Connectivity and Systemic Risk in Payment Systems

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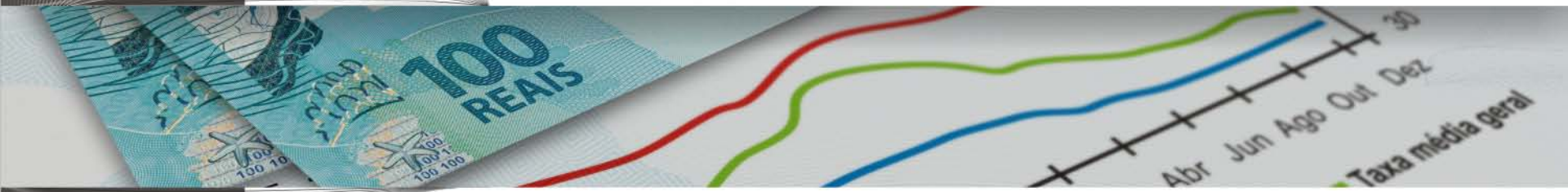

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Objectives

- Develop a framework for the identification of systemically important financial institutions from the National Payment System data
- The focus of the analysis is the network of the system's payments flows. The analysis will employ network theory concepts.

The Brazilian Payment System

- A system for the settlement of claims in the National Finance System
- Its core is the ***STR*** – *Sistema de Transferência de Reservas* – operated by the Banco Central do Brasil
  - Operates on reserve accounts held at the Banco Central do Brasil
- Also of interest is the *SITRAF – Sistema de Transferência de Fundos* – operated by the Câmara Interbancária de Pagamentos
  - Lost systemic relevance as of June 2011 but still important for interconnectedness

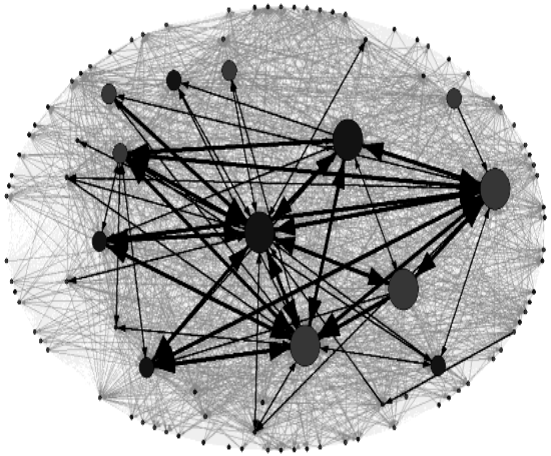
The Data

- Our sample is composed of ***Interbank Fund Transfers in the Brazilian Payment System***
  - From both STR and SITRAF
  - Between Financial Conglomerates and Institutions not belonging to a Conglomerate
    - Types I and 2: Commercial Banks, Universal Banks holding a commercial bank portfolio or a Savings and Loans Banks, and Investment Banks.
  - From 2006 to 2011

Connectivity in the Payment System

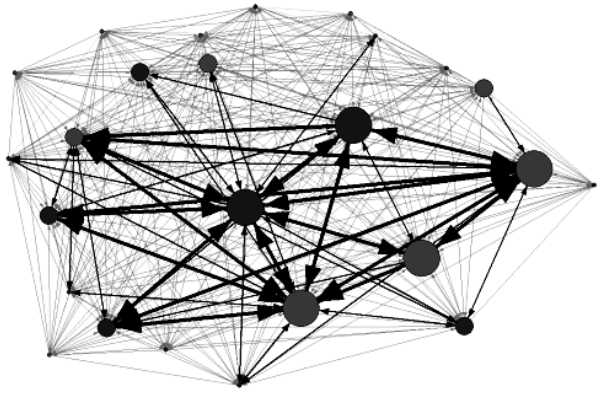
- **Centrality:** The number of institutions or conglomerates which were counterparty to a fund transfer *(edges in the graph)*
- **Dominance:** The relative importance of one institution's transfers on the other institutions
- **Criticality**: How one institution's transfers relate to others institutions' liquid assets

Centrality in the Interbank Funds Transfer Network



- The payments system network is scale free (connectivity follows a power law)

- The 25% more connected Financial Institutions and Conglomerates are responsible for 90% of all the flows



Probability distribution of Centrality – Power Laws

- A probability distribution follows a Power Law if::
  - $\Pr(N = x) = kx^{-\alpha}$
- A network whose centrality distribution follows a power law is a ***SCALE-FREE NETWORK***
- Evidence of scale-free networks in financial and payment systems:
  - Japan (Inaoka et al. (2004))
  - Austria (Boss et al. (2003))
  - USA (Fedwire) (Soramaki et al. (2007))

Centrality in the Interbank Funds Transfer Network – Power Laws

- In finance networks **α** typically range from 2 to 3
  - **α** ↑ implies that concentration ↑
- For our sample (IB fund transfers):

  α ≈ 3.45 (no significant change throughout the sample)

  - Estimated according to Clauset et al. (2009) – maximum-likelihood fitting

Payment system has money centers highly interconnected along with peripheral banks with few connections

Centrality results

- IB funds transfer network can be characterized as scale-free
  - In normal times, the topology has little impact, but during crises, it matters. (Georg (2011))
  - Scale-free networks are robust to random shocks, but vulnerable to simultaneous shocks to important nodes (Crucitti et al. (2004))
- *Analysis suggests that the institutions that form the IB network core (their centrality are in the upper tail of the power law distribution) are systemically important*

Dominance – First Steps

- Centrality is not enough to determine systemic importance. We need to examine the strength of each connection (volume transferred)

  Institutions that transferred more between them are closer together.

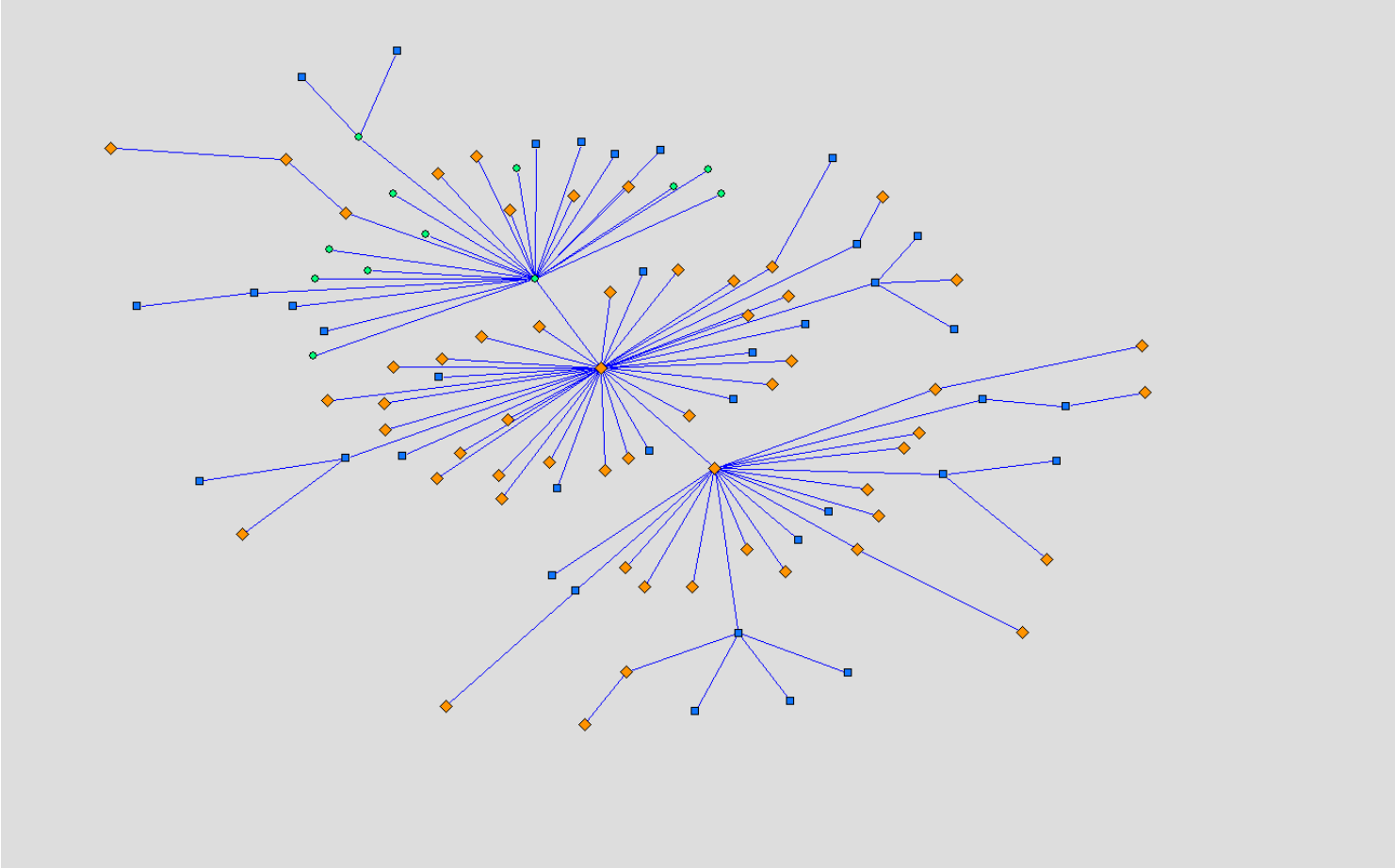
- Given institutions *i* and *j* such that there is an edge *(i,j)* in the network (that is, a transfer from *i* to *j*):
  - *w(i,j) = total amount transferred from i to j*
- From *w(i,j)* we define the distance $d^w(i,j)$ from institutions *i* and *j* (Cajueiro and Tabak(2007)):
  - *max_d = max(w(i,j) + w(i,j))* for all edges *(i,j)*
  - $d^w(i,j) = 2 - (W_{ij} + W_{ji}) / max\_d$

Minimum Spanning Trees – MST
A Comparison of Bank Types

- We will examine the MSTs generated for the IB fund transfer network in three periods:
  - Before the Global Financial Crisis – June, 2006
  - In September, 2008 (Lehman's Bankruptcy)
  - After the Global Financial Crisis – December, 2011
- From a measure of distance between two connected vertices in a network, the MST is the set of edges linking any two nodes with the shortest total distance (with no cycles)

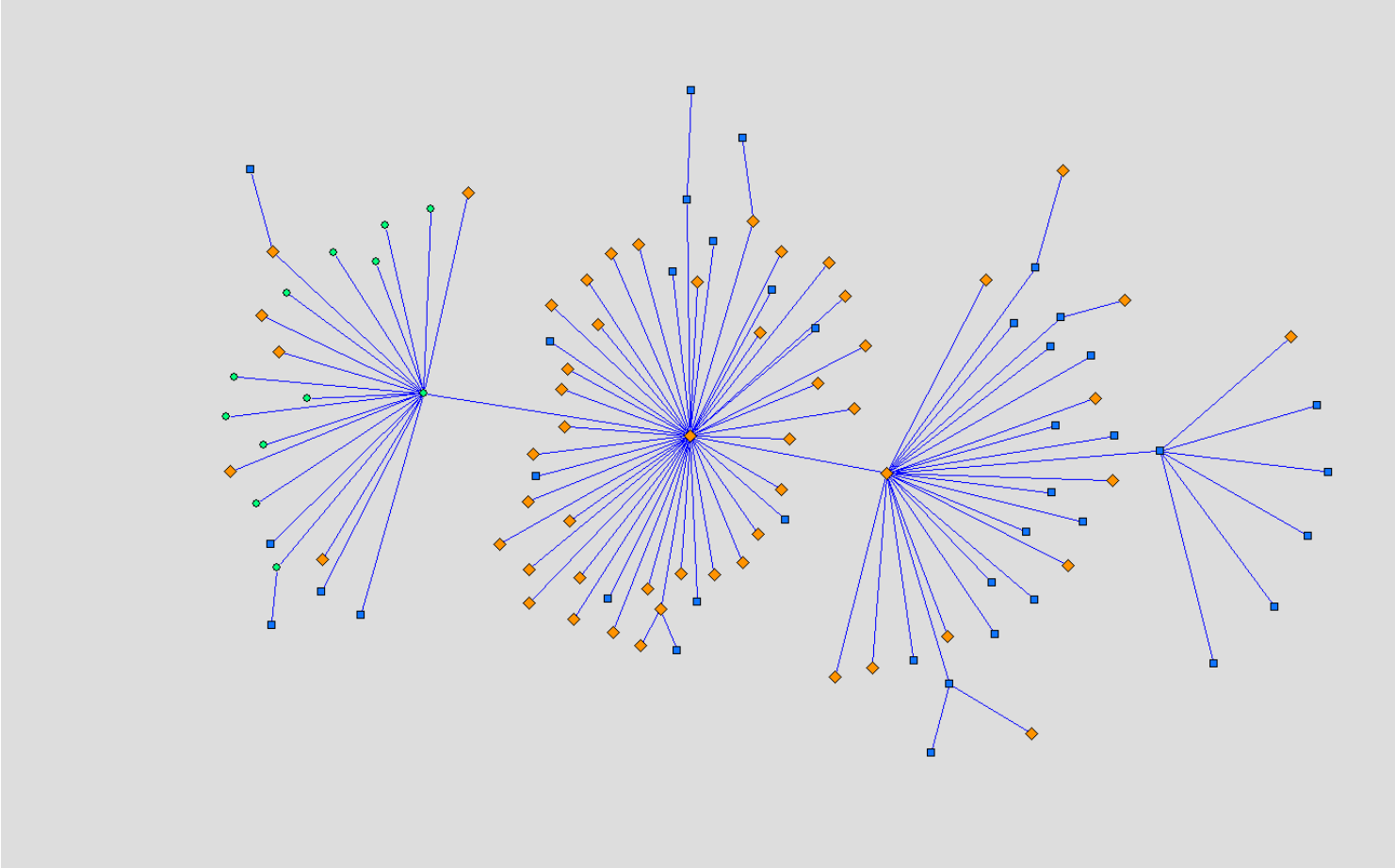
  In the MST each vertex will be connected to those that are closest

Minimum Spanning Trees – Jun, 2006



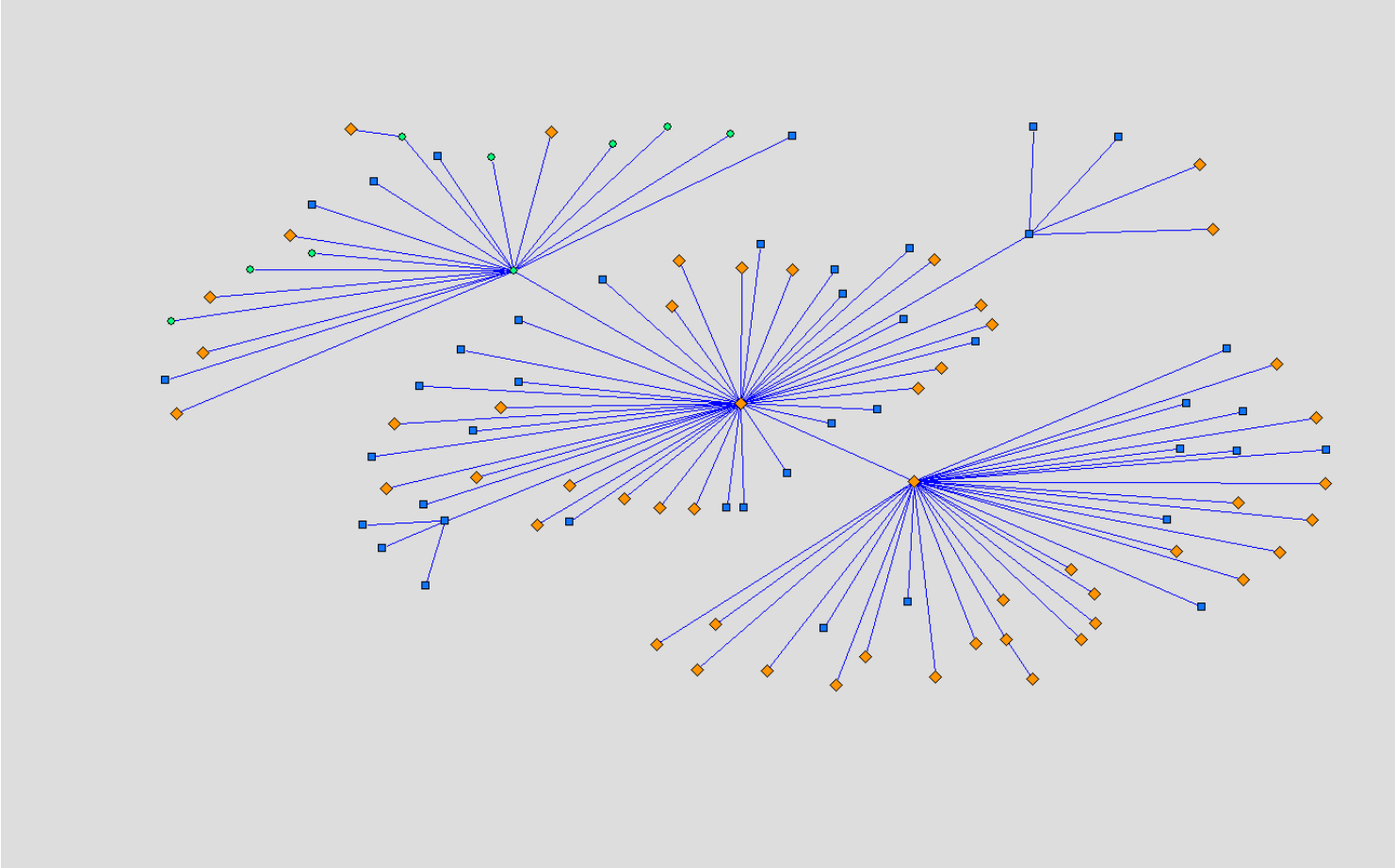
IB payments in June,2006. Types of control: State-owned (circle, green), Private Domestic (diamond, yellow), Foreign (square, blue)

Minimum Spanning Trees – Sep, 2008



IB payments in Sep,2008. Types of control: State-owned (circle, green), Private Domestic (diamond, yellow), Foreign (square, blue)

Minimum Spanning Trees – Dec, 2011



IB payments in Dec,2011. Types of control: State-owned (circle, green), Private Domestic (diamond, yellow), Foreign (square, blue)

What do these MSTs tell us?

- In our sample, the IB payment system shows 3 banks outstanding as money centers (2 private domestic, 1 state-owned)
- The state-owned banks relate more closely among themselves
- Foreign banks are mostly peripheral in the Brazilian IB fund transfer network
- The system appears to have become more concentrated after Sep, 2008

Dominance in Complex Networks

- It is a measure of the centrality of a node that takes into account direction and weight of payments. Introduced by Van Den Brink (2000)

  It represents the impact the suppression of a node causes in the relative revenues of its neighbors

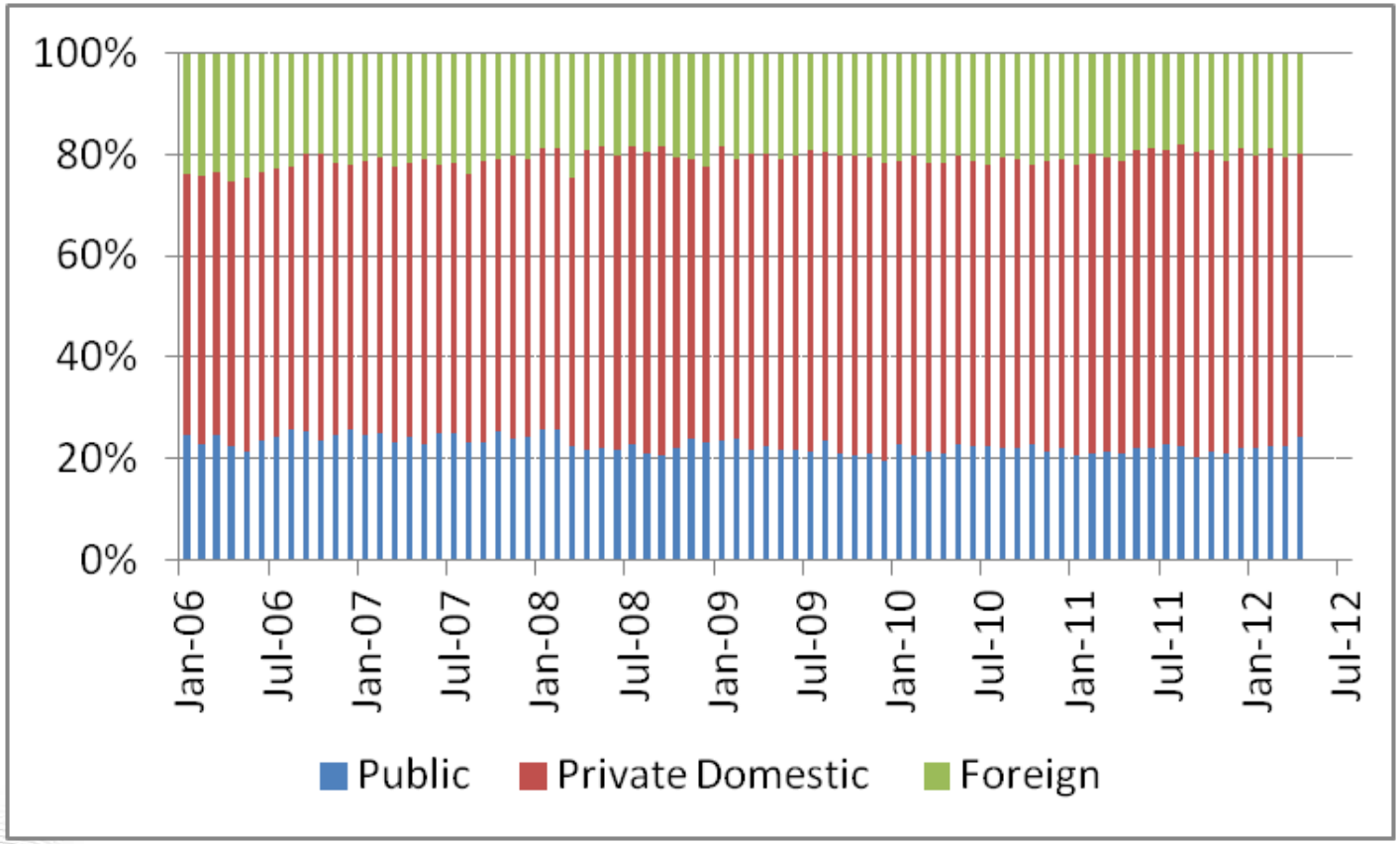
- Given institutions *i* and *j* and *w(i,j)* defined as before:

  $\beta(i) = \Sigma_j [W(i, j) / \lambda(j)]$

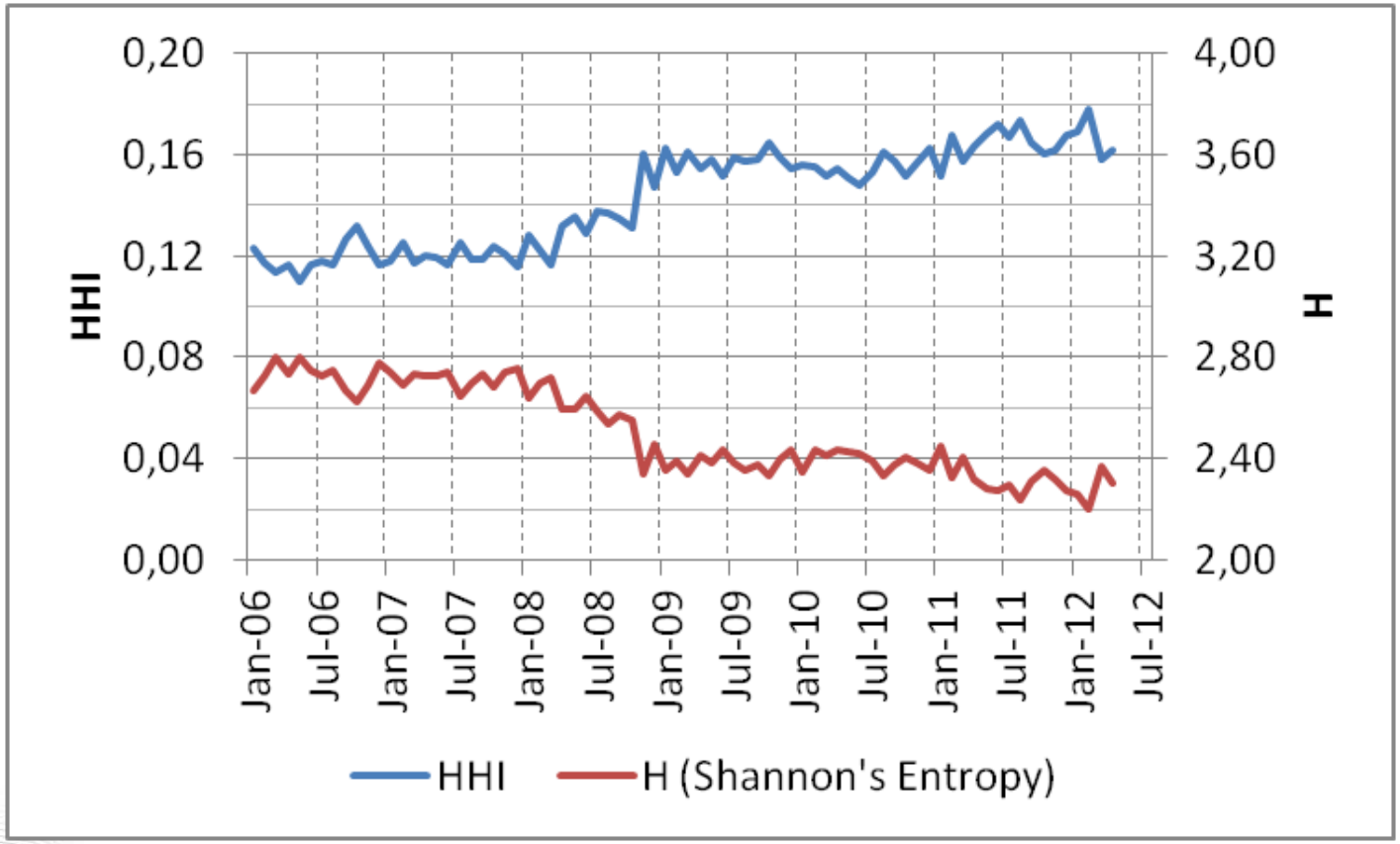
  where $\lambda(j) = \Sigma_i W(i, j)$

  β(i) is the dominance of i over the network

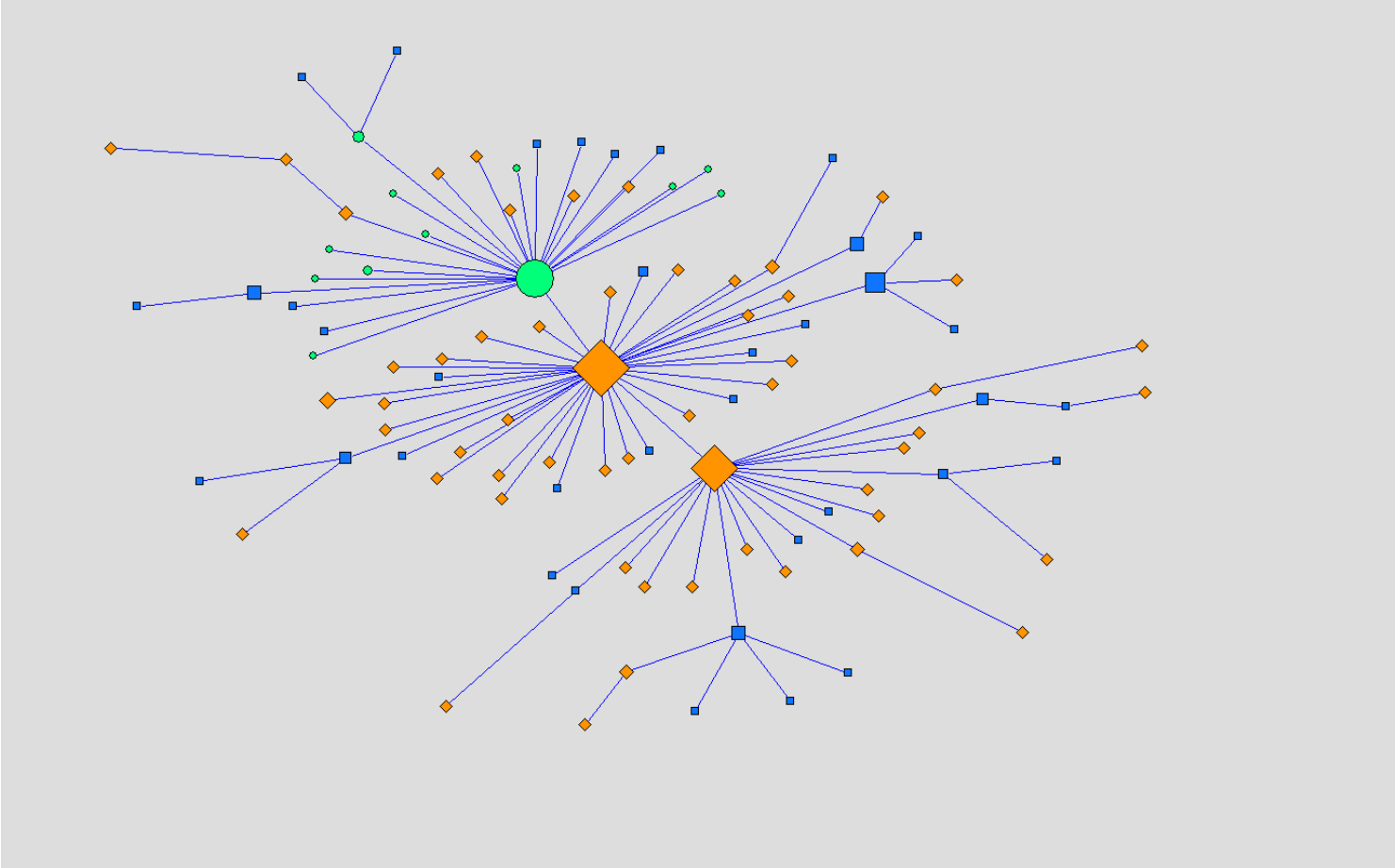
Dominance in Complex Networks
Banks by Type of Control



Dominance in Complex Networks
Concentration of Dominance

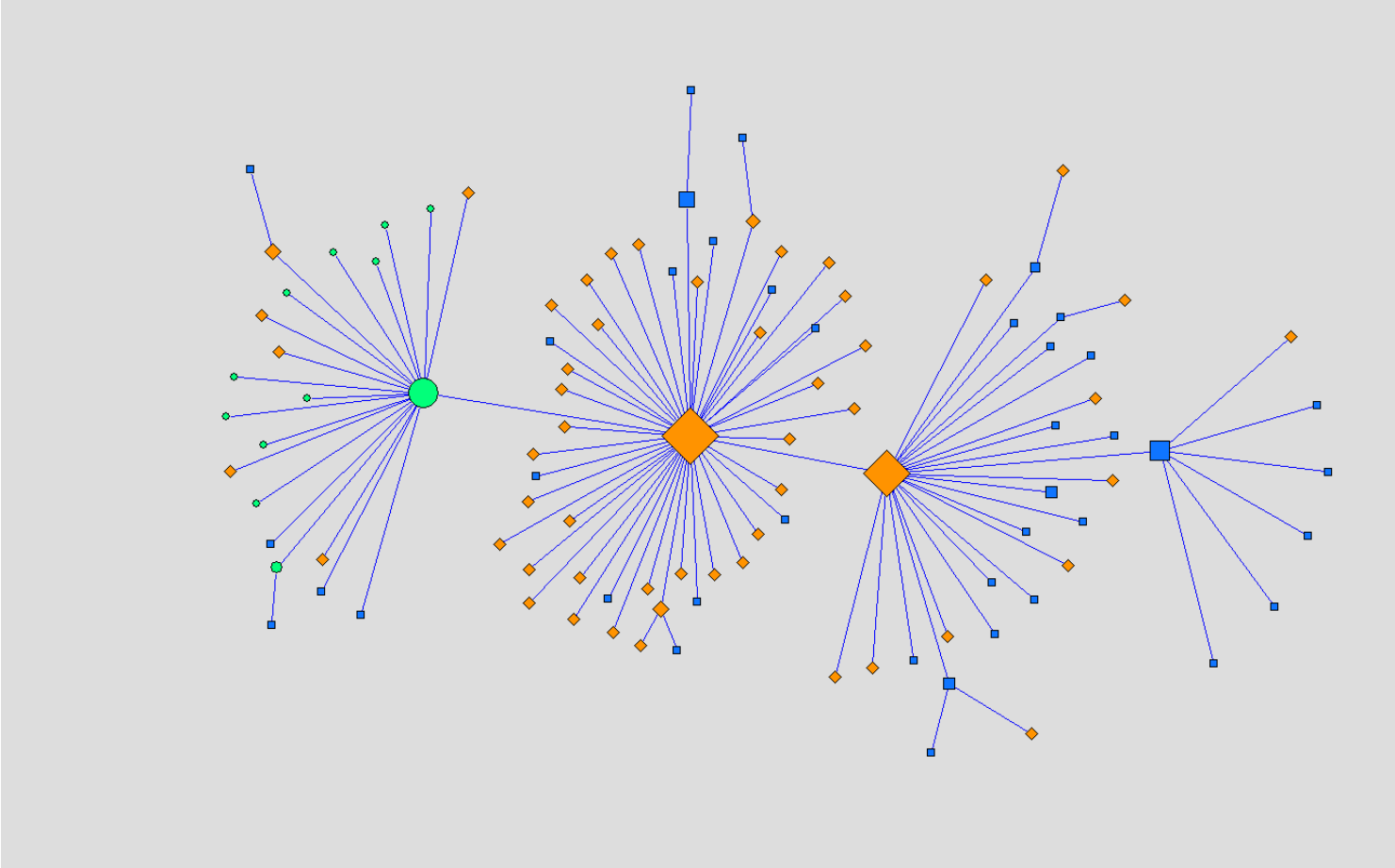


Minimum Spanning Trees – Jun, 2006



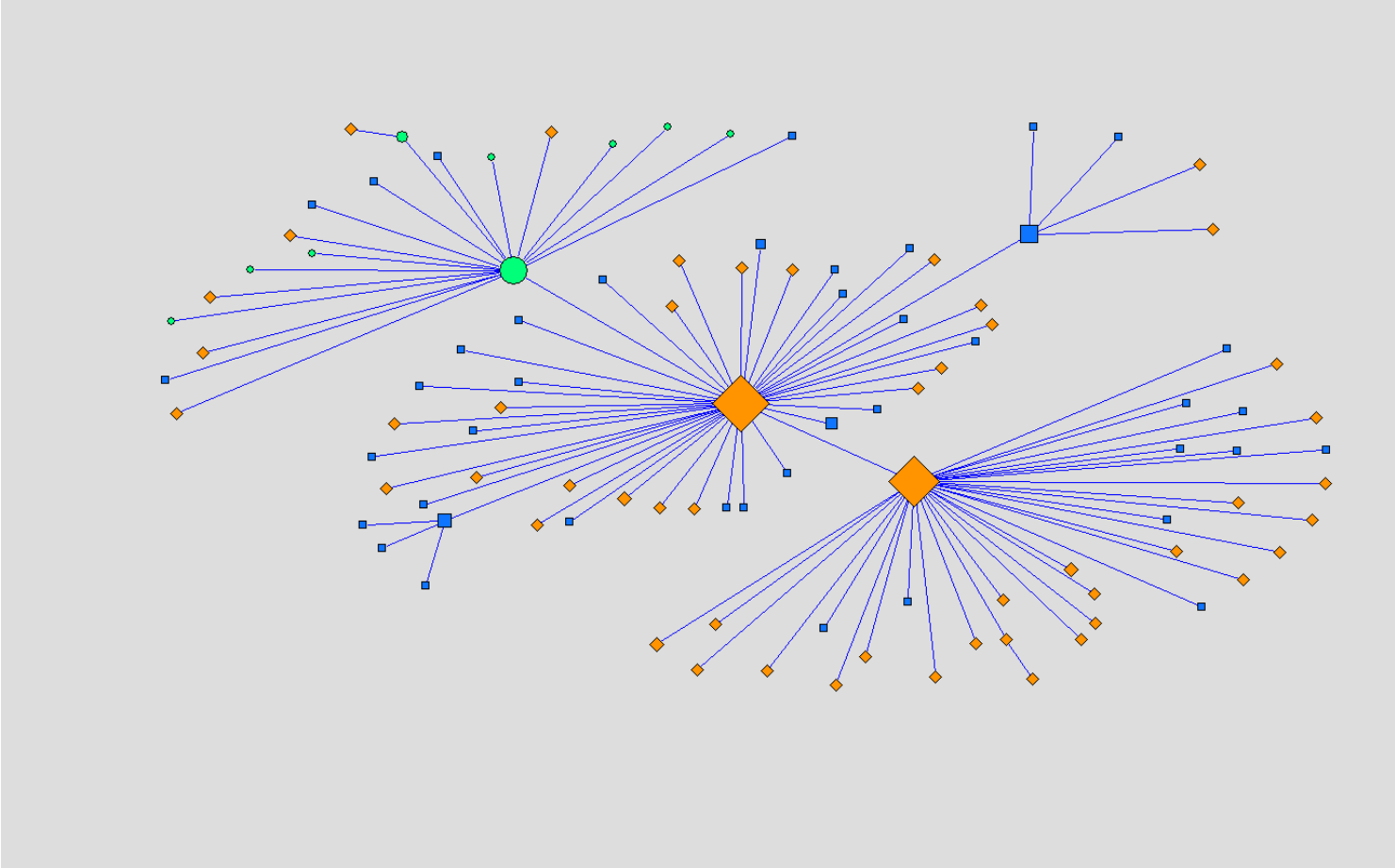
IB payments in Jun, 2006. Types of control: State-owned (circle, green), Private Domestic (diamond, yellow), Foreign (square, blue) – Size of node is given by its Dominance

Minimum Spanning Trees – Sep, 2008



IB payments in Sep, 2008. Types of control: State-owned (circle, green), Private Domestic (diamond, yellow), Foreign (square, blue) – Size of node is given by its Dominance

Minimum Spanning Trees – Dec, 2011



IB payments in Dec, 2011. Types of control: State-owned (circle, green), Private Domestic (diamond, yellow), Foreign (square, blue) – Size of node is given by its Dominance

Dominance results

The dominance results also indicate 3 banks outstanding as money centers (2 private domestic, 1 state-owned)

- Concentration of dominance has increased to moderately concentrated (HHI > 0.15 after Dec, 2008)
- Private domestic banks are responsible for 60% of the system's dominance. State-owned banks are responsible for 20% and foreign banks are also responsible for 20%

Exercise - Criticality of FIs

- **Dominance is a measure of importance, but it does not tell us how that could impact the system in a time of crisis**
  - ***In times of Crisis, Liquidity is Important***

Criticality is how one institution's transfers relate to others institutions' liquid assets

- We calculate the criticality for each institution as the sum of the ratio of its transfers to other institutions over the recipient's liquid assets.
- Given the Liquid Assets *A(j)* of institution *j*, and *w(i,j)* defined as before:

$$c(i,j) = w(i, j) / A(j)$$

$$C(i) = \Sigma_j \, c(i,j)$$

Exercise - Criticality of FIs - MST

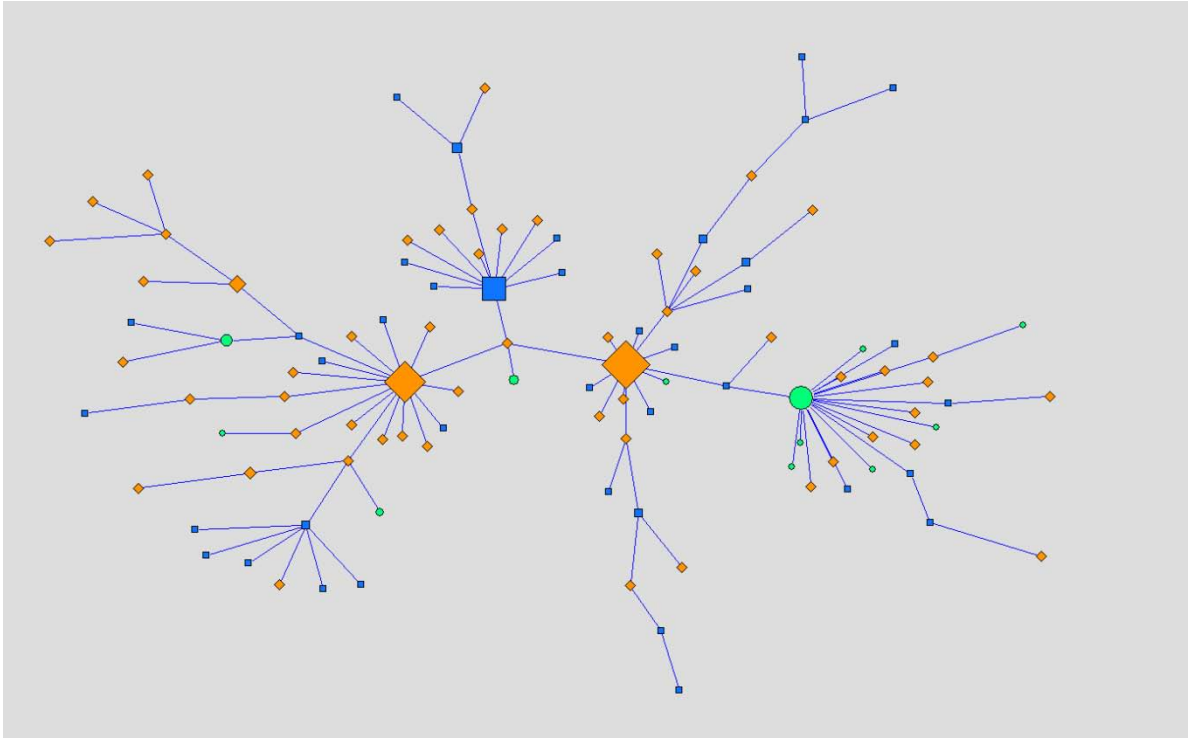
- Given *c(i,j)*, that is the impact of *i*'s transfers in the liquid assets of *j*, we define a criticality distance $d^c(i,j)$

  $d^c(i,j) = 2 - (c(i,j) + c(j,i)) / max(c(i,j) + c(j,i))$

- From this distance measure we will generate MSTs
- Each MST presents a ***WORST CASE DIFFUSION*** path for liquidity impacts related to IB funds transfers:

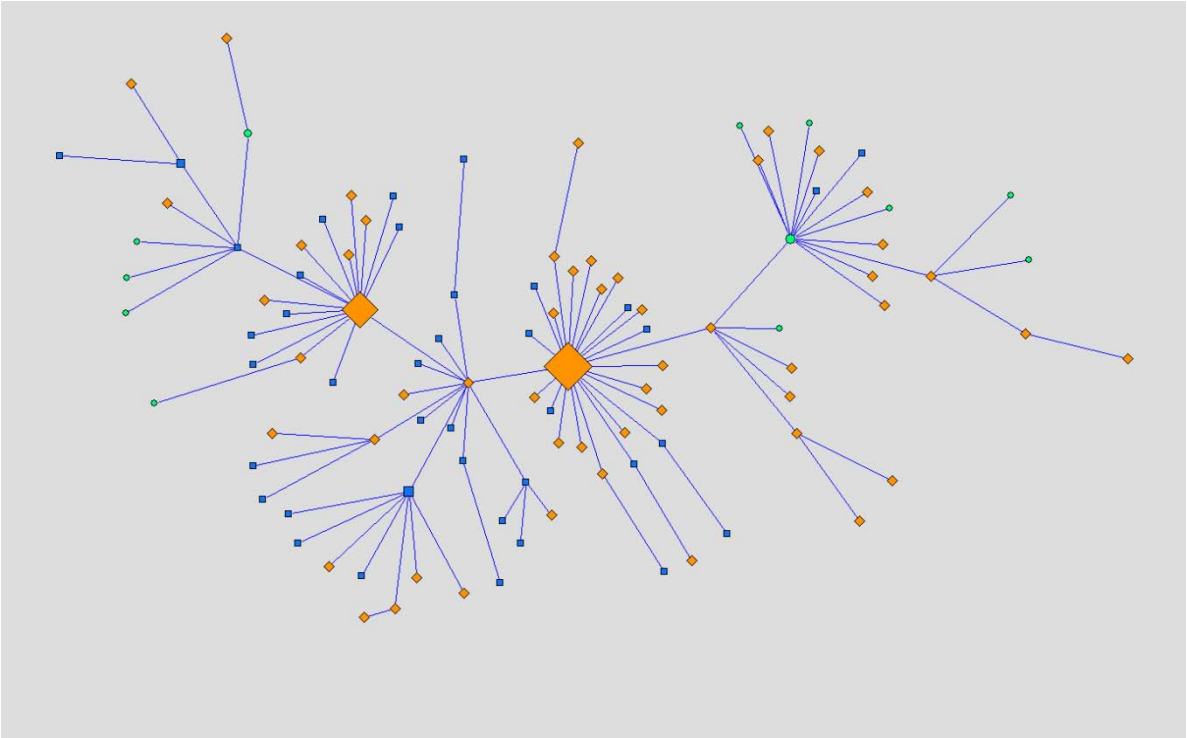
  That is, if the transfers from institution i are suppressed from the network, its neighbors in the MST are the institutions most likely to be impacted immediately

Exercise - Criticality of FIs
Worst Case Diffusion Path – Jan, 2007



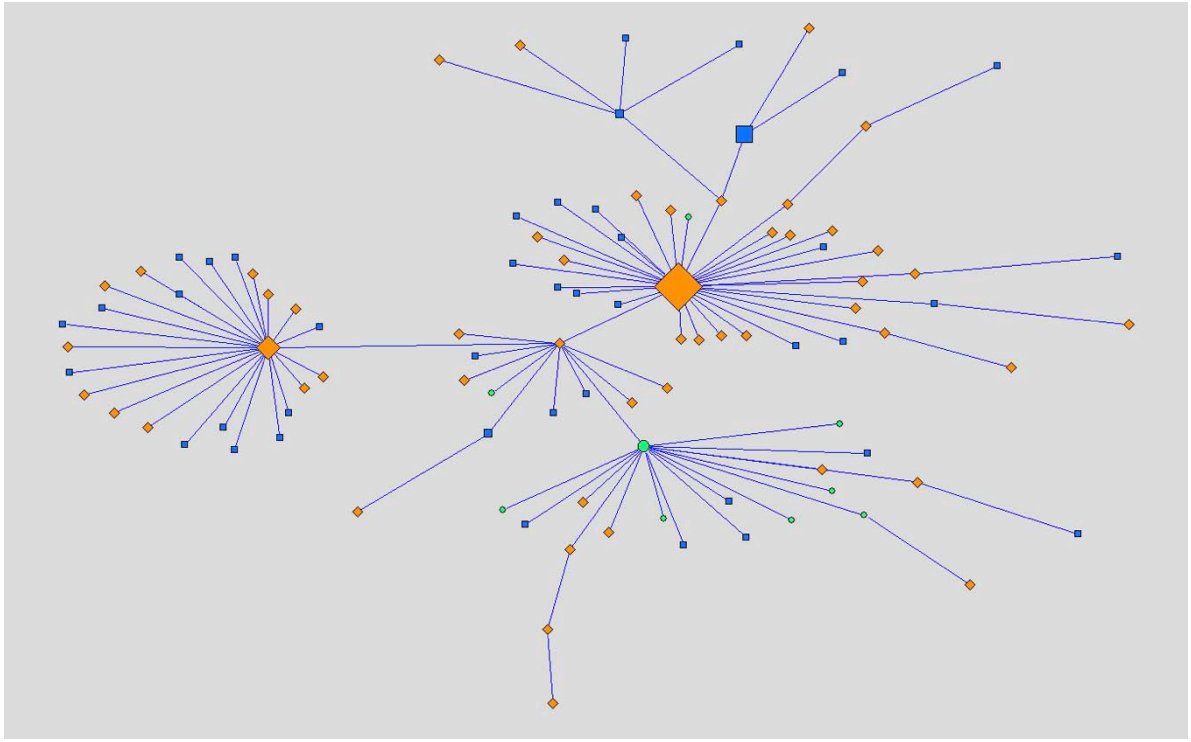
IB transfers in the last day of Jan,2007. Types of control: State-owned (circle, green), Private Domestic (diamond, yellow), Foreign (square, blue). Size of node is given by its Criticality

Exercise - Criticality of FIs
Worst Case Diffusion Path – Sep, 2008



IB transfers in the last day of Sep,2008. Types of control: State-owned(circle, green), Private Domestic (diamond, yellow), Foreign (square, blue). Size of node is given by its Criticality

Exercise - Criticality of FIs
Worst Case Diffusion Path – Dec, 2012



IB transfers in the last day of Dec,2011. Types of control: State-owned (circle, green), Private Domestic (diamond, yellow), Foreign (square, blue). Size of node is given by its Criticality

Exercise - Criticality of FIs Discussion

- The worst case diffusion path may change over time, but the systemic banks involved are, in general, the most dominants.
- The banks with high criticality act as focal points which concentrate the diffusion in the network

The Criticality measure can help regulators to identify institutions which need to be observed more closely when another institution in the network has liquidity problems

OUR CONTRIBUTION

A novel framework for the identification of systemically important of institutions from Payment System data

- This systemic importance of financial institutions can be analyzed from different dimensions
- It can be used as a complementary tool in the financial system regulator's toolbox
- It can be applied to real-time or near real-time data
- It can be augmented by simulations
- Although we used funds transfer data, the framework could also be used with other types of data, such as bank exposure

Conclusions

- The study of the structure of the connectivity of the payments systems indicates that there is a subset of financial institutions that are critical to the FNS (key players).
- We present a methodology that is helpful in assessing systemically important institutions within bank networks.
- It can also be a timely tool as payment system data is usually available in real-time or near real time.

THANK YOU

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