Journal of Banking & Finance xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Journal of Banking & Finance

journal homepage: www.elsevier.com/locate/jbf

The great entanglement: The contagious capacity of the international banking network just before the 2008 crisis ☆

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ARTICLE INFO

Article history:
Available online xxxx

JEL classification:
G21
G28
F3

Keywords:
Systemic risk
Interconnectedness
Network analysis
Information theory

ABSTRACT

Systemic risk among the network of international banking groups arises when financial stress threatens to crisscross many national boundaries and expose imperfect international coordination. To assess this risk, we consider three decades of data on the cross-border interbank market. We use Rosvall and Bergstrom's (2008) information theoretic *map equation* to partition banking groups from 21 countries into modules that reveal the contagious capacity of the network. We show that in the late 1980s four important financial centers formed one large super cluster that was highly contagious in terms of transmission of stress within its ranks, but less contagious on a global scale. But the expansion leading to the 2008 crisis left more transmitting hubs sharing the same total influence as a few large modules had previously. We show that this greater entanglement meant the network was more broadly contagious, and not that risk was more shared. Thus, our analysis contributes to our understanding as to why defaults in US sub-prime mortgages spread quickly through the global financial system.

1. Introduction

An astonishing feature of the 2008 financial crisis was how quickly and extensively initial losses in US subprime mortgages spread such that two years later, governments worldwide had to provide massive support to their banking systems. Write-downs were estimated to have reached 2.7 trillion US dollars (International Monetary Fund, 2009c). In this paper we apply network analysis to help understand the transmission of stress in the complex financial system that had built up before the crisis. In the years prior to the crisis, large banking groups had become highly interdependent across national borders through a complex web of direct claims on each other, ownership structures and other risk transfers and also through participation in common markets.[3] Because the system was so intertwined, the financial crisis was transmitted rapidly through default chains, funding squeezes, fire sale externalities and a rash of counterparty fear.

Our focus is on the international banking network. The international banking network is a set of bilateral claims (links) of different banking entities (nodes) on each other. Nodes are defined by separating banking groups (all the banks operating in a particular country) into their funding and credit arms; each node is a funding or credit arm of a particular banking group. This separation of banking groups into funding and credit arms allows us to distinguish between two different channels of contagion. Banks defaulting on loans transmit stress to their creditors via a credit channel. This is a situation where a problem at one banking group's funding arm is transmitted to another banking group's credit arm. However, it was also observed during the crisis that banks got in trouble because their creditors refused to keep lending to them – a funding

☆ The authors wish to thank Shekhar Aiyar, Martin Brooke, Martin Rosvall and seminar participants at the University of Missouri, Oxford University, the International Monetary Fund Conference on Operationalizing Systemic Risk Monitoring, May 2009, and the Geneva Finance Research Institute "Financial Networks" conference, June 2011. The views expressed in this paper are those of the authors and do not necessarily reflect those of the Federal Reserve Bank of New York, the Federal Reserve System, the Bank of England, the IMF, its Executive Board, or its management.

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[1] This paper is based on work done at the Bank of England and published in Bank of England Working Paper No 413.

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[3] For more on the evolution of financial markets from a network perspective see Haldane (2009).

http://dx.doi.org/10.1016/j.jbankfin.2013.12.025
0378-4266/

channel. This is a situation where stress flows from the credit arm of one banking group to the funding arm of another.

The first objective of the analysis is to cluster the funding and credit nodes of all the different banking groups together in a way that accurately reflects areas of concentration of financial stress. In particular, we wish to cluster nodes into modules so that stress travels between the members of a module with a greater intensity than it does to the nodes outside the module. For this purpose we use a network clustering technique developed by Rosvall and Bergstrom (2008), henceforth RB. RB's *map equation* determines the most parsimonious yet accurate description of the network that can be used to map the movements of an imaginary traveler, taking account of how likely he is to visit each node. Groups of nodes with long persistence times are clustered together. Because the approach clusters the network using information about flow, it has an advantage over generalized modularity approaches (for example Newman, 2006; Girvan and Newman, 2002 or Blondel et al., 2008) that focus on pairwise aspects of the link structure.

Success depends upon the proper specification of a transition probability matrix that governs the flow of stress through the system. We define this matrix using data on financial claims between banking entities. Our approach emphasizes mismatches between assets and liabilities. Under our specification, the tendency for stress to visit each module depends not only on the sum of the gross assets and liabilities of each banking group in the module, but also on the mismatch between liabilities and assets. The modules where financial stress visits the most are those with large and mismatched balanced sheets.

Clustering is in general a difficult numerical problem because of the vast number of modular permutations possible in even a small network. A crucial advantage of RB's approach is that it uses advances in information theory, in particular a generalization of Shannon's source coding theorem (Shannon, 1948), to simplify the computational burden associated with evaluating all possible clustering arrangements. For this reason, RB's approach is well suited to determine a revealing map of the flow of stress through the international financial network. While not well known to economists, this method has been heralded as among the best of the many network clustering algorithms used in other scientific applications (Lancichinetti and Fortunato, 2009).

Describing the system at a modular level is an important part of our analysis of systemic risk in the international banking network. Given our modular description of the network we can see which countries belong to the same module and hence are most heavily impacted by each other in times of financial stress.

We also examine the flow within and between modules. In a safer network, the most important modules will have a lower capacity to transmit financial stress; those modules will act as absorbers. If instead the important modules have a high propensity to transmit contagion, then financial stress is more likely to criss-cross many national boundaries and become truly systemic.

When financial stress crosses many national boundaries it is more problematic. This is in part because different legal systems and political preferences have to be compromised. For example, London School of Economics Law and Financial Markets Project (2009) explain that Lehman Brothers' global business operated with over a 100 data systems that were owned and managed by some of the 6000 legal entities within the group worldwide. Once the global firm failed, administrators in each country where the firm operated needed to co-operate over sharing the very high cost of running these data systems. Claessens et al. (2010) and Tucker (2010) emphasize difficulties in international co-ordination over crisis resolution. A corollary is that a network where financial stress can move rapidly across many national boundaries should feature greater risk that a small shock can lead to a systemic crisis.

Our results describe a dramatic evolution of the interconnectedness in the international banking network over time: in the late 1980s, the network is dominated by one or two very large modules comprising the US, Japan, UK and the Cayman Islands. But over the 1990s and 2000s, the larger modules reconfigure to create a network led by multiple important modules now also including continental European banks. By combining modularity with measures of the probability of contagion at that modular level, we show that the expected movement between modules increased over the 2000s, and reached a peak just before the crisis struck. This suggests that these multiple larger modules acted as transmitting hubs rather than absorbing centers. The international banking network featured a great capacity to be contagious because stress could then rapidly cross many borders and was less likely to be corralled within a few countries.

But how do we know that this different pattern of interconnectedness implies more contagion and not more risk-sharing? To test this we also carry out a simulation on our data set, adapting the method of Battiston et al. (2009) that allows for both contagion and risk diversification. We show that for a wide range of parameters, there was indeed a greater likelihood of transmitting contagion, especially just before the crisis. In no configuration can the later network be described as better at diversifying risk. This corroborates what we observed in the modular patterns described by the map equation.

2. The data

In any applied work on financial networks, a discussion of the limitations and appropriateness of data is important. We measure the claims held by each country's resident banks on each other country's resident banks as reported in the Bank for International Settlements (BIS) locational by residency statistics. Both domestically-owned and foreign-owned banking offices in the reporting countries record their on-balance sheet positions on other countries. Thus, the data are in the form of country aggregates and are consistent with the residency concept of national accounts. We include the following 21 reporting countries in our network: Austria, Australia, Belgium, Canada, the Cayman Islands, Switzerland, Germany, Greece, Denmark (excluding Faeroe Islands and Greenland), Spain, Finland, France (including Monaco), United Kingdom (excluding Guernsey, Isle of Man and Jersey), Ireland, Italy, Japan, Luxembourg, Netherlands, Portugal, Sweden, and the United States. Among these are those countries which are the most important to the network and many of the countries excluded do not have complete series. All together our subsample captures about 73% of total reporting banks' claims on banks in all vis-à-vis countries and the growth rate of the total claims in our subset is very similar to the growth rate in the total available to the BIS.

We apply our analysis to a sample starting in 1985 Q1 and ending in 2009 Q3. There are a few missing claims in the early data but we filled those in using the same proportion as the most complete data set that we have (2000 Q1). No one claim we filled in was more than 0.4% of the total value of all claims, and most were smaller than 0.1%. There were only eight claims filled in any year at most.

The ideal data set to measure cross-sectional systemic risk would contain the asset and liability positions of each banking entity vis-à-vis all of its counterparties, a breakdown of the maturity and currency denomination of all these financial contracts as well as the residency of and affiliation between these counterparties. But no such data set exists, or is likely to exist in the foreseeable future (Fender and McGuire, 2010). In its absence, the BIS locational by residency data set has to be judged in terms of its ability

Please cite this article in press as: Garratt, R.J., et al. The great entanglement: The contagious capacity of the international banking network just before the 2008 crisis. J. Bank Finance (2014), http://dx.doi.org/10.1016/j.jbankfin.2013.12.025