



Emergence of a core-periphery structure in a simple dynamic model of the interbank market[☆]



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ABSTRACT

This paper studies a simple dynamic model of interbank credit relationships. Starting from a given balance sheet structure of a banking system with a realistic distribution of bank sizes, the necessity of establishing interbank credit connections emerges from idiosyncratic liquidity shocks. Banks initially choose potential trading partners randomly, but over time form preferential relationships via an elementary reinforcement learning algorithm. As it turns out, the dynamic evolution of this system displays a formation of a core-periphery structure with mainly the largest banks assuming the roles of money center banks mediating between the liquidity needs of many smaller banks. Statistical analysis shows that this evolving interbank market shares the majority of the salient characteristics of interbank credit relationship that have been put forth in recent literature. Preferential interest rates for borrowers with strong attachment to a lender may prevent the system from becoming extortionary and guarantee the survival of the small peripheral banks.

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1. Introduction

While it had received only scarce attention for a long time, the interbank credit market has been in the focus of monetary policy authorities and financial economists since the outbreak of the still continuing financial crises in 2007/08. As it appeared from the contagion effects after the default of Lehman Brothers and the subsequent collapse of trading activity in unsecured money markets, interbank credit is a crucial component of the financial architecture of modern economies. Its disruption could lead to severe problems for the liquidity management of single institutions and the sudden rapture of established funding lines could trigger an avalanche of liquidity problems across the banking system. Macroprudential regulation and stress testing is paying more and more attention to the risks emerging from the various connections between financial institutions so as to make the system safer against interbank contagion effects. Understanding the structure of the existing network of credit relationships is, therefore, essential for an assessment of its potential risk. However, very little has been known until very recently about the topology of credit links between banks and its salient features.

In view of the events of the year 2008 and after, an increasing body of recent research has investigated the interbank market under the perspective of network theory. Indeed, interpreting the single banks as nodes and their credit

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relationships as links between nodes, one can represent such data in a straightforward way as a network, with credit volumes defining the so-called adjacency matrix of links between the underlying entities. With the surge of network research in the natural and social sciences, interbank data have occasionally been investigated from such a perspective even before the financial crisis, cf. [Boss et al. \(2004\)](#), [Inaoka et al. \(2004\)](#) or [Soramäki et al. \(2007\)](#). The predominant objective of this early literature had been to phenomenologically describe the data with popular network statistics such as the degree distribution, centrality of nodes etc. and to compare their structure with well-known canonical network models such as purely random, scale-free or small-world networks. Such a classification (if possible) could already provide important insights on the dangers of disruptions and inherent systemic risk as, for example, it is well-known that scale-free networks are in general robust to random disturbances but are highly vulnerable in the presence of targeted attacks on their most connected nodes.

Recently, attention has been shifting towards alternative models of the network structure that might be particular to socio-economic relationships and less so to phenomena in the natural world. A number of authors have argued that interbank relations might be akin to a core-periphery structure, a setting first proposed in sociology for networks of acquaintanceships (cf. [Borgatti and Everett, 2000](#)). The pioneering application of this model to interbank data is due to [Craig and von Peter \(2014\)](#). Using a data set on large loans and exposures between German banks they find a very stable set of banks forming the core of the system. They also found that alternative random and scale-free networks cannot explain the degree of stratification within the German banking system, and that total balance sheet size could predict how banks position themselves in the system.

[Fricke and Lux \(2014\)](#) have applied the core-periphery framework to data of the electronic platform e-MID that basically is used for short-term (overnight) liquidity provision. They also found that the structure of the networks derived from these data can be captured in a very robust way by a core-periphery model. Applying an asymmetric version of the core-periphery (CP) framework they also find that banks' roles as borrowers and lenders in the money market can be very different. Distinguishing between their "in-coreness" and "out-coreness" they found both measures to be virtually uncorrelated.

A core-periphery analysis of the UK interbank market is provided by [Langfield et al. \(2012\)](#) who use a comprehensive data set on connections between UK banks with a detailed breakdown into a large number of financial instruments. Identifying banks' roles in different segments of this multi-layered network topology, they also find some heterogeneity of their 'coreness' in different markets. [van Lelyveld and in't Veld \(2012\)](#) apply the core-periphery model to contractual obligations among Dutch banks at a quarterly frequency of reporting and also obtained a fit of the CP model in line with that reported in the papers discussed above. Summarizing this emergent literature, it appears that linkage structures between financial institutions can often be captured in a compact way by a core-periphery distinction or by assigning a 'coreness' statistic to the individual banks. Such an approach has been found to describe different data sets better than traditional network models inherited from the natural sciences and it has some economic appeal in that the network core mostly (though not exclusively) consists of large banks which assume the role of money center banks for the system.

A few papers have started to try and provide theoretical explanations for such a structure: [Hommes et al. \(2013\)](#) look at the formation of CP networks under the perspective of game-theoretic concepts of network stability. They find that such a structure would not be stable in a system of homogenous banks, but could be stable under sufficient size heterogeneity. In a somewhat different vein, [Castiglionesi and Navarro \(2011\)](#) show the stability of a CP network as the equilibrium structure in a setting where banks have the choice between a safe investment strategy and a 'gambling' project. The CP structure then emerges as the optimal way for providing liquidity insurance with 'gamblers' being positioned in the periphery.

We approach the question of how a CP structure might emerge from a different theoretical perspective using an elementary dynamic model of the interbank market. The basic ingredients to our model are as follows: (i) idiosyncratic liquidity shocks that hit all banks of a (closed) financial system in any period and that have to be evened out via the interbank market, (ii) a heterogeneous distribution of the balance sheet sizes of banks in accordance with empirical observations and (iii) a simple reinforcement-learning scheme that governs banks' decisions to contact other institutions as potential trading counterparts: If there has been a previous successful attempt at obtaining credit from a certain bank to overcome a liquidity shortage, the borrower will have a higher tendency of contacting this creditor again when another negative liquidity shock hits. If credit is denied, the 'trust' in this potential borrower will decline¹. Simulations show that this system quickly *self-organizes* into a core-periphery structure and also displays other realistic features found in interbank credit data. This finding suggests that the CP structure might be a natural consequence of a banking system with heterogeneous balance sheet size as we historically find it in industrialized economies. Not too much rationality and no knowledge of the complete structure of the system are, therefore, required on the part of liquidity managers, to deliberately create such a structure. On the contrary, single decentralized decisions based on past experiences would generically lead the overall system towards such a topology.

The present simple model is also, to the best of my knowledge, the first attempt to formulate a *dynamic* process of liquidity exchange within a heterogeneous banking system with fully specified balance sheet structure. It could, thus, be used as a starting point for various extensions studying other channels of connections between banks and could be used as a tool for dynamic stress tests in the presence of shocks to various types of assets and funding sources.

¹ [Iori et al. \(2014\)](#) use a similar trust function to explain preferential trading in the e-MID electronic overnight market for interbank credit.

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