Bank System and Econophysics: Recent Developments

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March 25, 2010

Overview

The talk discusses recent studies on banking and potential contributions using methods from Physics.

- Fertile ground after the recent crisis.
- Many Big questions in Finance and Banking
- Too big to fail x too interconnected to fail (literature from complex networks)
- What are the implications for regulation ?

Literature

Several paper have found evidence that the network of bank exposures contain relevant information regarding bank risks.
There is ample evidence of fat tails in the degree of banks connections.
Most of the literature has not studied the dynamics of these connections and the implications for regulation.

Bank lending networks

- Banking lending networks are one of the most important financial systems that are subjected to systemic risk. In fact, small shocks constrained only to a few banks can be spread by contagion and affect the entire system.
- In a banking system with a homogenous topology, the possibility of financial contagion depends strongly on the completeness of the structure of the system.
- Due to the development of the theory of complex networks, it has been possible to improve our knowledge banking networks.
- Knowing that banking networks have complex structure and dynamics models of heterogeneous banking networks have replaced the homogeneous ones.

Complex Network Tools and Systemic Risk

- Directed clustering coefficient may be used as a measure of systemic risk in complex networks.
- In particular, exploring data from the Brazilian bank interbank network, we show that the way that banks make clusters of lending relationships have different impact in terms of systemic risk.

Notation

Consider the following notation: Let A and W be respectively the directed adjacency matrix of the network and directed matrix of weights that represents the network. Let also d_i^{in}, d_i^{out} and $d_i^{\text{tot}} = d_i^{\text{in}} + d_i^{\text{out}}$, be respectively the in-degree of node i, the out-degree of node i the total degree of node i.
Furthermore, let $d^{\leftrightarrow} = \sum_{j \neq i} a_{ij} a_{ji} = A_{ii}^2$.

Bank lending networks

In binary directed networks, the clustering coefficient of node i for a binary network may be defined as the ratio between all the possible triangles formed by i and the number of all possible triangles that could be formed

$$C_i^D(A) = \frac{(A + A^T)_{ii}^3}{2[d_i^{tot}(d_i^{tot} - 1) - 2d_i^{\leftrightarrow}]}.$$

Bank lending networks

This clustering coefficient defined for the unweighed case can be easily extended to the weighted case by replacing the number of directed triangles formed with its weighted counterpart

$$\tilde{C}_i^D(W) = \frac{[\hat{W} + (\hat{W}^T)]^3_{ii}}{2[d_i^{tot}(d_i^{tot} - 1) - 2d_i^{\leftrightarrow}]}$$

where $\hat{W} = W^{[\frac{1}{3}]} = [w_{ij}^{\frac{1}{3}}]$.

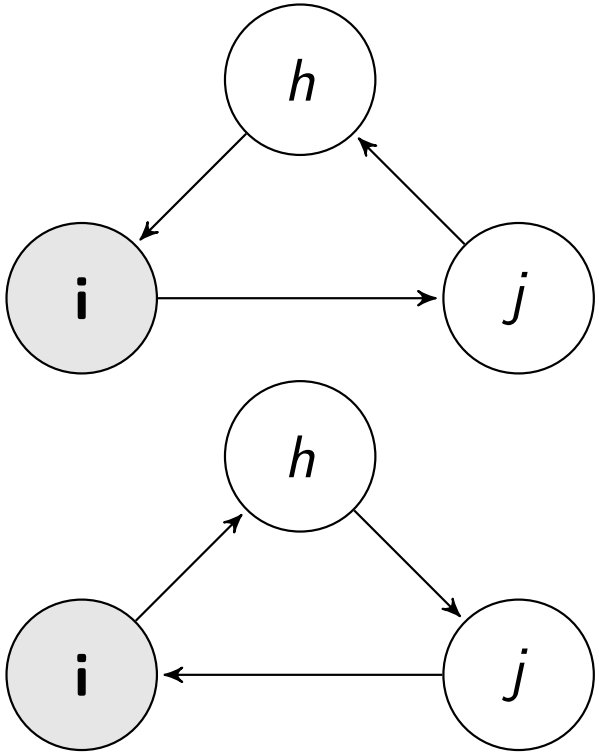
Definitions

- However, these two definitions are not enough to characterize the richness of patterns that take place in a complex directed network.
- In fact, these equations treat all the possible triangles as if they were the same.
- However, in directed graphs, edges that point in different directions should be interpreted differently.
- Therefore, four definitions are necessary

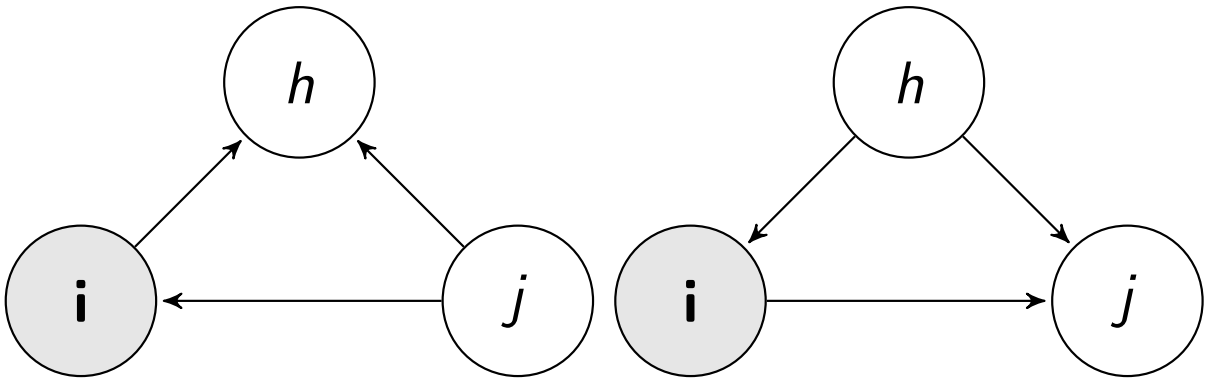
Definitions

- cycle, when there is a cyclical relation among i and its neighbors.
- Middleman, when one of the neighbor of node i holds two outward edges and the other holds two inward edges.
- In, when i holds two inward edges. It's a borrower.
- Out, when i holds two outward edges. It's a lender.

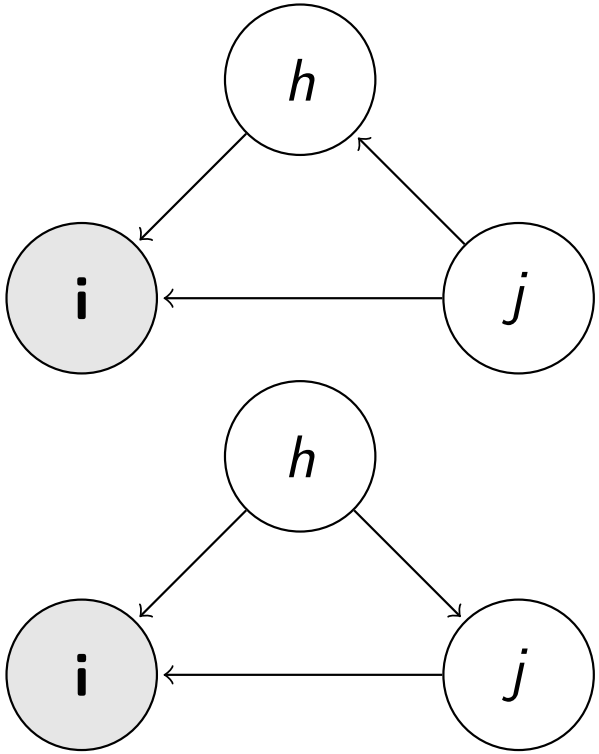
Cycle Clustering



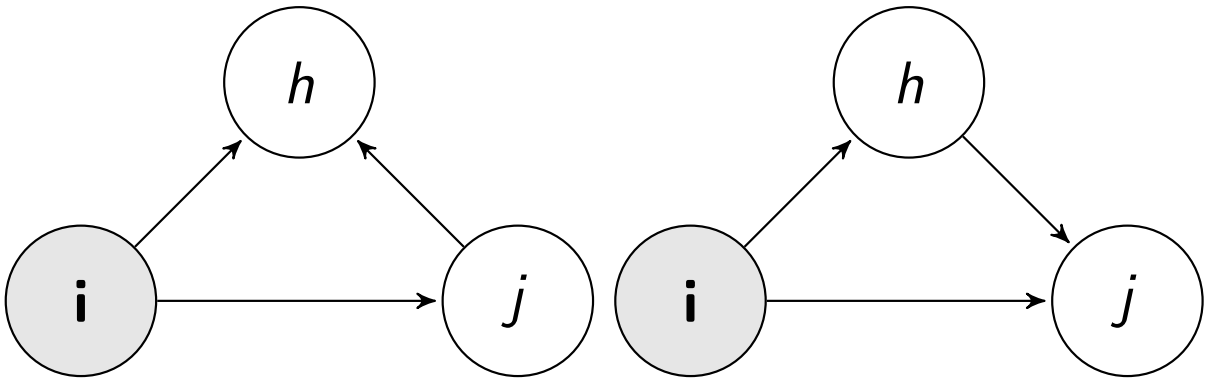
Middleman clustering



In Clustering



Out Clustering



Both unweighed and weighted clustering coefficients are interesting.
Although the former uses less information, it counts the number of triangles of a given type.
The latter uses more information, but it is strongly affected by the largest weights.
Since our network is directed weighted we consider here the weighted formulation.

In order to follow the discussion, we assume that an edge that arrives to node i coming from node j mean that bank i borrowed money from node and bank j lent money to bank i.
Note that in terms of systemic risk, these four patterns presented in the figures offer different interpretations.
In the first case bank i lends to bank j, which lends back to bank i.
Therefore, large values do not represent a higher risk for the banking system.

The $\tilde{C}_i^{mid}$ represents the case in which the counterparty of bank i, bank h, is either borrowing or lending from the other two banks.
In this case, large values imply a higher systemic risk.

The $\tilde{C}_i^{in}$ represents the case in which bank i is borrowing from both banks.
Therefore, it represents a situation in which bank i is increasing the risk of the banking system.
If bank i fails then it won't pay some or all the loans that it has made and subsequently the other two banks may not be able to meet their own obligations with each other, increasing the losses within the system.

Finally, $\tilde{C}_i^{out}$ is the case in which bank i is increasing it's own exposure at it is lending to two counterparties.
If one if these bank fails, as it may not pay the other bank the losses suffered from bank i may increase.
Therefore, if this clustering coefficient is high we can say that bank i has a large exposure and higher risk within the interbank network.
Overall, higher values for the coefficients $\tilde{C}_i^{mid}$ and $\tilde{C}_i^{in}$ imply higher systemic risk and higher values of $\tilde{C}_i^{out}$ imply higher exposure of bank i.

Bank exposures

- All banks operating within the Brazilian economy - public, domestic and foreign.
- All exposures within banks - Interbank, derivatives, fixed income.
- Daily exposures for a large time series - large high frequency panel data !

Results

- In this paper, we have interpreted the directed clustering coefficients as a measure of systemic risk.
- We have evaluated these clustering coefficients for the Brazilian interbank market data and we find that these measures vary strongly over time and across banks.
- Furthermore, we find that they are negatively correlated with interesting rate - which imply that banks reduce their risk exposure when interest rates increase.
- We find different behavior of banks due to ownership - different strategies !

Conclusions

- We can employ network measures to define systemically important banks and systemic risk (to some extent).
- Future research on modeling bank heterogeneity.
- Macro models - incorporate banking sector - difficult task - role for banks !
- Role of banks - importance within the recent crisis.

Future Developments

- Direct x Indirect contagion
- Simulation methods to assess systemic risk
- Interaction between market, credit and liquidity risks
- n-dimensional networks

End

Any suggestions or exchange of ideas - benjamin@ucb.br or benjaminm.tabak@gmail.com.
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Thanks for the attention!