Importance of Network Positioning in the Interbank Market

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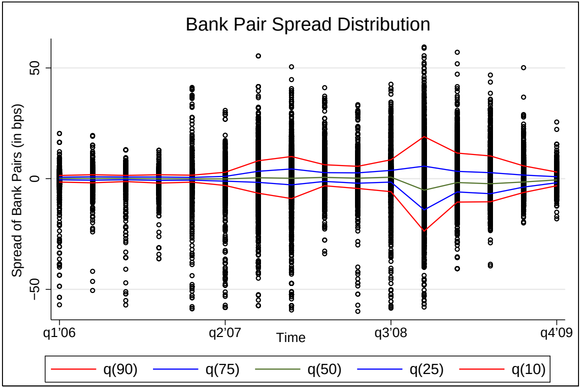
Aim of Study & Motivation

- Motivation
  - 2007-08 financial crisis has stressed the importance of market interconnectedness on financial stability.
  - Three main criteria to assess systemic importance of financial institutions; size, connectedness and substitutability
  - "Too-connected-to-fail" perception
- Empirical Analysis of e-MID daily transaction data with over-night(O/N) maturity to identify:
  - Determinants of spread for bank pairs
  - Effect of local and global network centrality measures
  - Impact of aggressors' role as lender vs borrower
  - Periodic impact: Phase I, II and III of financial crisis
- Contribution
  - Working with bank pairs in order to show the importance of network of both parties
  - Controlling position of the bank in the transaction(being quoter or aggressor in a transaction)
  - Effect of foreign-based banks in the sample

Effect of the suprime crisis on interbank market lending



Data

- Why the e-MID market?
  - Full information in the market
  - Fully transparent
  - Information on terms are available in real time
- The original dataset consists of tick data from e-MID between 1 January 2006 and 31 December 2009, separated into three main periods based on the latest financial turmoil:

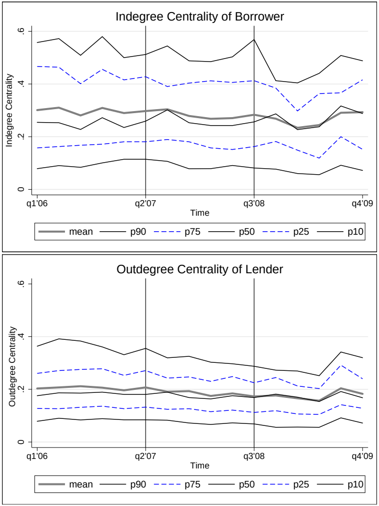
Period	Explanation	Number of Maintenance Periods
01 Jan 2006 - 30 Jun 2007	Phase I*	6
01 July 2007 - 30 Sep 2008	Phase II**	5
01 Oct 2008 - 31 Dec 2009	Phase III	5

* Bankruptcy of Two Bear Stearns Hedge Fund(31-jul-07)
**Lehman Brothers' collapse (15-sep-08)

- The dataset is analyzed in two groups; All O/N loans and O/N loans between only local banks(Italian-Italian)

Quantile Analysis of Local Network Measures: Degree

- *Indegree**: Number of counterparties from which a bank borrows loan.: $C_{in}(i) = \frac{\sum_j a_{ji}}{n-1}$
- *Outdegree**: Number of counterparties to which a bank lends loan: $C_{out}(i) = \frac{\sum_j a_{ij}}{n-1}$
- Figure illustrate the average and quantiles of indegree of borrower and outdegree of lender for three phases of 2007-2008 financial turmoil. Both variables show a higher inter-quantile range before Lehman's collapse than after. There is, however, a sharp decrease in the upper quantile of both measures during the second phase.



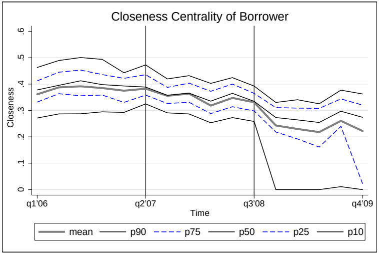
Quantile Analysis of Global Network Measures: Closeness

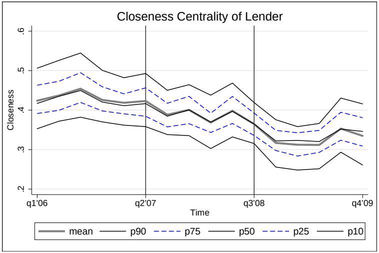
- *Closeness** is the inverse of the average shortest distance of a bank from all banks that are reachable from it.

$$Closeness(i) = \frac{1}{n-1} \sum_{j \neq i} \frac{1}{l(i,j)}.$$

- The higher the value, the lower the distance separating the bank from the counterparties. A bank with higher closeness centrality is directly connected to more banks in the network.

- Graphs present that closeness decreases during second and third phase of the 2007-2008 financial turmoil, a trend that is similar to local measures.





Quantile Analysis of Global Network Measures: Betweenness

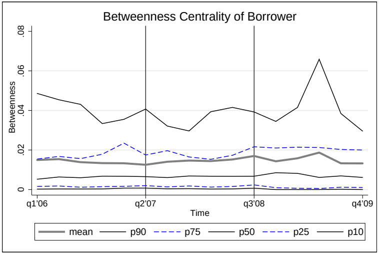
- *Betweenness* measures the shortest path between two banks (u and v) that passes through the bank k.

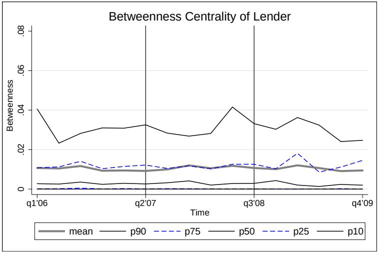
$$Betweenness(k) = \frac{\sum_{i,j} \frac{\sigma(i,j|k)}{\sigma(i,j)}}{(n-1)(n-2)},$$

where $\sigma(i,j)$ is the number of shortest paths from node i to j and $\sigma(i,j|k)$ is the number of such paths passing through the bank k.

- The intuition is that nodes who are "between" other nodes will be able to translate their broker role into power.

- Betweenness is also computed as volume-weighted where two nodes that trade more are closer, and the inverse of a weight is the length of a path.



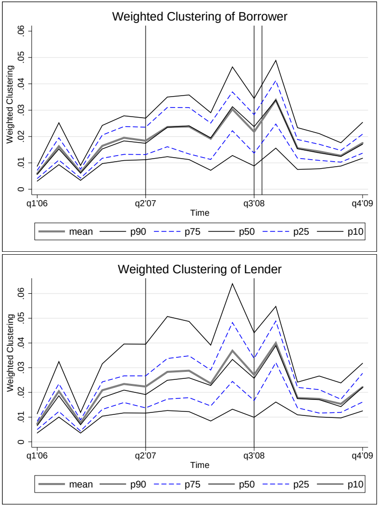


Quantile Analysis of Global Network Measures: Clustering

- *Clustering* is the probability of transaction between two counterparties of a bank
- How concentrated the neighborhood of a bank is
- Measure for sensitivity of counterparty risk
- Clustering increases and the range of values broadens in phase I and II of the crisis while it sharply decreases during the last phase with values confined in a narrow range. The increase in clustering points to a loss of trust in the banking systems at the onset of the crisis, with banks preferring to trade within small cliques or trusted counterparties. In this sense the increase in clustering may be interpreted as an early warning indicator of the financial crisis.

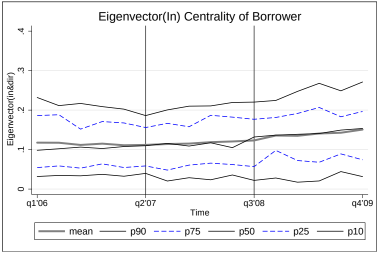
$$wClustering(u) = \frac{\sum_{uvk}(\hat{w}_{uv}\hat{w}_{uk}\hat{w}_{vk})^{1/3}}{deg(u)(deg(u)-1)}$$

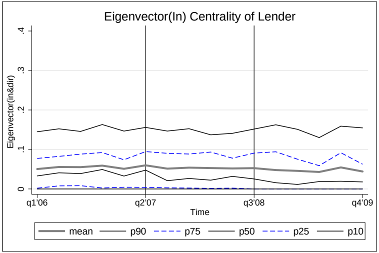
where $\hat{w}_{uv} = \frac{w_{uv}}{max(w)}$



Quantile Analysis of Global Network Measures: Eigenvector

- *Eigenvector Centrality* is defined as the principal eigenvector of the adjacency matrix defining the connected network and it is calculated as $\lambda v = gv$, where g is the adjacency matrix of the graph, λ is the eigenvalue which is a constant and v is eigenvector.
- The eigenvector centrality of a node can be interpreted as a fraction of time that a random walk(er) will spend at that node over an infinite time horizon.
- Higher value of the eigenvector measure better connected neighbours.
- There is a slight increase in the quantiles of eigenvector over time, that is, global concentration does not change a lot during 2007-2008 financial turmoil.
- Lenders are better connected to network than borrowers over all phases.



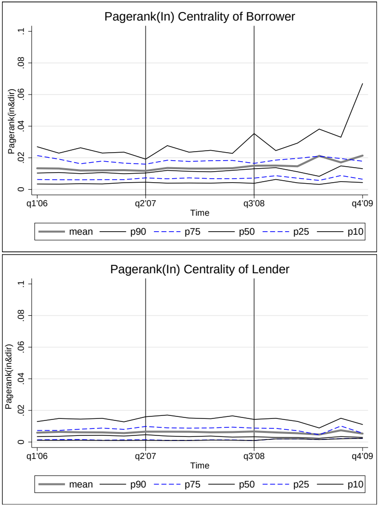


Quantile Analysis of Global Network Measures: Pagerank

- *Pagerank Centrality* is an eigenvector based algorithm. The score for a given node may be thought of as the fraction of time spent visiting that node in random walk over the verices. Pagerank modifies this random walk by adding to the model a probability of jumping to any other vertex.

$$PR(u) = \frac{1-d}{N} + d \sum \frac{PR(v)}{L(v)}$$

- We take damping factor as $d = 85\%$.



Quantile Analysis of Global Network Measures: Sinkrank

- *Sinkrank Centrality* is based on absorbing Markov chains(Soramaki, 2014). SinkRank is defined as;

$$SR(u) = \frac{n - m}{\sum_i \sum_j q_{ij}}$$

where m is the number of absorbing states and $n - m$ the number of non absorbing states and q_{ij} the element of the matrix $Q = (I - S)^{-1}$ and S is the matrix of transition probability for non-absorbing states. Q is a matrix whose elements give the number of times, starting in state i a process is expected to visit state j before absorption, that is the total number of visits a process is expected to make to all the non-absorbing states.

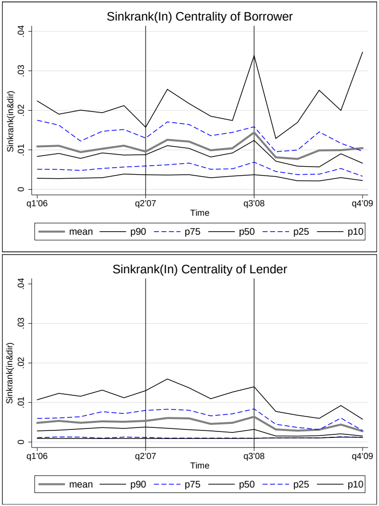
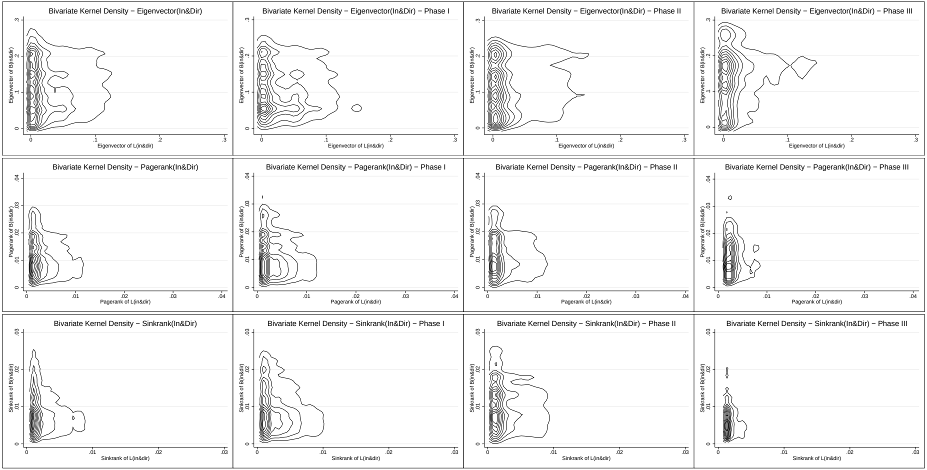


Figure: Bivariate Kernel Density - Global Network Measures (*Graph Type; Directed:Yes, Weight:None*)



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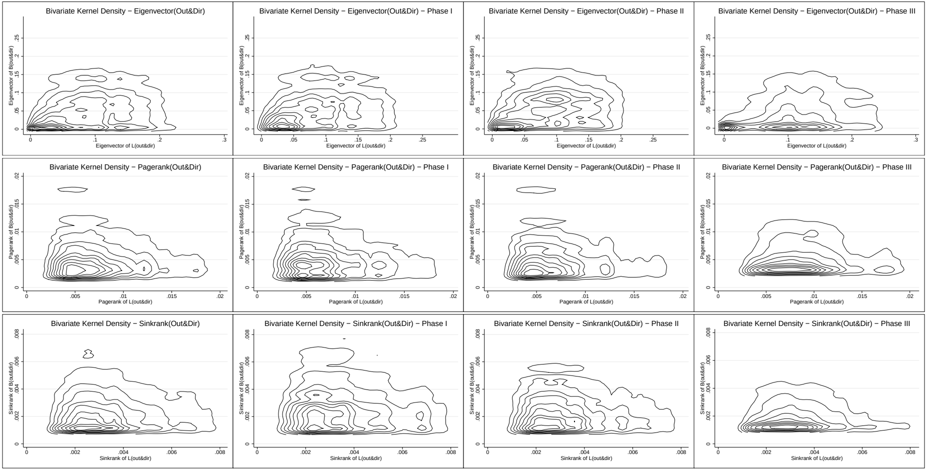

Methodology

- Interbank rate spread is calculated as

$$S_{ij,q} = \frac{1}{\sum_{t=1}^{T_{ij,q}} V_{ij,t}} \sum_{t=1}^{T_{ij,q}} (r_{ij,t} - \bar{r}_q) * V_{ij,t}$$

where $r_{ij,t}$ is transaction level interest rate outstanding for each pair of banks ij where $i \neq j$ at time t, and $\bar{r}_q$ the quarterly volume weighted average rate over all transactions carried out by the bank pairs.

- Spread calculation is based on e-MID volume weighted average rate as opposed to EONIA or ECB rates.
- We consider the following empirical model in order to examine the network centrality measures on bank spreads:

$$S_{ij,t} = \beta_0 + \beta_1 A_{ij,t} + \beta_2 B_{ij,t} + \beta_3 C_{ij,t} + \beta_4 D_{i,t} + \beta_5 E_{j,t} + u_{ij,t}$$
$$u_{ij,t} = \mu_{ij} + \delta_t + e_{ij,t}$$

where t indexes time, $A_{ij,t}$ and $B_{ij,t}$ are vectors of bank centrality measures including indegree, outdegree, closeness, betweenness centrality and eigenvector of lender and borrower respectively. C, D and E represent pair, lender and borrower related variables respectively, and $u_{ij,t}$ is the residual.

- We apply all our models to the panel data with bank pair and time fixed effects represented as μ_{ij} and δ_t respectively. The former captures bank characteristics to account for unobservable bank characteristics, such as ownership, and long-term pair relationships. The latter captures the evolution of the market across time and common shocks that affect all banks.
- We run the regression for each centrality measure separately.

Results - Local Network Measures

Table: All O/N Loans -Effect of Local Network Measures on Interbank Rate Spread

VARIABLES	(1) All	(2) Phase I	(3) Phase II	(4) Phase III	(5) All	(6) Phase I	(7) Phase II	(8) Phase III
Outdegree L/link(%)	-0.905***	0.669**	0.366	-1.443***	-0.639***	0.447	0.128	-1.301***
	(0.204)	(0.290)	(0.536)	(0.439)	(0.218)	(0.329)	(0.608)	(0.439)
Indegree B/link(%)	0.819***	1.316***	0.926**	3.508***	0.662***	1.420***	0.301	3.657***
	(0.154)	(0.235)	(0.402)	(0.290)	(0.168)	(0.286)	(0.424)	(0.318)
Indegree L/link(%)					0.544***	-0.366	-0.457	0.327
					(0.168)	(0.266)	(0.432)	(0.274)
Outdegree B/link(%)					-0.451***	0.162	-1.750***	0.559
					(0.157)	(0.246)	(0.427)	(0.378)
Transaction Ratio	4.849***	-0.326	2.267	6.432***	4.880***	-0.484	1.005	6.929***
	(1.742)	(1.173)	(1.793)	(1.653)	(1.748)	(1.170)	(1.803)	(1.664)
AM/PM Ratio	2.314***	1.149***	3.201***	1.596***	2.316***	1.148***	3.176***	1.600***
	(0.082)	(0.090)	(0.169)	(0.196)	(0.082)	(0.090)	(0.169)	(0.196)
Quot/Agg Ratio	1.506***	0.815***	1.679***	2.826***	1.501***	0.819***	1.686***	2.830***
	(0.103)	(0.120)	(0.214)	(0.273)	(0.102)	(0.120)	(0.214)	(0.273)
Reciprocity Ratio	-0.089***	0.032	-0.051	-0.061	-0.088***	0.033	-0.045	-0.092
	(0.017)	(0.038)	(0.033)	(0.174)	(0.016)	(0.038)	(0.029)	(0.177)
O/N Trading Amount of L	-0.003	-0.008	-0.028**	0.003	-0.008	-0.007	-0.023*	-0.002
	(0.005)	(0.005)	(0.012)	(0.047)	(0.005)	(0.005)	(0.012)	(0.047)
O/N Trading Amount of B	0.010**	-0.007*	-0.003	-0.140***	0.012**	-0.008*	0.002	-0.146***
	(0.005)	(0.004)	(0.012)	(0.022)	(0.005)	(0.004)	(0.012)	(0.022)
Observations	37,872	16,314	13,811	7,747	37,872	16,314	13,811	7,747
R-squared	0.090	0.035	0.078	0.179	0.091	0.036	0.081	0.180
Number of pair_id	6,674	5,218	4,992	3,109	6,674	5,218	4,992	3,109

Robust standard errors in parentheses. O/N Trading Volume is used as proxy for bank size. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Results - Local Network Measures

- Higher the proportion of number of pair trading in a given period higher interest rate during phase III of the financial crisis.
- Borrowing loans is more expensive in the morning.
- Quoter/Aggressor ratio of lender has significantly positive effect on interest rate spread.
- The borrowers with higher indegree pay premium when receiving loans for all time spans.
- Lenders also pay premium due to high number of borrower in order to diversify risk.
- The magnitude of premium they pay is even larger after Lehman Brothers collapse. We might thus speculate that financial uncertainty directs banks towards looking for better connections within the established network structure. Possibly this suggest that in the presence of systemic risk, banks diversify their transactions and incur in worse interest rates.
- Lender (Borrower) who engage in well connected borrowing (lending) activity benefit by obtaining better rates. Overall, this suggest that network effect depend on the joint lending and borrowing activities of the bank.

Results - Global Network Measures I. *GRAPH TYPE; Directed:Yes, Weight:None*

VARIABLES	All	Phase I	Phase II	Phase III
Betweenness of L(dir)	-6.283	-8.039	-4.244	-12.667
	(5.807)	(8.990)	(13.719)	(8.273)
Betweenness of B(dir)	-14.539***	-9.106	-32.713***	10.813
	(4.471)	(7.485)	(12.086)	(7.681)
R-squared	0.086	0.032	0.078	0.137
Closeness of L(dir)	-10.749***	3.927	0.641	-22.065***
	(1.822)	(2.412)	(4.161)	(4.327)
Closeness of B(dir)	-1.785***	-0.810	-4.714***	-5.418***
	(0.603)	(0.646)	(1.601)	(1.671)
R-squared	0.088	0.032	0.078	0.147
Eigenvector of L(in&dir)	3.055*	-4.130*	-5.163	8.552**
	(1.708)	(2.400)	(3.834)	(3.471)
Eigenvector of B(in&dir)	16.819***	11.605***	13.999***	40.419***
	(1.473)	(2.049)	(3.380)	(3.097)
R-squared	0.092	0.035	0.080	0.179
Pagerank of L(in&dir)	25.696**	-48.241**	10.403	35.923
	(12.530)	(19.865)	(25.656)	(23.821)
Pagerank of B(in&dir)	22.879***	46.054***	21.457	92.658***
	(5.109)	(11.971)	(20.918)	(8.318)
R-squared	0.086	0.034	0.077	0.161
Sinkrank of L(in&dir)	-3.627	-57.470**	4.627	28.973
	(16.878)	(23.722)	(27.922)	(45.603)
Sinkrank of B(in&dir)	61.062***	52.826***	-0.707	367.136***
	(12.517)	(14.601)	(23.821)	(27.808)
R-squared	0.087	0.034	0.077	0.170

Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Results - Global Network Measures II. *GRAPH TYPE; Directed:Yes, Weight:None*

VARIABLES	All	Phase I	Phase II	Phase III
Eigenvector of L(out&dir)	-10.546***	3.772	0.744	-24.033***
	(1.921)	(2.453)	(4.147)	(3.932)
Eigenvector of B(out&dir)	-10.333***	-4.909***	-26.211***	-12.904***
	(1.514)	(1.850)	(3.765)	(3.461)
R-squared	0.090	0.033	0.084	0.150
Pagerank of L(out&dir)	-67.698***	6.807	-9.538	-166.700***
	(11.340)	(13.209)	(19.086)	(22.853)
Pagerank of B(out&dir)	-40.057***	-39.330**	-50.523**	-12.931
	(11.711)	(17.328)	(23.324)	(29.510)
R-squared	0.087	0.032	0.078	0.147
Sinkrank of L(out&dir)	-149.110***	12.474	-13.805	-429.550***
	(25.163)	(22.990)	(45.098)	(58.284)
Sinkrank of B(out&dir)	-60.127**	-65.293**	-109.539**	-29.506
	(24.528)	(30.329)	(49.022)	(77.123)
R-squared	0.087	0.032	0.078	0.147

Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Results - Global Network Measures III. *GRAPH TYPE; Directed:Yes, Weight:Volume*

VARIABLES	All	Phase I	Phase II	Phase III
Betweenness of L(dir&w)	-1.543	-2.306	2.462	0.538
	(2.224)	(2.178)	(5.026)	(5.166)
Betweenness of B(dir&w)	-7.704***	-3.806**	-8.843***	3.770
	(1.742)	(1.687)	(3.267)	(4.361)
Eigenvector of L(in&dir&w)	-0.494	-2.247	1.666	30.679**
	(1.987)	(2.516)	(2.806)	(15.429)
Eigenvector of B(in&dir&w)	0.776	1.444*	6.386***	8.834***
	(0.705)	(0.845)	(1.673)	(1.617)
Pagerank of L(in&dir&w)	21.670***	-27.806**	11.715	30.408
	(7.719)	(12.038)	(10.150)	(24.264)
Pagerank of B(in&dir&w)	8.241**	15.685***	30.523***	93.541***
	(3.400)	(5.105)	(7.160)	(7.460)
Sinkrank of L(in&dir&w)	6.612	-36.515**	14.950	5.757
	(13.179)	(16.125)	(20.902)	(47.154)
Sinkrank of B(in&dir&w)	34.804***	22.836***	66.691***	274.181***
	(7.216)	(6.370)	(11.550)	(24.513)
Eigenvector of L(out&dir&w)	-2.455***	0.025	1.665	0.544
	(0.611)	(0.703)	(1.352)	(2.446)
Eigenvector of B(out&dir&w)	-0.297	2.685*	-1.064	-17.089***
	(1.331)	(1.592)	(3.803)	(4.740)
Pagerank of L(out&dir&w)	-45.644***	4.594	-12.289	-128.599***
	(6.900)	(7.066)	(11.665)	(16.730)
Pagerank of B(out&dir&w)	-39.235***	-12.891	-45.307**	-38.741**
	(8.574)	(11.949)	(20.177)	(17.470)
Sinkrank of L(out&dir&w)	-92.676***	11.914	-31.801	-379.794***
	(14.882)	(12.438)	(27.111)	(47.702)
Sinkrank of B(out&dir&w)	-61.343***	-20.660	-84.320**	-124.777**
	(17.824)	(20.572)	(42.077)	(54.383)

Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Results - Global Network Measures

Betweenness

- The most connected lenders cannot benefit from intermediation (broker) role.
- However, borrowers benefit from having better access to the market liquidity before Lehman Brother's collapse (phase II). In this way we can claim that the effect is not driven by market power, as otherwise both L and B would benefit from it, but by a too-connected-to-fail perception of the B.
- Results for the normalized trading volume weighted betweenness measures have similar results (weight is normalized using period total volume).

Closeness

- Closeness is significant and negative for borrower in phase II and III which is in line with the results for betweenness, but indicating that too-interconnected-to-fail perception also appeared after Lehman's collapse.
- There is strong negative effect for lender in phase III which suggest that lenders pay premium for being interconnected to the network when there is systemic risk is high

Results - Global Network Measures

Eigenvector, Pagerank, Sinkrank

Based on Incoming Link

- Although banks lend from lower rate during phase I, the effect changes sign after Lehman's collapse and they lend from higher rates in phase III when when they are connected to other highly-connected banks.
- Borrowers pay premium for being well-connected to the network in all phases of crisis.

Based on Outgoing Link

- Borrowers get more favorable rates if they are well-connected to the network. The effect is greater in phase II of crisis in terms of magnitude of coefficient.
- Lenders pay premium during last phase of crisis.

Conclusion

- The empirical results show that interbank spreads are significantly affected by the bank position in the network, measured by both local and global connectedness measures.
- Not only the bank's position in the network is important, but also the counterparty's interconnectedness
- In general, the highest effect in absolute value corresponds to either phase II or III, when banks became affected and/or aware of systemic risk.
- Interbank spreads are significantly affected by the banks positioning in the network
- Lenders are willing to pay a premium (i.e obtain lower rate) for better connections in the network. This effect is statistically significant for post-Lehman's Brothers collapse sub-period.
- Borrowers pay a higher premium for better local connections, but significantly benefit for better global positioning

THANKS..