Identifying Systemically Important Banks in Payment Systems

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Interbank Payment Systems

• Provide the backbone of all economic transactions

• Banks settle claims arising from customers transfers, own securities/FX trades and liquidity management

• Target 2 settled 839 trillion in 2010
Systemic Risk in Payment Systems

• Credit risk has been virtually eliminated by system design (real-time gross settlement)

• Liquidity risk remains
  – “Congestion”
  – “Liquidity Dislocation”

• Trigger may be
  – Operational/IT event
  – Liquidity event
  – Solvency event

• Time scale is intraday, spillovers possible
Agenda

• Centrality in Networks
• SinkRank
• Experiment and Results
• Implementation
Centrality in Networks
Common centrality metrics

Centrality metrics aim to summarize some notion of importance

**Degree**: number of links

**Closeness**: distance from/to other nodes via shortest paths

**Betweenness**: number of shortest paths going through the node

**Eigenvector**: nodes that are linked by other important nodes are more central, probability of a random process
Eigenvector Centrality

- Problem: EVC can be (meaningfully) calculated only for “Giant Strongly Connected Component” (GSCC)

- Solution: PageRank
PageRank

• Solves the problem with a “Damping factor” $\alpha$ which is used to modify the adjacency matrix ($S$)
  
  $G_{i,j} = \alpha S_{i,j} + (1 - \alpha)/N$

• Effectively allowing the random process out of dead-ends (dangling nodes), but at the cost of introducing error

• Effect of $\alpha$
  
  $\alpha = 0 \rightarrow$ Centrality of each node is $1/N$
  
  $\alpha = 1 \rightarrow$ Eigenvector Centrality
  
  Commonly $\alpha = 0.85$ is used

\[ \alpha = 0.85 \]

\[ \alpha = 1 \ (0.375, 0.375, 0.25) \]
Which Measure for Payment Systems?
Centrality depends on process

- Trajectory
  - Geodesics paths (shortest paths)
  - Any path (visit no node twice)
  - Trails (visit no link twice)
  - Walks (free movement)

- Transmission
  - Parallel duplication
  - Serial duplication
  - Transfer

Table 1
Typology of flow processes

<table>
<thead>
<tr>
<th></th>
<th>Parallel duplication</th>
<th>Serial duplication</th>
<th>Transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geodesics</td>
<td>&lt;No process&gt;</td>
<td>Mitotic reproduction</td>
<td>Package delivery</td>
</tr>
<tr>
<td>Paths</td>
<td>Internet name-server</td>
<td>Viral infection</td>
<td>Mooch</td>
</tr>
<tr>
<td>Trails</td>
<td>E-mail broadcast</td>
<td>Gossip</td>
<td>Used goods</td>
</tr>
<tr>
<td>Walks</td>
<td>Attitude influencing</td>
<td>Emotional support</td>
<td>Money exchange</td>
</tr>
</tbody>
</table>

Distance to Sink

- Markov chains are well-suited to model transfers along walks.
- Absorbing Markov Chains give distances:

  - From B
    - To A: 1
    - To B: \( \frac{2}{3} \cdot 2 + \frac{1}{3} \cdot 1 = \frac{5}{3} \)
    - To C
  - From C
    - To A: 2
    - To B: 1
    - To C: \( \sum_{i=1}^{\infty} (2i - i) \left( \frac{2}{3} \right) \left( \frac{1}{3} \right)^{i-1} = 2 \)
    - From B: \( \sum_{i=1}^{\infty} (2i) \left( \frac{2}{3} \right) \left( \frac{1}{3} \right)^{i-1} = 3 \)
SinkRank

- SinkRank is the average distance to a node via (weighted) walks from other nodes

- We need an assumption on the distribution of liquidity in the network at time of failure
  - Assume uniform -> unweighted average
  - Estimate distribution -> PageRank-weighted average
  - Use real distribution -> Real distribution are used as weights

SinkRanks on unweighed networks
SinkRank – effect of weights

Uniform (A,B,C: 33.3%)

PageRank (A: 37.5% B: 37.5% C:25%)

“Real” (A: 5% B: 90% C:5%)

Note: Node sizes scale with 1/SinkRank
How good is it?
Experiments

• Design issues
  – Real vs artificial networks?
  – Real vs simulated failures?
  – How to measure disruption?

• Approach taken
  1. Create artificial data with close resemblance to the US Fedwire system (BA-type, Soramäki et al 2007)
  2. Simulate failure of a bank: the bank can only receive but not send any payments for the whole day
  3. Measure “Liquidity Dislocation” and “Congestion” by non-failing banks
  4. Correlate 3. (the “Disruption”) with SinkRank of the failing bank
Data generation process

Based on extending Barabasi–Albert model of growth and preferential attachment

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<thead>
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<th>Fedwire</th>
<th>Model</th>
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<tr>
<td>nodes</td>
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<td>connectivity</td>
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<td>degree ($k$)</td>
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<td>max ($k$-in)</td>
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<td>2210</td>
</tr>
<tr>
<td>max ($k$-out)</td>
<td>1922</td>
<td>2215</td>
</tr>
<tr>
<td>payments ($\cdot 1000$)</td>
<td>411</td>
<td>411</td>
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</table>
Distance from Sink vs Disruption

Relationship between Failure Distance and Disruption when the most central bank fails. Highest disruption to banks whose liquidity is absorbed first (low Distance to Sink).
SinkRank vs Disruption

Relationship between SinkRank and Disruption

Highest disruption by banks who absorb liquidity quickly from the system (low SinkRank)
Implementing SinkRank
Implementation example
More information at

www.fna.fi

www.fna.fi/blog

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http://www.economics-ejournal.org/economics/discussionpapers/2012-43