An Empirical Study of the Mexican Banking System’s Network and its Implications for Systemic Risk
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Outline

Motivation
  Relevant concepts and literature

Data
  Interbank exposures’ data
  Payment system’s data

Network theory
  Topological and other measures
  Centrality measures

Results

Extended Network of exposures
Interconnectedness

- The GHOS, the oversight body of the BCBS, agreed on a consultative document setting out measures for G-SIBs.

- Measures include:
  - methodology for assessing systemic importance
  - additional required capital
  - arrangements by which they will be phased in

- Objectives:
  - strengthen the resilience of G-SIBs
  - create incentives to reduce systemic importance
Interconnectedness

- Assessment methodology based on an indicator-based approach:
  - size
  - interconnectedness
  - lack of substitutability
  - global (cross-jurisdictional) activity
  - complexity

- Additional loss absorbency requirements are to be met with a progressive CET1 ranging from 1% to 2.5%.

- An additional 1% surcharge would be applied.
Network models and payment systems.

- Studies describing payment systems around the world:
  - Soramki et al. (2006)
  - Bech & Atalay (2008)
  - Becher et al. (2008)
  - Propper et al. (2008)
  - Wetherilt et al. (2010)
Network models and financial contagion.

- Direct contagion through the interbank market widely studied by central banks in several countries, Upper (2007).
  - maximum entropy assumption
  - individual idiosyncratic failures
- Contagion has been studied by simulating networks in Nier et al. (2007) and Gai & Kapadia (2010). They use randomly generated networks.
  - random models use scale free properties which interbank exposures networks exhibit
Network models and systemic risk.

- More recently contagion and systemic risk have been studied:
  - Muller (2006)
  - Babus (2007)
  - Mistrulli (2007)

- Others include contagion within a wider simulation framework:
  - Boss et al. (2006)
  - Aikman et al. (2009)
  - Alessandri et al. (2009)
  - Marquez-Diez-Canedo et al. (2009)
  - Martinez-Jaramillo et al. (2010b & 2010b)
  - Gauthier et al. (2010a & 2010b)
Other Related Works.

- Empirical analysis of the Italian interbank market, Iori et al. (2008)
- Simulation to model interbank lending and study contagion, Iori et al. (2006)
- Coupled stochastic processes, Battiston et al. (2012)
- Cascade processes on networks, Lorenz et al. (2009)
Interbank’s data

- daily data from January 2004 onwards
- a time window contemplating data from the 3rd of January 2005 to 31st December 2010
- comprises deposits and loans, securities, and foreign exchange

Three type of networks:

- Interbank
- Interbank - CLS
- Interbank - FX
SPEI’s data

- daily data from January 2004 onwards
- a time window contemplating data from the 3rd of January 2005 to 31st December 2010

Three types of networks:

- Low value
- Large value
- Total value

Network built accumulating the daily payments between each pair of banks in both directions.
Topological measures

- Topological measures
  - Degree
  - Clustering coefficient
  - Reciprocity
  - Affinity
  - Completeness Index

- Other measures
  - Strength
  - Flow
  - Herfindahl-Hirschman Index (HHI)
  - Preference Index
Centrality measures

- Concept commonly used in social networks
- Several important interpretations
  - power
  - influence
  - independence
  - control
- Characteristics of a relevant financial institution (Henggeler-Muller (2006)):
  - possesses many linkages to other members (degree)
  - Amount of assets, liabilities or flow is very large (strength)
  - its failure could transmit contagion rapidly (closeness)
  - its counterparties are also relevant (eec & pagerank)
  - there are many paths which passes through it (betweenness)
Centrality measures

- **Strength centrality**
  - The sum of its interbank assets and liabilities.

- **Degree centrality**
  - A vertex is more important if it is connected to many other vertices.

- **Betweenness centrality**
  - A vertex with high betweenness centrality can stop or distort the information that passes through it.

- **Closeness centrality**
  - A node with high centrality would depend less on others.
Centrality measures

- Entropic Eigenvector Centrality (Bonacich (1972))
  - Based on Perron’s eigenvector ($e^{PF}$)
  - Considers the relevance of its neighbors.

- PageRank centrality (Page et al. (1999))
  - Based on the Google’s algorithm
  - Considers the centrality of its neighbors.

- A principal components unified measure of centrality
  - different measures equally important
  - preserve most informatino provided by such measures
  - from the policy making perspective, it is important to have only one measure of importance enabling to rank vertices
## Scale-free Networks

<table>
<thead>
<tr>
<th>p-value</th>
<th>Interbank</th>
<th>Interbank - CLS</th>
<th>Interbank - FX</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; .05</td>
<td>&lt; .1</td>
<td>&lt; .05</td>
</tr>
<tr>
<td>Degree</td>
<td>77%</td>
<td>60%</td>
<td>81%</td>
</tr>
<tr>
<td>In Degree</td>
<td>81%</td>
<td>66%</td>
<td>83%</td>
</tr>
<tr>
<td>Out Degree</td>
<td>80%</td>
<td>60%</td>
<td>80%</td>
</tr>
<tr>
<td>Exposures</td>
<td>57%</td>
<td>50%</td>
<td>63%</td>
</tr>
</tbody>
</table>

Table: Percentage of days in which the exposures network exhibited power law distributions.
SPEI Network

Figure: January the 3rd 2005

Figure: July the 27th 2010

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Interbank exposures network

Figure: January the 3rd 2005

Figure: December the 31st 2010
An Empirical Study of the Mexican Banking System’s Network and its Implications for Systemic Risk
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Interbank

Bank 13’s flow

LPI bank 7

An Empirical Study of the Mexican Banking System’s Network and its Implications for Systemic Risk
An Empirical Study of the Mexican Banking System’s Network and its Implications for Systemic Risk

**Figure:** Lending HHI bank B

<table>
<thead>
<tr>
<th></th>
<th>Interbank</th>
<th>Interbank - CLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Size</td>
<td>26.7</td>
<td>26.7</td>
</tr>
<tr>
<td>Completeness Index</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Average Degree</td>
<td>9.0</td>
<td>8.7</td>
</tr>
<tr>
<td>Reciprocity</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Average Distance</td>
<td>1.7</td>
<td>1.8</td>
</tr>
<tr>
<td>Total Arcs</td>
<td>279.7</td>
<td>262.2</td>
</tr>
<tr>
<td>Average Strength*</td>
<td>7.1</td>
<td>6.4</td>
</tr>
<tr>
<td>Total Volume*</td>
<td>125.5</td>
<td>110.8</td>
</tr>
</tbody>
</table>
Interbank’s centrality

Figure: Principal components centrality
Pairwise correlations

- Degree vs. Strength
- Degree vs. Closeness
- Degree vs. Betweenness
- Degree vs. PageRank
- Degree vs. EEC
- Strength vs. Closeness
- Strength vs. Betweenness
- Strength vs. PageRank
- Strength vs. EEC
- Closeness vs. Betweenness
- Closeness vs. PageRank
- Closeness vs. EEC
- Betweenness vs. PageRank
- Betweenness vs. EEC
- PageRank vs. EEC
SPEI’s centrality

Figure: Low vs large centrality bank C

Figure: Low vs large centrality bank D

An Empirical Study of the Mexican Banking System’s Network and its Implications for Systemic Risk
Interbank’s centrality

Figure: Changes in ranking for banks A & B

Figure: Changes in behavior bank C
PC centrality ranking vs. Asset size ranking
## Congruence: Low value vs. Large value network

<table>
<thead>
<tr>
<th>Number of banks</th>
<th>Top 1</th>
<th>Top 3</th>
<th>Top 10</th>
<th>Average Overlapping</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>0.53</td>
<td>0.97</td>
<td>0.97</td>
<td>0.70</td>
</tr>
<tr>
<td>28</td>
<td>0.60</td>
<td>1.00</td>
<td>1.00</td>
<td>0.69</td>
</tr>
<tr>
<td>29</td>
<td>0.48</td>
<td>1.00</td>
<td>1.00</td>
<td>0.68</td>
</tr>
<tr>
<td>30</td>
<td>0.58</td>
<td>1.00</td>
<td>1.00</td>
<td>0.64</td>
</tr>
<tr>
<td>31</td>
<td>0.57</td>
<td>1.00</td>
<td>1.00</td>
<td>0.58</td>
</tr>
<tr>
<td>32</td>
<td>0.52</td>
<td>1.00</td>
<td>1.00</td>
<td>0.61</td>
</tr>
<tr>
<td>33</td>
<td>0.33</td>
<td>1.00</td>
<td>1.00</td>
<td>0.67</td>
</tr>
<tr>
<td>35</td>
<td>0.62</td>
<td>1.00</td>
<td>1.00</td>
<td>0.63</td>
</tr>
<tr>
<td>36</td>
<td>0.62</td>
<td>1.00</td>
<td>1.00</td>
<td>0.68</td>
</tr>
<tr>
<td>37</td>
<td>0.60</td>
<td>0.98</td>
<td>0.98</td>
<td>0.62</td>
</tr>
<tr>
<td>38</td>
<td>0.26</td>
<td>1.00</td>
<td>1.00</td>
<td>0.64</td>
</tr>
<tr>
<td>39</td>
<td>0.43</td>
<td>0.94</td>
<td>0.94</td>
<td>0.62</td>
</tr>
<tr>
<td>40</td>
<td>0.51</td>
<td>1.00</td>
<td>1.00</td>
<td>0.60</td>
</tr>
<tr>
<td>41</td>
<td>0.52</td>
<td>0.98</td>
<td>0.98</td>
<td>0.58</td>
</tr>
</tbody>
</table>
### Congruence: Exposures vs. payments network

<table>
<thead>
<tr>
<th>Number of banks</th>
<th>Top 1</th>
<th>Top 3</th>
<th>Top 10</th>
<th>Average Overlapping</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>0.16</td>
<td>1.00</td>
<td>1.00</td>
<td>0.73</td>
</tr>
<tr>
<td>28</td>
<td>0.12</td>
<td>0.98</td>
<td>0.98</td>
<td>0.76</td>
</tr>
<tr>
<td>29</td>
<td>0.12</td>
<td>1.00</td>
<td>1.00</td>
<td>0.74</td>
</tr>
<tr>
<td>30</td>
<td>0.36</td>
<td>1.00</td>
<td>1.00</td>
<td>0.70</td>
</tr>
<tr>
<td>31</td>
<td>0.27</td>
<td>0.97</td>
<td>0.97</td>
<td>0.60</td>
</tr>
<tr>
<td>32</td>
<td>0.23</td>
<td>0.98</td>
<td>0.98</td>
<td>0.64</td>
</tr>
<tr>
<td>33</td>
<td>-</td>
<td>1.00</td>
<td>1.00</td>
<td>0.77</td>
</tr>
<tr>
<td>35</td>
<td>-</td>
<td>1.00</td>
<td>1.00</td>
<td>0.71</td>
</tr>
<tr>
<td>36</td>
<td>0.15</td>
<td>1.00</td>
<td>1.00</td>
<td>0.71</td>
</tr>
<tr>
<td>37</td>
<td>0.12</td>
<td>0.97</td>
<td>0.97</td>
<td>0.69</td>
</tr>
<tr>
<td>38</td>
<td>0.05</td>
<td>1.00</td>
<td>1.00</td>
<td>0.72</td>
</tr>
<tr>
<td>39</td>
<td>0.15</td>
<td>0.92</td>
<td>0.92</td>
<td>0.64</td>
</tr>
<tr>
<td>40</td>
<td>0.27</td>
<td>0.98</td>
<td>0.98</td>
<td>0.68</td>
</tr>
<tr>
<td>41</td>
<td>0.03</td>
<td>0.98</td>
<td>0.98</td>
<td>0.65</td>
</tr>
</tbody>
</table>
Average correlations\(^1\) on rankings

<table>
<thead>
<tr>
<th></th>
<th>Exposures vs. Payments</th>
<th>Low vs. Large</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum</td>
<td>0.77</td>
<td>0.65</td>
</tr>
<tr>
<td>Minimum</td>
<td>-0.29</td>
<td>-0.38</td>
</tr>
<tr>
<td>Average</td>
<td>0.25</td>
<td>0.06</td>
</tr>
</tbody>
</table>

\(^1\)Correlations were computed for the largest time-window when the number of banks was constant at 40.
Extended network
Figure: Exposures by type of exposure
Figure: Exposures by type of intermediary
Figure: Exposures by region of the counterpart
Loans

Figure: Loans by region of the counterpart
Net exposures

Figure: Net Exposures
Over-Exposure for Banks

Figure: Number of banks which are overexposed
Over-Exposure for Brokerage houses

Figure: Number of brokerage houses which are overexposed
Over-exposure and contagion I

Figure: Original Network.
Over-exposure and contagion II

Figure: Network after the initial shock.
Over-exposure and contagion III

Figure: Network after contagion.
Over-exposure and contagion IV

![Chart showing over-exposure and contagion before and after a shock. The chart uses different colors to represent different categories of exposure.](chart.png)
Stress testing conceptual framework

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After contagion

…… After the shock

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Scenario generator

\[
\begin{pmatrix}
\text{esc}_1 \\
\text{esc}_2 \\
\vdots \\
\text{esc}_{n}
\end{pmatrix}
\]

RiskWatch

\[
\begin{pmatrix}
\ell_{0, \text{esc}_k} \\
\ell_{1, \text{esc}_k} \\
\vdots \\
\ell_{r, \text{esc}_k}
\end{pmatrix}
\]

Contagion phase

Loss distribution

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After contagion

…… After the shock

---

Figure : Banco de Mexico stress testing framework.
What to do when there is no supervisory data

Figure: Adrian and Brunnermeier CoVaR network.
Summary

- The payments system network is more connected than the interbank exposures network.
- Importance in the payments network is different than in the exposures network.
- The unified centrality measure can be employed on the methodology proposed by the BCBS to determine G-SIBs.
- Bank’s importance changes depending on the type of payment and depending if they are acting as lenders of borrowers.
- Bank’s behavior can change over time.
- Determining systemic importance based only on asset’s size could be misleading.
- Most centrality measures are robust.
- Topology of the network is not enough to characterize systemic importance.
Future work:

- Network formation models
- Studying other financial networks, like the securities settlement network
- Bank’s behavior in distress
- Bank’s funding strategies
- Link to economic variables
Thanks

Thank you!