Measuring financial integration: A network approach

Ying Xu (ANU)
&
Jenny Corbett (ANU)

(with assistance from Brett Cuthbertson, ANU)
What do we know about financial interconnections?

• We can map connections
• But can we comprehend the complexity of networks?
• Can we see the critical points?
• Think about what you know about financial connections in Asia:
  • Where do financial flows go; who is connected with whom; are there central nodes; where are they?
  • You are not alone in being unable to answer these questions.
Recent focus

• Some recent work looking for the link between systemic importance and fragility comes from the central bank concerns.
• Simple mapping approaches for global system give some visual clues but hard to interpret.
• Most network studies are either purely theoretical or simulation based.
• But we need some way to interpret network characteristics – maps alone hard to read.
Global network 1999

Note: data compiled from BIS banking statistics; map drawn by the network software ‘Pajek’.
Global network 2013

Note: data compiled from BIS banking statistics; map drawn by the network software ‘Pajek’.
Asian network 1999

Note: data compiled from BIS banking statistics; map drawn by the network software ‘Pajek’.
Asia network 2013

Note: data compiled from BIS banking statistics; map drawn by the network software ‘Pajek’.
A way to capture network features

- Network methods can capture financial interconnectedness in a different way
- Network approaches provide a framework to illustrate interconnections in a system
  - They are descriptive, not theoretically-based, methods
  - but they do measure interconnectedness in a system
    - can take the system as a whole and capture all connections in it
    - could be developed to identify possible shock transmission channels
Network methods

• The field draws on theories and methods including graph theory from **mathematics**, statistical mechanics from **physics**, data mining and information visualization from **computer science**, and social structure from **sociology**.

• A small network
  – 4 vertices/nodes
  – 8 directed links
<table>
<thead>
<tr>
<th>Network structures</th>
<th>Characteristics</th>
<th>Graphs</th>
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<tbody>
<tr>
<td>Random network</td>
<td>A set of $n$ isolated nodes connected with successive links between them at random</td>
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<tr>
<td>Regular network</td>
<td>In- and-out degrees of each node are equal to each other; nodes have the same number of links (homogenous network)</td>
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<td>Small-world network</td>
<td>Small average path length like a random network but highly clustered like a regular network; homogenous network</td>
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<td>Scale-free network</td>
<td>The majority of nodes have one or two links but a few nodes have a large number of links. The distribution follows a power law.</td>
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Methodology

- **Financial interconnectedness (integration)** index of any country $i$ at year $t$, $x_{it}$, is the weighted sum of the interconnectedness of all other countries $j$ ($j = 1..J$), $x_{jt}$, that link to it through bank claims $a_{ijt}$

$$x_{it} = \sum_{j=1}^{N} \frac{a_{i\leftarrow jt}}{\sum_{i=1}^{N} a_{i\leftarrow jt}} x_{jt}$$

- The weight for a link $j \rightarrow i$ is share of the bank claims from $j$ to $i$ in country $j$’s total foreign claims at year $t$
- The weight represents the strength of a link
Example

- A small international banking network of 4 countries and connections among them and its transition matrix:

\[
\begin{bmatrix}
a_{11} & a_{12} & a_{13} & a_{14} \\
a_{21} & a_{22} & a_{23} & a_{24} \\
a_{31} & a_{32} & a_{33} & a_{34} \\
a_{41} & a_{42} & a_{43} & a_{44}
\end{bmatrix}
= \begin{bmatrix}
0 & 0 & 1 & 1/2 \\
1/3 & 0 & 0 & 0 \\
1/3 & 1/2 & 0 & 1/2 \\
1/3 & 1/2 & 0 & 0
\end{bmatrix}
\]
FI indexes: Top 10 in the global network

- USA
- UK
- Germany
- France
- Netherlands
- Japan
- China
- Hong Kong
- Spain
- Luxembourg

Results for the global network

- **USA, UK, Germany, and France** are the most financially interconnected countries.
- By contrast, most countries have low and similar level of connectedness.
- Consistent with the existing studies:
  - Distribution of connectivity measured by the FI index follows a power law, typical of scale-free networks, only in a more extreme form (comparing Figure A and B).
  - Such a network is robust to random shocks but vulnerable to targeted attacks.
FI indexes: Top 5 in the European network
FI indexes: Top 5 in the European network

The diagram shows the trend of FI indexes for the UK, Germany, France, the Netherlands, and Spain from 1999 to 2013. The x-axis represents the years, while the y-axis represents the index values ranging from 0.000 to 0.250. Each line represents a different country, with distinct colors for easy identification:

- UK: Light blue dashed line
- Germany: Dark blue solid line
- France: Light blue solid line
- Netherlands: Light green dashed line
- Spain: Light green solid line
Results for the European network

• The European network resembles the global network only at a smaller scale (UK in the core and most of the other European countries in the periphery)

• Distribution of FI shows a scale-free network
  – The European network is vulnerable to targeted attacks on the UK banking system
FI indexes: the Asia network
Tentative Results for the Asian network

• Regional integration:
  – **HK** historically very well integrated in the region
  – **China** is rapidly integrated with the regional partners
  – In spite of being highly integrated with the global financial market, **Japan** is not fully integrated with the regional counterparts

• The distribution also shows a scale-free network
  – **China** started to form the ‘core’ of the Asian network

• Caution due to data issue:
  – Only Japan and Australia have complete data, other countries have inflow data only. We are seeking more complete data.
Conclusion

• Propose a new measure of financial integration highlighting interconnectedness in the system

• Use the new measure to show
  – **US** and **UK** and other industrial countries remain the most interconnected countries in the world in spite of the GFC
  – **Japan** is highly integrated with the world financial market but less integrated with the Asian counterparties
  – **China** is rapidly integrated with the world as well as the Asian financial market since the GFC
• The global and regional banking networks all display scale-free, long-tail structures, indicating the vulnerability to targeted attacks on countries in the ‘core’ of the networks

• Future work:
  – More data from BIS to address the data issue
  – Other dimensions of financial linkages among countries (e.g. cross-border portfolio positions)
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