Macro-Prudential Issues: Systemic Risk and the Network Approach
Background

• Financial market innovation has contributed to the increase in cross-border and cross-market interdependencies

• Interdependencies have significant benefits

• But also entail risk transfers that had not been fully considered by financial regulators and institutions themselves...

...complicating the assessment of counterparty risk, risk management and policy responses

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A dichotomy emerged

Prior to the Crisis

• the National Bank of Belgium,
• Banco de México,
• the Swiss National Bank,
• the Deutsche Bundesbank,
• De Nederlandsche Bank,
• Oesterreichische Nationalbank and
• the Bank of England

worked on identifying institutions whose failure could lead to significant negative disruptions in the provision of credit and economy activity.
A dichotomy emerged

- While several central banks conducted systemic linkage analysis...
  ... it is not clear the extent to which this analysis informed policy discussions.

- What drove this dichotomy?
  - lack of complete and accessible data on interlinkages (partly due to confidentiality concerns),
  - Incomplete information about new products and markets, and
  - a “markets know best” approach.
Things have changed

• There is now a clear recognition of the need to go beyond prudential oversight on a ‘stand alone’ basis …

• Identifying potentially systemic financial institutions has become a priority

• A policy reality
  – The Turner Report
  – The Dodd-Frank bill

• An implosion of technical analysis
How to operationalize this designation?

Just in 2009

• GFSR: Assessing the Systemic Implications of Financial Linkages (April)
• Cleveland Fed: “On Systemically Important Financial Institutions and Progressive Systemic Mitigation” Policy Discussion paper (August)
• BIS: The systemic importance of financial institutions (September)
• FSA: Discussion Paper on the Regulatory Reform to the Banking Crisis (October)
• G-20 Finance Ministers and Central Bank Governors: Guidance to Assess the Systemic Importance of Financial Institutions, Markets and Instruments: Initial Considerations (October)
Identifying systemic institutions

Cleveland Fed:

- Size, contagion, correlation, concentration, and context.

- Three-tiered system to classify systemically important financial institutions.
Tier One

- Tier one would include high-risk institutions—large, highly complex financial institutions …large, interstate banks and multi-state insurance companies.

Tier Two

- based on how connected they are, or their involvement in critical market activities, or how their condition may be affected by stress in the economy.

Tier Three

- low probability that a failure or stress would cause any widespread ripples throughout the financial system.
Identifying systemic institutions

• G-20 Finance Ministers and Central Bank Governors: Guidance to Assess the Systemic Importance of Financial Institutions, Markets and Instruments: Initial Considerations (October)
Identifying systemic institutions

• (i) the volume of financial services provided by the individual component of the financial system;
• (ii) interlinkages where individual failure triggers domino effects.
• (iii) the degree of complexity of financial institutions,
• (iv) leverage
Identifying systemic institutions

The Dodd-Frank Act

• Size: Automatic Systemic Designation – Bank holding companies with $50 billion or more in assets are automatically subject to enhanced prudential standards. No opportunity for notice or appeal.

• By designation: The Act establishes the Financial Stability Oversight Council (the “Council”).
  ✓ The Council will designate systemically important institutions
  ✓ Office of Financial Research (OFR) to collect, analyze and disseminate relevant information for anticipating future crises
Identifying systemic institutions

• Common themes
  – Size
  – interconnectedness
    • Direct
    • Indirect
How to assess systemic linkages

• Those that draw inference from market data:
How to assess systemic linkages

• Those relying on firm-specific default data such as default intensity models Gieseke et.al. (2010)

• Those relying on balance sheet data such as

  – Network analysis
What is network analysis?

• Network analysis consists of the mapping and measurement of exposures among institutions.
• The nodes in the network represent institutions while the links represent relationships across nodes.
• Network analysis provides elements for visual and analytical representation of exposures.
<table>
<thead>
<tr>
<th>Implemented/Calibrated using</th>
<th>Network Simulations¹</th>
<th>Default Intensity Model²</th>
<th>Co-Risk Analysis³</th>
<th>Time-Varying Multivariate Density, Distress Dependence, and Tail Risk⁴</th>
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<tbody>
<tr>
<td>Outputs</td>
<td>Bank for International Settlements cross-border interbank exposures data.</td>
<td>Default data from Moody’s Default Risk Service.</td>
<td>Five-year individual CDS spreads of financial institutions.</td>
<td>Individual CDS-PoDs and/or stock prices.⁵</td>
</tr>
<tr>
<td>Advantages</td>
<td>(1) Provides metric on domino effect induced by alternative distress events; (2) Identifies systemic linkages and vulnerable countries/institutions; (3) Quantifies potential capital losses at country/institutional level; and (4) Can track potential contagion paths.</td>
<td>(1) Provides metric of potential banking failures due to direct and indirect systemic linkages; and (2) Provides probability measure of tail events.</td>
<td>(1) Estimates of unconditional and conditional credit risk measures for different quantiles (or “risk regimes”); and (2) Estimates of the effect on conditional credit risk induced by “source” institutions on “locus” institutions during stress regimes.</td>
<td>(1) Recovers multivariate density and thus common distress in the system: JPoD, BSI; (2) Distress dependence matrix; and (3) Probability of cascade effects triggered by a particular financial institution.</td>
</tr>
<tr>
<td>Shortcomings</td>
<td>(1) Allows identification of most systemic and vulnerable institutions within a system; and (2) Can be used to elaborate “risk maps” of contagion effects.</td>
<td>(1) Captures effects of direct and indirect linkages among financial institutions, as well as the regime-dependent behavior of their default rates; and (2) Very good predictive power.</td>
<td>(1) Captures institutions’ codependence risk from direct and indirect linkages; and (2) Can be used to elaborate “risk maps.”</td>
<td>(1) Able to use other PoDs; (2) Multiple outputs; (3) Includes linear and nonlinear dependence; and (4) Endogenous time-varying distress dependence.</td>
</tr>
</tbody>
</table>

¹ Estimated for all financial institutions in the model. ² Default Intensity Model (DIN) is a model that uses default data to estimate the probability of default for a specific institution. ³ Co-Risk Analysis (CRA) is a model that estimates the risk of distress across different institutions. ⁴ Time-Varying Multivariate Density (TVMD) is a model that estimates the density of distress across different institutions over time. ⁵ Individual CDS-PoD and/or stock prices.
Network Analysis: Theoretical work


— Important ‘comparative statics’ analysis that helped us understand factors behind domino effects: the size of interbank exposures relative to capital; the network structure.
Allen y Gale (2000)
Networks analysis by central banks

- Sheldon and Maurer (1998) for Switzerland,
- Upper and Worms (2000) for Germany
- Wells (2002) for the UK,
- Boss, Elsinger, Summer and Thurner (2003) for Austria,
- Mistrulli (2007): Italy
- Jaramillo and Marquez (2009) for Mexico

- Cifuentes, Calvo y Poblete (2011): Look at the Chilean payments system
  Furfine (1999) looks at (FedWire)
Network metrics

• Centrality
  ✓ Out Degree number of links leaving a node
  ✓ In Degree the number of links into a node

• Distance the number of links to go from node i to node j

• Diameter maximum distance in the network

• Path Length distance from a node to other nodes in the network.

• Clustering Coefficient probability that 2 nodes that are linked to another node be linked to each other.

• Conectivity ratio of links to total potential links
Examples for Banking Networks

Fig. 1. ‘Complete market structure’ according to Allen and Gale (2000).

Fig. 3. Money centre bank according to Freixas et al. (2000).

Fig. 4. Two-tier structure of the German interbank market.

Application to International Banking Data

• Hattori and Suba (2007) provide interesting application of network metrics to study recent trends in the international banking system.

• Consider a wide range of network metrics: connectivity, path length, in- and out-degree, etc.

Implications:

– cross-border bank network has become more tightly connected (higher connectivity, shorter average path length, higher average degree, and higher clustering coefficient)

– crises have not reversed the strong globalization process begun in early 1990s.
Implications:

- regarding financial stability:
  
  • Higher average degree implies greater possibility for agents to finance from outside a country, and thus lower probability of a financial crisis in the country triggered by domestic causes.
  
  • Conversely, once crisis occurs in one country, global impact could be more significant because countries are exposed to greater number of countries
Global Banking Network: An update
Global Banking Network: An update

Figure 4. Trends in network indicators, 1978–2009

Source: Authors’ calculations using BIS locational banking statistics (quarterly and annual).
Notes: Results are shown for the core-periphery network. In the upper panels the smooth curves are nonparametric local polynomial smoothed estimates. In all panels we superimpose the dates of the two global waves of capital flows discussed in the text: 1987–98 and 2002–08 (as dated in IMF, 2007).

Camelia Minoiu and Javier A. Reyes
• Allen y Gale (2000): Complete structure => less contagion

• Cifuentes and Shin (2005): When interconnections are low, increased connections => fragility.

• At very low levels of interconnection, fragility increases.
Network Analysis

- Trigger failure (initializes algorithm)
- Contagion rounds (algorithm internal loop)
- Final failures (algorithm converges)
Estimating Interbank Exposures

• Researchers have relied on a number of sources to complete the matrix X:
  – Bilateral exposures from balance sheet data
  – Data from credit registers
  – Data from payment systems
  – Estimation by maximum entropy
Network Software Packages

- There are a number of software packages for visualizing and analyzing networks (some are free or low-cost). For e.g.,
  - Pajek: package to analyze large networks; it runs on Windows and is free for non-commercial use.
  - UCINET: comprehensive package for analyzing social network data. Can read and write a multitude of differently formatted text files, including Excel files.
  - InFlow 3.1: a commercial package that performs network analysis and network visualization in one integrated product (no need to manage multiple files). InFlow is designed to work with Microsoft Office.
Network Analysis: from Espinosa-Solé (2009)

We start from the following stylized balance sheet identity:

\[
\sum_{j} x_{ji} \quad k_i \quad d_i \\
\sum_{j} x_{ij} \\
\]

Where 
- \( x \) stands for interbank lending,
- \( a \) : bank \( i \)'s other assets,
- \( k \) : bank \( i \)'s capital,
- \( b \) : other borrowing, and
- \( d \) : deposits.
Network Analysis: Tracking shocks

We consider two shocks: (i) a credit shock

<table>
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<tr>
<th>Pre-Shock Balance Sheet</th>
<th>Post-Shock Balance Sheet</th>
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<tr>
<td>$\sum_{j} x_{ij}$</td>
<td>$\sum_{j} x_{ij}$</td>
</tr>
</tbody>
</table>
Network Analysis: Tracking shocks

(ii) and a funding shock

\[ \sum_{j} x_{ji} \]

\[ a_i \]

\[ b_i \]

\[ \sum_{j} x_{ij} \]

\[ (1 + \delta) \rho x_{ih} \]

\[ \sum_{j=h} x_{ij} \]

\[ \delta \rho x_{ih} \]

\[ k_i \]

\[ d_i \]
Network Analysis

- To analyze a hypothetical credit shock, Espinosa and Solé simulate the individual default of each institution’s cross-border interbank claims and then track the domino effects triggered by this event.

- Specifically, it is assumed that a bank’s losses are fully absorbed by its capital. A bank fails when its capital is not sufficient to fully cover its interbank losses.
Network Analysis: Algorithms

– Parameters:
  • \( \lambda \) is loss-given default,
  • \( \delta \) is asset price haircut,
  • \( \rho \) fraction of s/t funding not rolled-over
Network Analysis: Tracking shocks

Institution $i$ fails

Assess the impact of parameter assumption including on LGD & haircut for each institution: is capital $\leq 0$?

Institution $j$ fails

Institution $k$

Institution $m$

Institution $n$ fails

Compile list of all failed institutions up to this point and re-start algorithm for remaining (non-failed) institutions
Network Analysis

• This hypothetical experiment is quite extreme but it illustrates the importance of assessing systemic linkages.

• In Espinosa Sole (2010), we used BIS consolidated data on an immediate borrower basis to assess cross-border contagion stemming from a credit event and a credit plus liquidity event.
Network Analysis

• In the past, researchers found modest “domino” effects

• Perhaps because the studies were not based on actual exposures but rather, on estimates based on maximum entropy thus distributing exposures evenly across counterparties. ..

• Another problem: the focus on credit risk
Network Analysis: Main Findings

1. Provides clean metric on the domino effect of capital losses and failures induced by alternative credit events
2. Compounding shocks reveals additional systemic countries/institutions
3. It is possible to quantify amount of potential capital losses at institutional level (stress-tests’ second round effects).

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<th>Country</th>
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4. Also possible to identify vulnerabilities. For instance, Belgium, Netherlands, Sweden, and Switzerland have highest hazard rate.
Network Analysis: Main Findings

6. Allows to track potential contagion paths.
### Table 1a. Japan: Post Simulation Capital Impairment (Credit Shock)

<table>
<thead>
<tr>
<th>Trigger Country</th>
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<th>Mar-08</th>
<th>Dec-08 (preliminary)</th>
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### Table 1b. Japan: Post Simulation Capital Impairment (Credit and Funding Shock)

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Note: "---" indicates a capital impairment larger than 100 percent of pre-shock capital.
# Japan: Contagion Paths

December 2008

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Contagion/vulnerability Index

The goal now is to integrate into an index, the interaction of

- direct credit and liquidity network effects
- indirect contagion effects, e.g., via credit risk transfer and
- systemic effects
Contagion/vulnerability index

International Financial Contagion
Easy to Define, Difficult to Measure

Summary
International financial contagion, as defined in this report, represents the transmission of financial distress from one country to another, linked to an initial adverse shock event. Examples of shock events could include the collapse of a major bank or banking system, or the failure of a major borrower such as a sovereign state. Fitch Ratings and other market observers, including certain regulators, believe that increased vulnerability of the global banking sector to such contagion was a noteworthy contributor to the severity and breadth of the recent global financial crisis.

The purpose of this report is to explore various ways to measure vulnerabilities to financial contagion in the banking sector, to look at recent historical trends with respect to vulnerabilities over time, and to comment upon situations in which vulnerabilities to contagion may still be most acute. To accomplish this, the agency conducted two forms of high-level, quantitative analysis:

- a “network analysis”, which considers asset and liability exposures between banking systems via loans, deposits, investments or borrowings; and
- a “common lender analysis”, which focuses on cross-country lender/borrower relationships, with consideration given to both direct and indirect forms of exposure.

Fitch’s network analysis indicates that vulnerability to contagion was on the rise in the period leading up to the financial crisis, beginning in 2003-2004. This trend is most evident in the Non-Risk Weighted Contagion/Vulnerability Index (see Chart 1). As can also be observed, the index started to decline as the financial crisis took hold and finally started to abate. Details of the agency’s network analysis, including a discussion of its limitations, can be found beginning on page 3 of this report.

Chart 1: Indices of Contagion/Vulnerability - Summary
Indices calculated using network analysis and BIS data

- Non-risk-weighted total
- Risk-weighted: developed countries
- Risk-weighted: emerging countries

In addition, under its common lender analysis, Fitch evaluated approximately 2,300 lender-borrower relationships across 23 countries to calculate indices of vulnerability. Details describing this analysis and limitations begin on page 8. Consistent with what Fitch observed under its network analysis, in aggregate the results of the common lender analysis suggest an increasing trend in vulnerabilities beginning in 2003 through 2007, followed by a decline thereafter.

www.fitchratings.com

12 October 2010
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The table above shows the contagion/vulnerability index for various countries, using a post-simulation capital impairment approach. Capital impairment is measured in percent of pre-shock capital.
Contagion/vulnerability index

- Indirect contagion effects: Include risk transfer data

\[
Z_{ij} = x_{ij} + \sum_{h} \tau_{jh}^i - \sum_{h} \tau_{hj}^i
\]

\(z\) stands for *ultimate exposure* of bank \(j\) to bank \(i\),
\(x\) is immediate exposure of bank \(j\) to bank \(i\),
\(\tau\) is risk transfer from bank \(h\) to \(j\) referenced on \(i\).

- We also performed credit and credit plus liquidity event analysis with ultimate exposure data
Network Analysis: indirect contagion effects

Key to include off-balance sheet data in analysis, as it can dramatically alter the risk map

(March 2008)
Contagion/vulnerability

Network Analysis

• Is transparent. The analysis is very clear about
  – Data
  – Parameter, such as: loss-given default, haircut and other assumptions

• But abstracts from many potentially important considerations
  – Even rating agencies include considerations for potential government support
  – Not all institutions have the same likelihood of failure
Contagion/vulnerability

Next steps

• combine the deterministic capital impairment losses arising from credit plus liquidity events (for data inclusive of risk transfers) with

• (stochastic) simulation of systemic events over a short horizon.
Recent approaches

• A simulated network approach, Hałaj and Kok (2013)

\[ \text{SPI}_j^w = \frac{\sum_{j=1}^{N} TA_j P_{ij}^w}{\sum_{j=1}^{N} TA_j} \]

- With TA, the ratio of assets to the amount of capital

\[ P_{ij}^{(k)} \] is the probability of default of the bank \( j \) at time \( k + 1 \) given that the probabilities of default of banks 1, 2, ..., \( N \) at time \( k \) are \( P_{i1}^{(k)} , P_{i2}^{(k)} , ..., P_{iN}^{(k)} \).
Data Gaps

1. off-balance-sheet linkages (domestic and cross-border) cannot always be included in their interbank exposures matrix,

2. many CBs lack a comprehensive data set due to limited disclosure on complex structured credit products,

3. there are challenges of collecting information on non-bank financial intermediaries (investment banks, insurance companies, hedge funds),

4. inaccurate measures of risk transfers,

5. lack of consistency in information disclosures complicates risk exposure assessments, both across institutions and products.
Data Gaps

Several recommendations in the joint IMF-FSB *Financial Crisis and Information Gaps* report

- Development of measures of aggregate leverage and maturity mismatches
- A template for SIFIs’ exposures to financial sectors and markets
- Include separate identification of non-bank financial institutions in the sectoral breakdown of the BIS consolidated banking statistics
- The tracking of funding patterns of international financial systems
- A standardized template covering the international exposure of large non-bank financial institutions
Data Gaps

• Proposals for templates of bank-level data on
  – banks’ exposures and funding positions
  – by counterparty country, instrument, currency, and remaining maturity.
  – banks’ intragroup positions
  – the number of branches and subsidiaries
THANK YOU