Financial network analysis

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Growing interest in networks

2003

Linked

How Everything Is Connected to Everything Else and What It Means for Business, Science, and Everyday Life

Albert-László Barabási

2003

Nexus

Mark Buchanan

2004

Six Degrees

The Science of a Connected Age

Duncan J. Watts
“Is network theory the best hope for regulating systemic risk?”

CFA Magazine, July 2009

“Meltdown modeling - Could agent-based computer models prevent another financial crisis?”

Nature, August 2009

“... need for new and fundamental understanding of the structure and dynamics of economic networks.”

Science, July 2009
In the face of the crisis, we felt abandoned by conventional tools.
In the absence of clear guidance from existing analytical frameworks, policy-makers had to place particular reliance on our experience. Judgement and experience inevitably played a key role.

Jean-Claude Trichet, (Now former) President of the ECB,
Opening address at the ECB Central Banking Conference,
Frankfurt, 18 November 2010
Network maps

- Recent financial crisis brought to light the need to look at links between financial institutions
- Natural way to visualize the financial system
- ‘Network thinking’ widespread by regulators
- Mapping of the financial system has only begun

Eratosthenes' map of the known world, c.194 BC.
Visualising financial networks


Europe's Web of Debt
(Bill Marsh / The New York Times, 1 May 2010)
Network theory

- Financial Network Analysis
- Social Network Analysis
- Graph & Matrix Theory
- Biological Network Analysis
- Network Science
- Computer Science
Main premise of network analysis: the structure of the links between nodes matters.

The properties and behaviour of a node cannot be analysed on the basis of its own properties and behaviour alone.

To understand the behaviour of one node, one must analyse the behaviour of nodes that may be several links apart in the network.

Financial context: network of interconnected balance sheets.
Network basics

• Terminology
  – node/vertex -> Bank/banking group
  – link/tie/edge/arc -> Financial interlinkages, bilateral positions, exposures
  – directed vs undirected
  – weighed vs unweighted
  – graph + properties = network

• Algorithms/measures
  – Centrality -> Systemical importance
  – Flow -> Liquidity
  – Community/pattern identification
  – Distance, shortest paths
  – Connectivity, clustering
  – Cascades, epidemic spreading -> Contagion
“Prototypical” topologies

- Lattice
- Complete
- Random
- Ring
- Weighted random
- Scale-free
“Homophily”
- “Birds of one feather flock together”, “herd behaviour”
- Ideas, attributes, etc tend to cluster together and enforce each other
- Examples: Some obvious (age, social status), others less (obesity, happiness, divorces)
- How about: risk appetite, portfolio decisions, etc.

“Small world phenomenon”
- “Six degrees of separation” (6.6 on MSN messenger)
- The shortest path between any two nodes is very short
- Implications for contagion?

“Robust yet fragile”, “Scale-free networks”
- “The removal of "small" nodes does not alter the path structure of the remaining nodes, and thus has no impact on the overall network topology.”
Network analysis for Oversight

• Mostly interested in contagion process, high policy interest for measures of systemic importance

• A growing body of empirical research on financial networks
  – Overnight loans: Atalay and Bech (2008), Bech and Bonde (2009), Wetherilt et al. (2009), Iori et al. (2008) and Heijmans et al. (2010), Craig & von Peter (2010) …
  – More at www.fna.fi/blog
Possible objectives

• Identify important/vulnerable banks

• Identify contagious links

• Understand contagion process
Common centrality measures

**Degree**: number of links

**Closeness**: distance 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
Centrality depends on network process

**Trajectory**  geodesic paths, paths, trails or walks
**Transmission**  parallel/serial duplication or transfer

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<thead>
<tr>
<th>Table 1</th>
<th>Typology of flow processes</th>
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<td>Parallel duplication</td>
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<td>Geodesics</td>
<td>&lt;No process&gt;</td>
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<td>Paths</td>
<td>Internet name-server</td>
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<td>Walks</td>
<td>Altitude influencing</td>
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The GWCC has a ‘Giant Strongly Connected Component’ (each node can reach each other).

Empirical networks often consist of a ‘Giant Weakly Connected Component’

.. a ‘Giant In Component’ (which flows into GSCC)

And several disconnected components

.. and a ‘Giant Out Component’ (to which GSCC flows)
Intelligence

- Can we algorithmically detect financial crisis? Payment data as early warning tool?

- Financial crisis are different and rare. The patterns to be recognized must be frequent enough for computers to learn

- Pattern recognition is hard for computers -> the best Go programs only manage to reach an intermediate amateur level

- A solution is to augment human intelligence (in contrast to AI)

- Intelligence amplification (William Ross Ashby 1956)
Interactive visualization examples...
Ring layout
Force-directed layout
Chord layout
Tools

• Pajek, Universty of Ljublana, Slovenia
  – Focus on social network analysis of large networks
  – pajek.imfm.si

• Gephi, Gephi Foundation, France
  – Focus on graph visualisation “Like Photoshop for graphs”
  – www.gephi.org

• FNA, Soramaki Networks, Finland
  – Focus on Financial/Payment Networks, time-series, dashboards
  – www.fna.fi

• Many others
  – Cytoscape, Graphviz, Network Workbench, NodeXL, ORA, Tableau, Ucinet, Visone, etc.
Thank you