Analytical Methods for Financial Systemic Risk

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1 Workshop Participants

- Ian Buckley - Canadian Securities Transition Office
- Zachary Feinstein - Washington University in St. Louis
- Mark Flood - University of Maryland
- Grzegorz Halaj - Bank of Canada
- Thilo Meyer-Brandis - Ludwig Maximillians University Munich

2 Overview of the Field

Systemic risk (SR) is the risk of failure of the financial system, as exemplified by the financial crisis of 2007-2008. Imagining, exploring and analysing potential channels of vulnerability in large-scale financial networks requires a wide range of concepts. Many-body physics, agent-based modelling, random graph theory and mean field games are some of the currently active areas that need to be merged with financial mathematics, computer simulations and probability theory in order to understand such a complex system. The broad goal of this workshop was to capitalize on the opportunity offered by BIRS to bring together an international team of senior researchers in SR to discuss new directions, unsolved problems and the unification of different approaches.

Systemic risk research has developed very extensively over the last 10 years, with major advances in both the scope and depth of questions addressed. As a result, it has become increasingly challenging to maintain a current view of the entire topic, and it is a difficult field to enter as there is no clearly identified main line of research. However, these characteristics also make it an exciting, innovative topic in financial mathematics, with new people entering from different areas bringing in different mathematical approaches. The book [1] provided an excellent collection of new ideas and results that were coming up

soon after the financial crisis when research on systemic risk was expanding rapidly. In a different vein, [2] provided a technical overview of systemic network problems that can be understood with random graph methods. It seems however that now is an excellent time for an up-to-date coherent, textbook style introduction to systemic risk that covers the entire breadth of the field, highlighting a broad range of techniques, delivered at a level accessible to new grad students and people working in the financial regulatory system. This would be an invaluable resource on which to base a comprehensive graduate course or web course targeted at a world wide audience.

3 Progress made during the workshop

To capitalize on the diverse expertise of the workshop participants, the team decided at the outset to depart from a traditional math workshop setting with specialized talks. Instead, we identified the goal for the team to develop a "hypothetical" Master level course in systemic risk, packaged with a textbook, plus a comprehensive range of subsidiary material. While we began our meeting thinking of this as a good organizational theme, by the end of the very first morning, we realized that this course will be real, not hypothetical, and that the topics to be developed for the course must provide an exact map of the entire subject. Moreover, targeting a hypothetical master level student allowed us to explore the entire subject at an introductory level from different points of view, and also to enter more deeply into specific areas to highlight more advanced research-level techniques. During the BIRS week, we were able to identify some of these specific areas as new open problems that the team may develop into publishable research results.

Based on this "Master Course/Text" theme, we spent much of the workshop scoping out, and teaching each other, the main threads of SR, to identify the overall aims and key results for each thread. By the end of the week, a great deal of progress had been made in identifying the most effective strategies for promoting systemic risk as an area of applied research that has growing strategic and societal importance. In a nutshell, there is a crying need for an unbiased, coherent, and comprehensive summary of the main threads of systemic risk viewed at a global scale.

Since the May 2019 workshop, the BIRS participants are already actively implementing this vision, and have embarked on a 5 year project that can be summarized by the following rough outline of the chapters of our textbook. The team's intention is to engage the broader SR community to add expert co-authors and junior researchers to the many sections under development, while maintaining a firm curatorial control over the content and style. Within one year, we hope to have a preliminary version of the webtext to post in the public domain. Subsequent versions of the webtext will provide the SR community with a continuously evolving review of the entire subject from a global perspective.

1. **Overview of SR** A survey of what systemic risk means, how it can be described, and how it has been treated up to now in the economics literature.

2. **Deterministic Channels of SR** Systemic risk is a multi-faceted phenomenon which intertwines numerous simpler effects or channels. Stress can propagate through default contagion, liquidity contagion or fire-sales to mention just a few examples. To

keep the book at an accessible technical level, these channels will be developed using the so-called Eisenberg-Noe framework. The focus here will be on mathematical models that provide a detailed qualitative understanding.

3. **Random Financial Networks** Stochasticity is central to systemic risk. At the simplest level, the deterministic channels just described and modelled act on systems that are not well observed. This uncertainty over the state of the system is best modelled by a random financial network. This chapter will focus on simulation methods and their relation to mathematical results that can be proven within certain classes of random SR models.

4. **Systemic Risk Data and Calibration** This part of the course/book will give an overview of issues relating to data available for calibrating SR models. The two special characteristics of SR is that the required data is difficult to collect and that it has immense *strategic value*. Consequently it is never available in the public domain, and data held by government agencies is also incomplete. These facts present an immense challenge to academic researchers. This chapter will review relevant databases in the public domain, survey methods to reconstruct required data missing from the public data, and provide access to archives of benchmark databases, both real and surrogate (simulated).

5. **Application: Macroprudential Stress Testing** The most important practical application of SR theory is at the core of the *macroprudential ("macropru") stress testing* exercises conducted by the central banks of the major economies. Traditional microprudential ("micropru") stress testing is a well-established procedure run by financial regulators in most developed countries. Large banks are provided with a small number of medium term (several years long) economic scenarios, and the test requires all individual banks to report on the detailed characteristics of their future profit and loss distribution resulting from following their operational strategy. Macropru stress testing extends the micropru test to provide a detailed assessment of the stability of the entire system under the same type of scenario. The central regulator takes the micropru results for the individual banks', and then applies a fully-developed systemic risk model to determine risk measures for the additional damage to the entire system stemming from the knock-on effects of systemic contagion. This final chapter will review the common features of macropru in different countries and delve into the implementation issues that must be addressed.

References

[1] J.-P. Fouque and J.A. Langsam. *Handbook on Systemic Risk*. Cambridge University Press, 2013.

[2] T. R. Hurd. *Contagion! Systemic Risk in Financial Networks*. SpringerBriefs in Quantitative Finance. Springer Verlag, Berlin Heidelberg New York, 2016.