b_j(t) E[r^b_j(t)] + \omega^C_j(t) r^H \tag{2}$$

- Firms are price takers but do not accept rates higher than r^{max}.
- These bounds frame the rates at which lending takes place. Each firm accepts loans from the bank posting the lowest rate to it.

Learning

- A given bank may not achieve the desired level of lending to firms at each point of time.
- Banks update their rates in order to achieve their target lending to firms (increase rates if achieve their target, decrease their rates if do not achieve their target).

After banks have committed to lend to firms, they receive a shock on their deposit.

- In case banks end up with negative positions on their central bank accounts after the shock, they enter the interbank market as borrowers. If they cannot borrow all they need on the IB market they borrow from the central bank at r_H.
- In case banks end up with positive positions on their central bank accounts after the shock, they enter the interbank market as lenders. If they cannot lend all they wish on the IB market they deposit their excess liquidity in their central bank accounts and earn r_L.

- Interbank lending is restricted to an exogenous pre-determined network.
- Lending on the interbank market does not bear liquidity risk and banks are willing to lend all their excess cash
- Lender charges a risk premium to lend to risky banks
- Borrowers compete for liquidity and update their rates in order to achieve their target borrowing in the IB market (decrease rates if achieve their target, increase rates if do not achieve their target).
- Banks learn to choose λ, subject to the statutory ratio, in order to maximise profits, compatibly with the volatility of their deposits, the demand of firms and the cost of borrowing.
- We study two scenarios for how banks assess counter-party risk: Model B (Benchmark) assumes a uniform probability based on market data; Model D (Disclosure model) assumes information on individual balance sheets which enables idiosyncratic risk to be measured.

Leverage Ratio

- The new (Basel III) leverage ratio is defined as a minimum percentage (3%) of the capital measure to the exposure measure. One of the impacts of this new approach is that it considerably widens the definition of what constitutes leverage in the banking system, pushing banks to either increase their capital or reduce their intermediation activity.
- While advocates of tougher regulation generally support this tightening, its critics question if obliging banks to reduce their leverage ratio will increase systemic safety more than it reduces the intermediating role of the banking system, which in effect is the lubricant for the real economy.

- Low statutory leverage ratios can reduce idiosyncratic and systemic risk on the interbank market, but they have an anti-competitive effect on bank lending.
- On the other side, high statutory leverage ceilings can make banks particularly vulnerable to systemic failure, especially in 'bad' times.
- Greater bank connectivity can have a non-monotonic effect on bank stability, first increasing the risk of contagion and then decreasing it. Consistent with Iori et. al. [2006]
- Counter-cyclical leverage ratios tend to reduce defaults (relative to fixed ratios) but also reduce mean turnover from banks to the real sector.

Parameters

- *Target update frequency*, how frequently leverage target is updated. Default: every period.
- *Number of firms per bank*. Default: 25/50/100 for "Low"/"Medium"/"High" demand.
- *Mean firm loan demand size*. Default: 20.
- *Number of banks each firm approaches*. Default: 5.
- *Connectivity*, how likely it is for any two banks to be connected on interbank market. Default: 0.2.
- r_H, Central Bank Lending Rate. Default: 0.09
- r_L, Central Bank Lending Rate. Default: 0.02
- T^g, *Number of periods after borrowing from the Central Bank a bank is denied an inter bank loan* Default: 1
- T^h, *Period over which banks default are observed* Default: 1
- *Probability of firm loan default*. Default: 0.01.
- *Number of Banks*. Default: 100.
- *Initial deposit*. Default: 500.
- *Initial equity*. Default: 100.
- *Deposit volatility*, weight for proportion of deposits withdrawn and allocated to another bank (in proportion to equity). Default: 0.1.

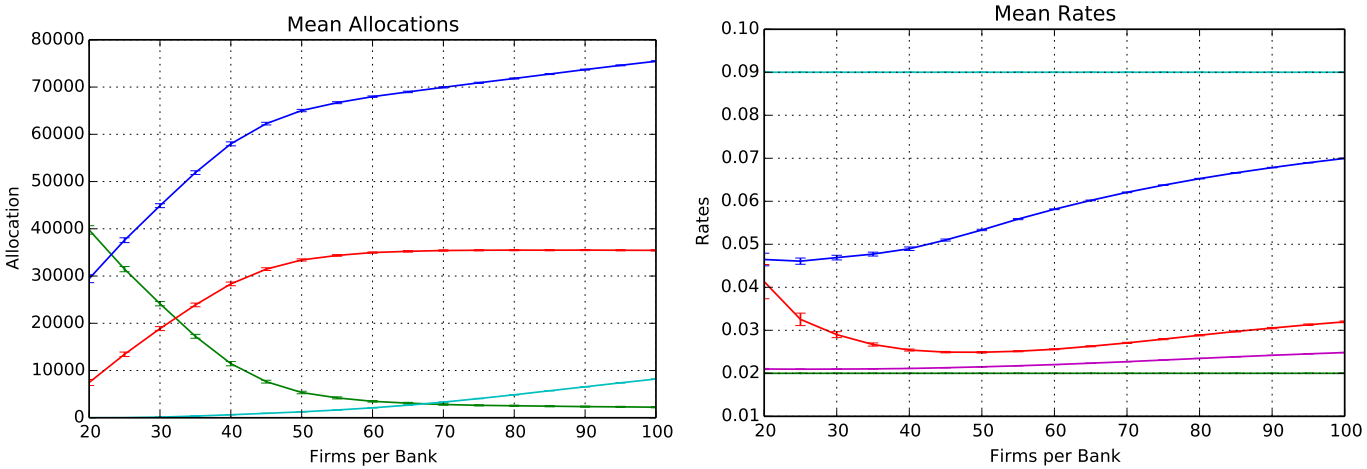


Figure: Allocations and interest rates with varying sizes of the real economy: Model B. Firm Lending (Blue), Interbank Lending (Red), Central Bank Reserves (Green), Central Bank Borrowing (Turquoise), Average Cost of Funds (Purple).

- Allocations of funds are as expected.
- Interbank rates decrease and then increase.
- Related to high default probability in states of very low demand and greater competition for borrowing in high demand.
- In the Low economy only a small number of highly exposed banks seek funds on the interbank market. This makes lending on the interbank market particularly risky and rates reflect this riskiness.

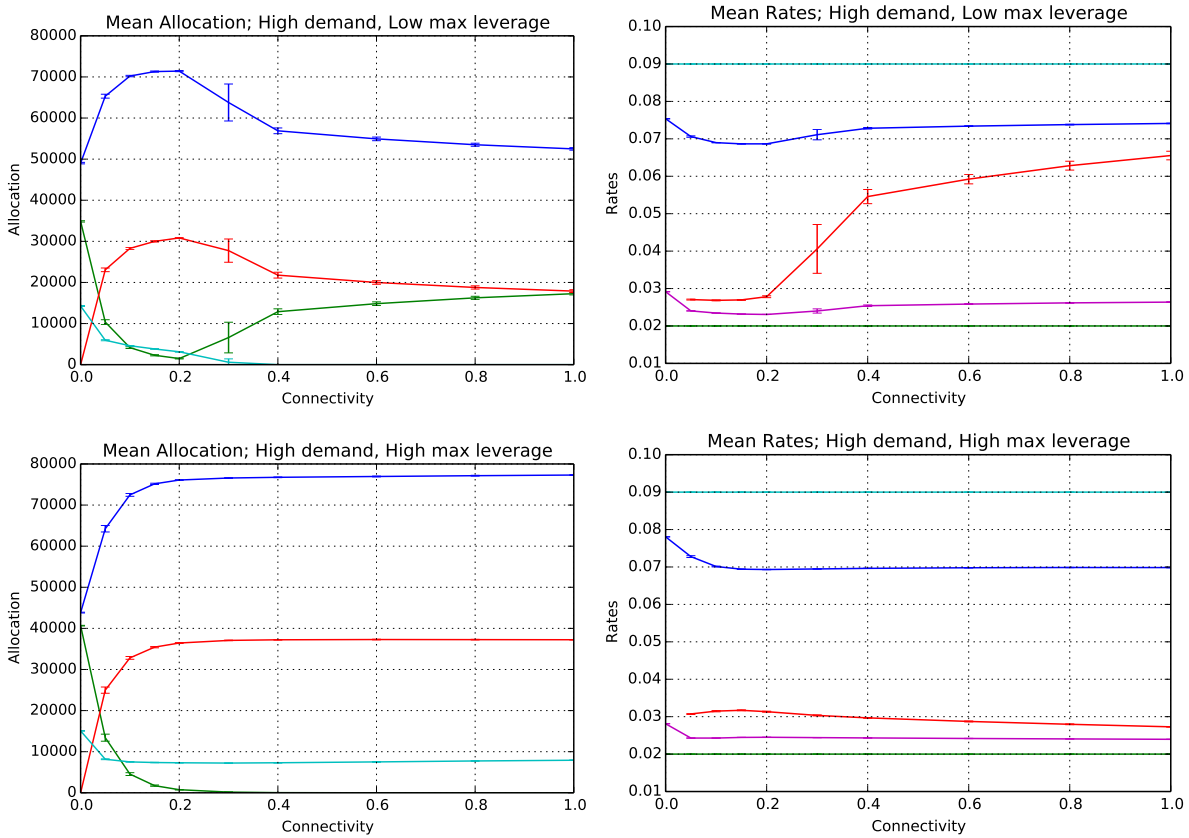


Figure: Average allocations and interest rates for varying connectivity with High demand. Low Max Leverage = 10 (Top), High Max Leverage = 40 (Bottom); Firm Lending (Blue), Interbank Lending (Red), Central Bank Reserves (Green), Central Bank Borrowing (Turquoise), Average Cost of Funds (Purple).

- At the low ceiling most banks fill their order book with loans to the real sector and few banks are left with funds to lend on the interbank market. Increasing connectivity increases competition and this pushes up interbank interest rates. Higher funding costs then lead to higher rates on firm loans and this acts as a dampener on activity in both markets.
- Relaxing the leverage ceiling from 10 to 40 allows individual banks to take on more firm lending and also increases the availability of funds on the interbank market. In this case, increasing connectivity beyond a certain level leads to a plateau in allocations across all markets and a gradual decrease in interbank rates. After a connectivity of 0.2, a constant level of firm lending is achieved, which on average means a constant demand for interbank borrowing, so increasing connectivity leads to competitive pressures from the supply side of the interbank market.

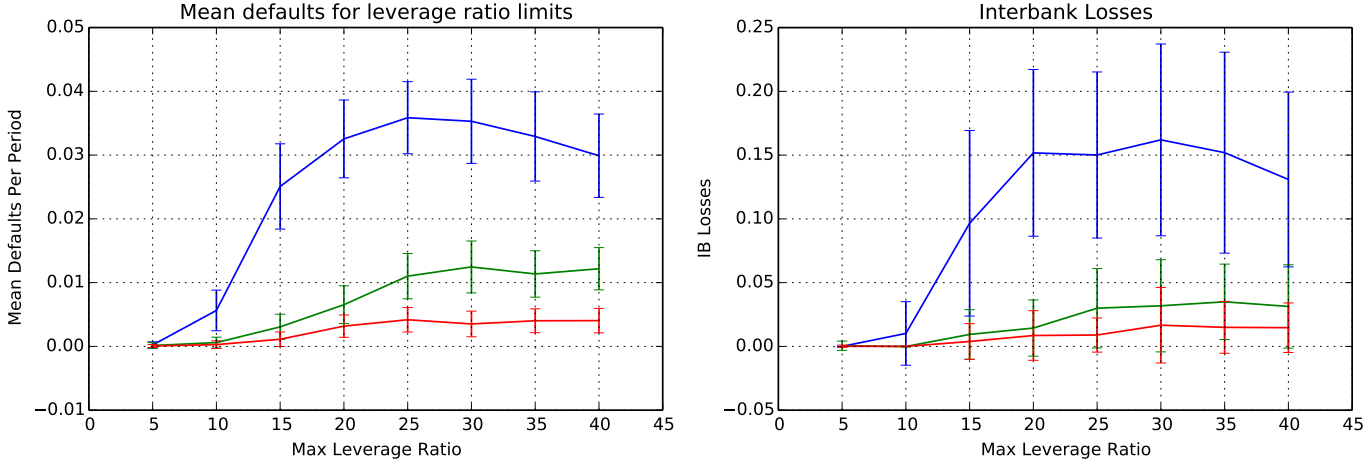


Figure: Mean default per period at varying leverage ratios: Low Demand (Blue), Medium Demand (Green), High Demand (Red).

- Bank failures are more likely under conditions of low demand.
- Inverse U-shape seems to arise because increasing leverage increases concentration of loans into few highly exposed banks, this increases also interbank rates, but increasing leverage even further allows for more diversification and thus reduces risks.

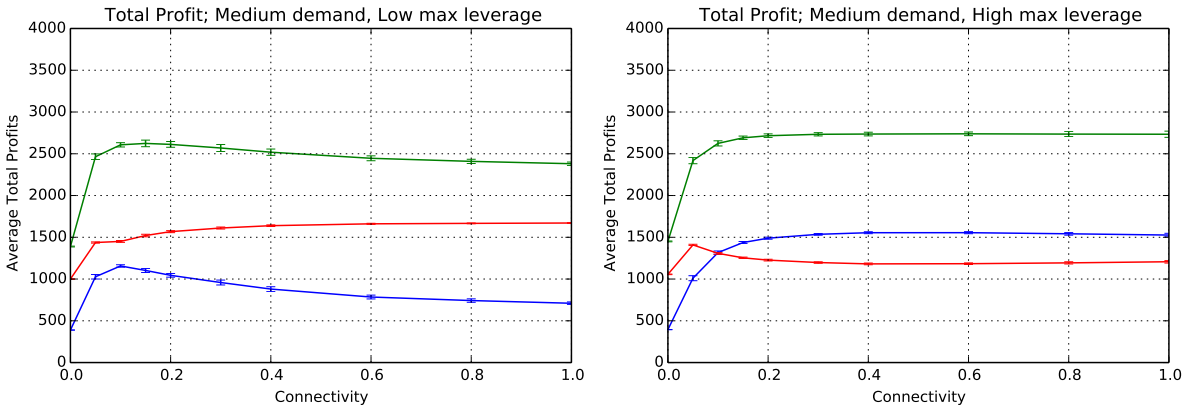


Figure: Economy-wide profits at varying levels of connectivity: Medium Demand. Statutory Leverage = 10% (Left), Statutory Leverage = 20% (Right); Firm Profits (Blue), Bank Profits (Red), Aggregate (Green).

- Anti-competitive effect of low statutory ceiling: Firm profits are reduced relative to bank profits.
- Anti-efficiency effect: Aggregate profits are also lower.
- Not much effect in going from 20% statuary leverage to 40%

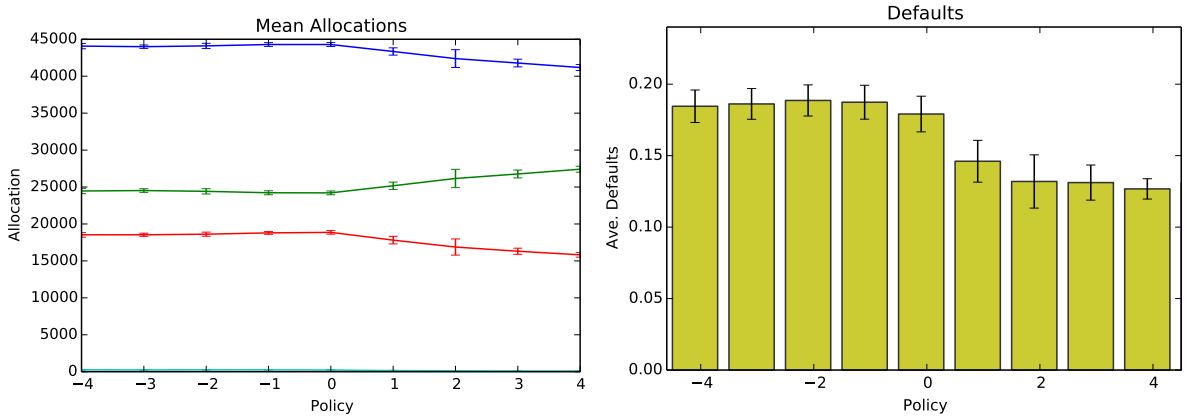


Figure: The effect of variable leverage ratios on allocations and bank defaults. Firm lending (Blue), Interbank Lending (Red), Central Bank Reserves (Green), Central Bank Borrowing (Turquoise).

- Counter-cyclical leverage rules reduce bank failures but also lower average lending activity over the business cycle.
- Asymmetry: Low demand = not much activity anyway; raising leverage ceiling has little effect.
- Counter-cyclical rules appear to have more bite in booms than in recessions.
- Pro-cyclical ratios worsen instability with little effect on allocations.

- Both bank performance and bank stability depend on the state of the real economy as well on regulatory constraints.
- Loan pricing depends on demand and riskiness which in turn varies with demand in non-monotonic ways.
- Counter-cyclical leverage ratios improve stability but reduce the intermediating role of the banking system.

- Introduce more heterogeneity
- Allow for longer maturity loans to firms
- Introduce empirically based and endogenously determined bank/firm and firm/firm networks.

THANK YOU