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Mapping change in the overnight money market

Morten L. Bech [a], Carl T. Bergstrom [b,c], Martin Rosvall [e], Rodney J. Garratt [d,*]

[a] Bank for International Settlements, Switzerland
[b] Department of Biology, University of Washington, United States
[c] External Faculty, Santa Fe Institute, United States
[d] Federal Reserve Bank of New York, United States
[e] Integrated Science Lab, Department of Physics, Umeå University, Sweden

HIGHLIGHTS

- We use a network clustering approach known as the *map equation*.
- We identify changes in lending patterns in the US overnight money market.
- Dramatic changes in lending patterns occur after the Federal Reserve begins paying interest on reserve balances.
- Analysis of micro-scale rates of change suggests these changes were triggered by the collapse of Lehman Brothers.

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ABSTRACT

We use an information-theoretic approach to describe changes in lending relationships between financial institutions around the time of the Lehman Brothers failure. Unlike previous work that conducts maximum likelihood estimation on undirected networks our analysis distinguishes between borrowers and lenders and looks for broader lending relationships (multi-bank lending cycles) that extend beyond the immediate counterparties. We detect significant changes in lending patterns following implementation of the Interest on Required and Excess Reserves policy by the Federal Reserve in October 2008. Analysis of micro-scale rates of change in the data suggests these changes were triggered by the collapse of Lehman Brothers a few weeks before.

1. Introduction

The overnight money market is an important part of the US financial system. Banks and certain other financial institutions use this market to reallocate liquidity among each other. As such, the market is the marginal source of funding for many financial institutions and the rates at which funds trade play a key role for monetary policy implementation, financing arrangements, and in the extension of credit in the economy.

In this paper, we demonstrate how a network clustering technique known as the *map equation* [1,2], that has been used successfully to shed light on the structure of scientific publishing, can be used to simplify and highlight important aspects of the overnight money market. Our analysis focuses on the period of unprecedented stress that hit the US financial system in the autumn of 2008. We show how the map equation can be used to better understand how the market responded to key events that occurred during this period, including the collapse of Lehman Brothers and the introduction of the Interest

* Corresponding author.
E-mail address: Rodney.Garratt@ny.frb.org (R.J. Garratt).

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on Required and Excess Reserves (IOER) policy initiated by the Federal Reserve, and form testable hypotheses on behavioral aspects of market participants.

Analysis of the overnight money market is complicated by the fact that there are several hundred active participants in this market [3,4]. Hence, it is difficult to identify patterns or changes in behavior without advanced techniques. We model the flow of payments generated by loans between institutions as a large weighted and directed network. Each node of this network represents an individual institution. Each link represents a loan; the value of loans between node A and node B determines the weight on the link from A to B. Given a network partition, the map equation measures the per-step description length of movements of flow on a network. Minimizing the map equation over all possible network partitions gives an optimal clustering with respect to the dynamics on the network. In the original formulation of the map equation, the flow was induced by a random walker guided by the directed and weighted links of a network. Because here the weighted and directed links already represent flow, which need not be ergodic, we measure the description length of the raw data and do not encode the movements necessary to make the flow ergodic [5,6]. In this way, we are able capture the actual payment flows associated with lending activity and reveal clusters of banks for which there is long persistence time.

To distinguish meaningful structural change from mere noise in the data, we perform parametric bootstrap re-sampling of the networks and assess the significance of each cluster [7]. Our maps reveal significant, tractable changes in clustering over the most intense period of the recent financial crisis. In particular, there are dramatic changes in lending patterns following the decision by the Federal Reserve to start paying interest on depository institutions' required and excess reserve balances.[1] Changes in lending patterns identified by the map equation may be a culmination of changes that began at an earlier point in time. Analysis of micro-scale rates of change in the data suggests the collapse of Lehman Brothers was the driving force behind the clustering changes we observed.

2. Related literature

Refs. [8,9] identify the network structure of two types of financial networks using the maximum likelihood approach developed in Ref. [10]. These works determine the network structure that is most likely to generate observed flows assuming that flows within groups are more likely than flows across groups. Both studies apply the technique to small networks: Ref. [8] considers the sterling unsecured loan market in the United Kingdom during 2006–2008 (12–13 banks), while Ref. [9] considers payment flows through the Canadian Large Value Transfer System from (14 banks). Ref. [11] examines interbank lending for the much larger, German banking system using a related approach in which a core–periphery structure is assumed, i.e., specific borrowing and lending relationships are assumed that apply to core versus non-core banks, and the assignment of banks to the core is selected which minimizes errors.[2] Both Refs. [9,11] consider pre-crisis data. Ref. [9] finds that a relatively stable, core–periphery structure emerges endogenously in the Canadian payment system with five core banks. Ref. [11] finds a relatively stable core size from 1999 until the middle of 2006 at which point the core size fell sharply from around 45 banks to 35 banks. Ref. [8] identifies a large increase in the core size and overall connectivity in the sterling unsecured loan market following Lehman's default.

The main difference between our approach and the maximum likelihood approach is that clustering arrangements in the latter are based solely on each node's direct connections and all links are undirected—meaning that no distinction is made between the borrower and the lender. This approach is appropriate for identifying changes in direct lending relationships, but it may not detect broader dependencies that exist through intermediate banks, nor does it help identify how funding shocks might propagate through the network. Under the map equation approach, both the direction and weights of all network linkages are utilized and direct and indirect linkages matter. Bank A will not tend to be clustered together with bank B if the lending relationship is unidirectional unless there is a broader lending cycle which connects the two banks through other banks. We argue that this approach may be preferred for identifying areas of funding risk. Moreover, instead of encoding a random walker that occasionally teleports to a random node for an ergodic solution, as in the original formulation of the map equation, we use a version that only encodes actual flows between banks without any need for teleportation [6]. In this way, our results only depend on the data and not on any parameter choice.

3. Data

Unfortunately, no data sources cover the entire overnight money market, at least in the US.[3] This is in part due to the over-the-counter nature of the market and the different platforms used to clear and settle transactions. Here, we look at

[1] Coinciding with IOER, the Federal Reserve's balance sheet expanded dramatically as reserves were added to the system, initially through credit and liquidity facilities created to support the financial markets during the crisis, and then by the Quantitative Easing. Since the fall of 2008, depository institutions in the United States have accumulated over $2.5 trillion in excess reserves, compared to the pre-crisis level in single digit billions. For more on IOER see http://www.federalreserve.gov/monetarypolicy/reqresbalances.htm.

[2] For a larger network, like the one considered in Ref. [11] (around 2000 banks), it is not feasible to examine all possible clustering combinations. The added structure imposed by Ref. [11] allows for a greedy algorithm.

[3] See http://www.federalreserve.gov/newsevents/press/bcreg/20130625a.htm for details on new data collection requirements related to selected money market instruments.