Post-Mortem Examination of the International Financial Network

Matteo Chinazzi\textsuperscript{1} Giorgio Fagiolo\textsuperscript{1}
Javier A. Reyes\textsuperscript{2} Stefano Schiavo\textsuperscript{3}

giorgio.fagiolo@sssup.it
http://www.lem.sssup.it/fagiolo/Welcome.html

\textsuperscript{1}Sant’Anna School of Advanced Studies (Italy)
\textsuperscript{2}University of Arkansas (USA)
\textsuperscript{3}University of Trento (Italy)

Global Systems as Networks of Networks
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Motivations

The Crisis and Financial-Market Interconnectdness
- Banks too connected to be allowed to fail?
- Financial integration and potential worldwide spreading of local shocks
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- **The Crisis and Financial-Market Interconnectdness**
  - Banks too connected to be allowed to fail?
  - Financial integration and potential worldwide spreading of local shocks

- **The Role of Network Theory**
  - We need a better understanding of the structure and evolution of financial networks, defined as systems where economic players (countries, banks, financial institutions) do not act in isolation but rather are linked via a complex set of interactions (Schweitzer et al., 2009, Science)
Related Literature

**Theory: Contagion effects in the inter-bank lending network**

- Allen & Gale (2000): Shocks are more easily dissipated within full networks, sparser networks less robust; cf also Freixas et al. (2000), Leitner (2005)
- Gai & Kapadia (2010): higher connectivity reduces likelihood of widespread default, but implies also more fragility (when contagion occurs, effects can be tougher)
- Role of node heterogeneity: positive effects of higher density on diversification is counterbalanced by fragility implied by network stars (Iori et al, 2006; Caccioli et al 2006).
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- **Empirics: Exploring topological properties of inter-bank networks**
  - Global banking network (Hale, 2011)
This Paper

- **Country-level International Financial Network (IFN)**
  - Weighted-directed multigraph where nodes are world countries and links represent debtor-creditor relationships in equities and short/long-run debt
  - Schiavo, Reyes & Fagiolo, 2010; Minoiu & Reyes, 2011
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- **Research Questions**
  - Has the 2008 financial crisis resulted in a significant change in the topological properties of the IFN?
  - Is country “position” in the IFN a good predictor of its performance during the crisis?
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**What do we do?**
- Explore the topological properties of the IFN as the crisis unfolds
- Perform econometric analyses to examine the ability of *country network statistics* to explain cross-country differences in crisis intensity (cf. Rose and Spiegel, 2010, 2011; Frankel and Saravelos, 2011; Lane and Milesi-Ferretti, 2011; Giannone et al., 2011)
Main source of data: Coordinated Portfolio Investment Survey (CPIS), collected by the International Monetary Found (IMF)

Data include cross-border portfolio investment holdings of equity securities, long-term debt securities and short-term debt securities listed by country of residence of issuer

We have complete bilateral data for roughly 70 countries for the period 2001–2010

Additional data include: World Development Indicators (WDI), collected by the World Bank
We build a 5-layer weighted-directed multigraph, where each directed link is weighted by the value of security – in millions of current dollars – issued by the origin node and held by the target.

- TPI = Total Portfolio Investments, i.e. the graph is built considering all the financial exposures between countries.
- ES = Equity Securities, i.e. consider only equity securities.
- TDS = Total Debt Securities, i.e. consider only debt securities.
- LTDS = Long-term Debt Securities, i.e. consider only long-term debt securities.
- STDS = Short-term Debt Securities, i.e. consider only short-term debt securities.
The IFN

Links connect issuing country to security holder. For example, A issues securities held by B and D (i.e. A is a debtor of B and D) where $w_{ab}$ and $w_{ad}$ are the values of such securities in (millions of) current dollars.
Network Statistics

- In/Out Degree and Strength
- Average Nearest-Neighbor Degree (ANND) and Strength (ANNS)
- Binary (BCC) and Weighted (WCC) Clustering Coefficient
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- Hubs and Authority Centrality

Financial authorities are primary sources of investments, i.e. countries that hold securities issued by many hubs

Financial hubs are primary borrowers, i.e. countries that issue securities held by many authorities
Evolution of IFN Structure: Pre vs Post Crisis (1)

- **Density**
  - IFN density increased until 2007, dropped in 2008, and then increased again.
  - The crisis caused some countries to revise their relationships, reducing their financial linkages (Hale, 2011).
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**Node Degree/Strength Distributions**
- From bimodal (pre) to unimodal (post) distributions, especially in the ES layer.
- Very connected nodes seem to have reduced their exposures. This is especially true for nodes that had many creditors as compared to the average behavior of all other countries.
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The financial crisis not only changed the topology of the network by decreasing the overall number of connections among the countries, but also by altering the distributions of such statistics.
ANND/ANNS

- ANND/ANNS distributions shift to the right and become less dispersed: countries tend to connect over time to more/better connected countries.
- Negative shocks can be better absorbed since their impact is shared by many countries, but can diffuse more easily throughout the network (Gai and Kapadia, 2010).
Evolution of IFN Structure: Pre vs Post Crisis (2)

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**Node Clustering**
- Clustering distributions in equity vs debt layers go in opposite directions
- Equity: shift to the left in 2008, but then moves to the right again
- Debt: steady shift to the left after 2008
- Equity securities recovered more quickly from the 2008 shock, whereas investment behavior in debt securities have been strongly impacted by the crisis
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This is observed in many other stats: debt layers require more time to invert the trend after the crisis.
Evolution of IFN Structure: Pre vs Post Crisis (3)

Correlation Structure among Node Network Statistics

- Countries with a large number of creditors/debtors tend also to hold/issue more dollars of securities.
- Over time: Countries who have more debtors increase securities they hold; countries that have more creditors tend to diminish their exposures.
- IFN is disassortative: neighbors of well connected and highly influential countries have fewer creditors/debtors and hold/issue less securities.
- No structural changes in correlation structure before and after the crisis: robustness of IFN (see also WTW).
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Rich-Club in the IFN?

- Binary IFN: Creditors/debtors of many countries interact with countries that are not debtors or creditors of each other (hub-and-spoke structure)
- Weighted IFN: NS-WCC correlation is positive and high, hinting to a rich-club structure
- Opsahl et al. (2008) coefficient suggests a rich-club core composed of top 25/30 countries (in terms of NS) linked to the periphery
Evolution of IFN Structure: Pre vs Post Crisis (4)

- **Hub-Authority Centrality**
  - Top hub-authority centrality ranks feature developed economies and well-known financial centers (Luxembourg, Switzerland, tax heavens)
  - In the weighted case there is a higher likelihood that countries display both high hub and authority centrality than in the binary case
  - Presence of many tax heavens among the top binary financial authorities
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Tax Heavens in the IFN
- Opposite roles that Cayman Islands and Luxembourg play in the IFN
- Cayman Islands are more important as a financial hub than as a financial authority
- Luxembourg appears to be a financial authority but not a financial hub
- Cayman Islands are more important as a country where depositing money, while Luxembourg is more useful to incorporate companies that then can be employed as holdings for companies operating elsewhere
The crisis forced countries to revise their relationships, implying an overall reduction of financial linkages and a distributional shift.
Evolution of IFN Structure: Summing Up

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- Disassortative network, rich-club emergence in weighted IFN.
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Centrality analysis hints to important role of tax heavens.
Impact of Network Structure on Crisis Intensity

- Literature on Early-Warning Systems (EWS)
  - Explaining cross-sectional difference in crisis intensity and finding predictors of systemic-risk building up
  - See Berkmen et al, 2009; Blanchard et al, 2010; Claessens et al, 2010; Rose & Spiegel, 2010, 2011; Frankel & Saravelos, 2011; Lane & Milesi-Ferretti, 2011; Giannone et al, 2011
  - Weakness: they do not properly consider international linkages
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- **Our Empirical Strategy**
  - Define a measure of crisis intensity
  - Select a vector of macro-economic controls
  - Add country network indicators
  - Run cross-sectional or panel GMM estimation to see if network indicators can explain crisis intensity (given macroeconomic controls)
Cross-Sectional Estimation: Setup

Benchmark Econometric Specification

\[ y_{i,2008} = \gamma x_{i,2006} + \theta g_{i,2006} + \nu_{i,2008} \]

where \( y_i \) is any crisis measure, \( x_{it} \) is a vector of macro-economic controls, \( g_{it} \) is a vector of network measures, \( \nu_{i,t} \) is the error component and \( i = \{1 \ldots 74\} \).
Cross-Sectional Estimation: Setup

- **Benchmark Econometric Specification**

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- **Crisis Intensity, Controls and Network Measures**
  - Credit market regulation, rGDP pc, bank credit to private sector over GDP, current account over GDP, etc.)
  - ND in and out; directed ANNDs; BCC; BAC (endogeneity issues)
Cross-Sectional Estimation: Results

- **Real Measures of Crisis Intensity**
  - Controls: GDP suffered more in countries with higher income, less regulated capital markets, smaller current-account surpluses, and those experiencing credit crunches.
  - Network Effects: The higher the number of debtors (ND-in) the smaller crisis intensity (risk diversification?)
  - Nonlinear effect of connectivity: the marginal effect of an increase in ND-in vanishes for very connected countries (those in the core).
  - Network variables allow for a substantial improvement of GoF.
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- **Financial Measures of Crisis Intensity**
  - Controls: Stronger negative effect of income (subprime crisis)
  - Network variables: Stock market performance increases (non-linearly) with both ND-in and ND-out, and with the number of creditors of a country creditors (out-out ANND)
  - Adding network variables improves even more GoF
Panel GMM: Motivations and Setup

- **Problems with Cross-Section Estimation**
  - Small sample size forces to use small set of controls and network effects
  - Endogeneity (dependent variables and network effects)
  - Omitted variable bias

A (partial) solution:
We fit a panel GMM using Arellano & Bond (1991) estimator and we employ Windmeijer (2005) correction for finite samples, including crisis dummy variables as interaction terms for network indicators.

Robustness analysis: we overcome small sample-bias problems by running all possible regression specifications (around 1.3 million) stemming from the choice of all controls plus 4 network indicators (out of 26 available). This allows us to see how stable are network-effect results for all possible specifications.

Significance and sign of the impact of a network variable is evaluated looking at \( (p\text{-val, estimated coeff}) \) surface plots obtained gathering data from all regressions where that network variable enters the specification.
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Panel GMM: Example of Significant Regressors

(a) NDin - TPI

(b) log(WCC) - TPI
Panel GMM: Example of *Unsignificant* Regressors

Figure 9: Rich-club behavior. Null Model: M1, see Appendix D (links are completely reshuffled so as to fully permute the weight matrix).

(a) \text{log(BAC)} - \text{ES}

(b) \text{WAC} - \text{TPI}

Figure 10: GMM regression analysis: Examples of significant regressors

(a) \text{log(BAC)} - \text{ES}

(b) \text{WAC} - \text{TPI}

Figure 11: GMM regression analysis: Examples of not significant regressors
Panel GMM: Main Results

- **Risk diversification vs vulnerability**
  - Significant *first- and second-order* network regressors have a positive effect on stock-market performance, supporting the risk-diversification hypothesis.
  - Significant *higher-order* binary network regressors (e.g. clustering and centrality) tend to enter negatively, hinting to higher vulnerability due to country embeddedness within the IFN.
  - High WCC values shield instead a country from contagion, as that typically means being part of the IFN rich-club.
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- **Role of Network Variables**
  - Unsignificant interaction effects between crisis dummies and network indicators
  - The role of network indicators remains the same before and after the crisis
  - Network indicators can be used to predict country vulnerability to shocks, no matter whether we are in a period of distress or not
The structure of the IFN has been severely hit by the financial crisis
Detectable impact not only at the aggregate level (density) but also on node-specific network statistic distributions (degree, ANND, etc.)
Different layers (debt vs security) of the IFN responded in a different way to the crisis
Take-Home Messages

- The structure of the IFN has been severely hit by the financial crisis.
- Detectable impact not only at the aggregate level (density) but also on node-specific network statistic distributions (degree, ANND, etc.).
- Different layers (debt vs security) of the IFN responded in a different way to the crisis.
- Country network indicators exert a significant and stable role in explaining both real and financial impact of the crisis on a country.
- Their effects are typically non-linear (Iori et al, 2006; Caccioli et al, 2011).
Take-Home Messages

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- Detectable impact not only at the aggregate level (density) but also on node-specific network statistic distributions (degree, ANND, etc.).
- Different layers (debt vs security) of the IFN responded in a different way to the crisis.
- Country network indicators exert a significant and stable role in explaining both real and financial impact of the crisis on a country.
- Their effects are typically non-linear (Iori et al, 2006; Caccioli et al, 2011).
- Higher local connectivity shields country from severe impact via risk diversification.
- Higher (binary) global embeddedness in the IFN exposes a country to a higher vulnerability, especially if the country is not within the rich-club of the IFN.
Extensions

- Targeted shocks and network-resilience tests
- Exploring alternative (synthetic?) crisis indicators
- Expanding the analysis using a macroeconomic multi-network (financial linkages, trade, FDIs, human mobility, etc.)
- Replicating our exercises on the global banking network (Fagiolo, Minoiu, Reyes, fc)
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Paper: