Network Models of Financial Systemic Risk 13frg184

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1 Overview of the Field

In the aftermath of the 2008 financial meltdown, scientists and economists have rushed into the field of network science as it can be applied financial systemic risk. This exciting new area of research brings challenges from both the understanding of complex adaptive systems and the economics of financial institutions. Since this event, research groups around the world have been created, all with a common goal to better understand the linkages between banks, and the chains of defaults that may be transmitted through these linkages.

Current understanding sees financial systemic risk as being the risk that a modest sized shock to the financial system triggers a domino-type cascade of bank failures that could engulf a significant fraction of the network. One can identify four key channels through which systemic risk may flow: the impact of large correlated losses across asset classes, cascades of default, cascades of funding illiquidity and market illiquidity leading to major firesales of assets. The first and fourth effects are not really network effects, but network science can have a great deal to say about the risks associated with cascades of default and illiquidity.

The stakes are high in this research area. The potential consequences of preventing the next global financial crisis are of course enormous. Understanding the factors that drive systemic risk, has the potential to yield valuable tools for central bankers and financial regulators, and to inform the current international debate on financial regulation.

Our focussed research group consisted of members of the research team working on a project called "Financial Systemic Risk: a Network Science Approach", sponsored by the Global Risk Institute in Toronto. The major aim of this project is to combine Monte Carlo methods and the analytical framework based on Watts' 2002 information cascade paper [10], and apply these techniques to increasingly sophisticated models of financial risk networks.

2 Recent Developments and Open Problems

Eisenberg and Noe 2001 [3] provides a basic accounting model for a network of banks with their interbank exposures. If ever a bank defaults, it will create a cascade of shocks to their creditor banks. This paper provides the mathematical resolution of the credit shortfalls that result. This foundational paper has provided the basis for most subsequent work on systemic risk.

The paper of Watts 2002 [10] introduces a very basic model for cascade dynamics in complex networks. This paper gives an analytic treatment of what has been called an information cascade in a friendship network, whereby a small number of early adopters influence their friends to adopt the new technology. In a susceptible network, the new technology becomes established while it dies out in a non-susceptible network. Susceptibility is determined by an analytic condition on the model parameters.

Upper 2011 [9] reviews 15 pre-crisis economic studies of the financial networks in several countries. These papers share a common methodology stemming from Eisenberg and Noe, and all came to similar conclusions about the stability of these existing networks. Their collective failure to anticipate the 2007-08 crisis has provided the impetus for subsequent systemic research.

Nier et al 2008 [7] provided the first in-depth Monte Carlo study of stylized network models, and provided striking illustrations of the sometimes paradoxical nature of cascades in networks. The paper showed clearly that graph connectivity, for example, is not monotonically related to systemic risk.

Gai and Kapadia 2010 [5] adapted the analytical treatment of Watts' 2002 paper to the problem of cascading defaults in financial systems. They were able to get an analytical formula describing the cascade in their deliberately simplified model, and to validate this formula via Monte Carlo simulation.

A very basic difficulty in this subject is the sparsity of available interbank exposure data. In general, financial institutions are highly motivated by business considerations not to share information about their counterparties, and consequently, little data has been available in the recent past on the state of interbank networks. This fact is changing rapidly due to the recognition of systemic risk as a fundamental threat to our economies. There is currently great interest in developing new techniques of statistical inference that can capitalize on newly available databases to better match models to existing financial networks.

3 Presentation Highlights

1. Double cascade model of illiquidity and insolvency (talk by Tom Hurd)
   This work extends models of Gai, Haldane and Kapadia [4], (also Hurd and Gleeson [6]), to models of a double cascade of liquidity stresses and default shocks in a theoretical financial network. In this work we have developed a number of probabilistic methods that lead to detailed analytical formulas for dynamics that more typically are dealt with by large scale Monte Carlo simulations. While the analytical results have been proven, there still remains significant work to solidify the computational methods for implementing such models, and observing their properties.

2. Top-down models of economic networks (talk by Tom Hurd)
   Idea: conceive of plausible scale-free financial network models that can be calibrated easily to aggregated balance sheet data. We considered that the underlying random graph can be taken as a preferential attachment (scale free) model, and that balance sheet random variables would also exhibit fat tails. In this class will be some interesting LTIA models (locally tree-like independent, amenable to exact math analysis). There are a number of potential uses.

3. Risk-sharing contracts (talk by Alfred Lehar)
   Idea: In an existing network (say a stylized network), two banks may decide to exchange a risk-sharing contract. What contracts make sense, and how would this affect their systemic risk, and the SR of the network as a whole?

4. Agent-based models for bank formation (talk by Matheus Grasselli)
   He presented a model that aims to understand how a will bank arise spontaneously in a society of individual economic agents: Place an Allen-Gale type two period model within a system of economic agents, wave the wand of "entrepreneurship", and watch banks arise.

5. Economic rationale for bank linkages and optimal bank structure (talk by Alfred Lehar)
   Central Idea: we should understand why linkages form in the first place, e.g. for risk sharing, for current account management, etc. A parallel issue is to understand better what optimization problems are solved by banks' balance sheets: this will improve the stylized modelling of bank behaviour needed as an ingredient in systemic risk models.

6. Core-periphery models (talk by Tom Hurd)
   Idea: when the core network connections for SIFIs (systemically important financial institutions) are known, but the larger network of OFIs (other financial institutions) is not well understood, one can couple the core model to a statistical "top-down model" for the periphery. This will allow efficient separation of computational effort, focussing on the core network while treating the periphery in a stylized way.

We also had interesting talks and discussions on a variety of other topics: (a) the detailed structure of the EU network (Davide Cellai); (b) Systemic Probability Index (Grzegorz Halaj, European Central Bank, Frankfurt, talk delivered by blackberry) and other ways to reduce computational burden in identifying systemically important institution in financial networks; (c) a new Markov formulation of Watts' cascade which promises to provide a mathematically rigorous foundation for the topic. (Quentin Shao).

4 Scientific Progress Made

1. We were able to implement a calibration of a database that captured the state of the European financial network on a date in summer 2011. Our resultant model specification has fat-tailed degree, buffer and exposure distributions, in the class of models discussed in Talk 3.2 above.
2. Significant progress was made to finalize the numerical experiments that are discussed in Talk 3.1 above "Double cascade model of illiquidity and insolvency". Since our BIRS week, a paper [8], introducing this model and its properties, has been finalized and submitted for publication.
3. Lehar and his coauthor have finished a working paper [2] on bank linkages and submitted it for publication. The paper got a revise and resubmit at Management Science.

5 Outcomes of the Meeting

In addition to making headway on resolving questions posed in our original proposal, a number of unanticipated, but promising, new avenues arose during the meeting. For example, the problem of bringing the work of Lehar into a network setting suggested that the effect of risk-sharing contracts between banks could have a significant impact on reducing systemic risk. Progress on this problem would be of interest in mainstream finance. In a similar vein, contingent capital, of which the so-called "CoCos" are an important example, can have a positive effect on improving banks' capital buffers in times of network crisis. This problem can be studied within our new double cascade model.

A further thread arising from our discussions involves the construction of "real-world" networks that can match better the stylized facts of major systems, notably the US banking system, as determined by [1]. We hope soon to be able to run experiments that address the stability of model financial systems whose topology has these observed characteristics.

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