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A network model of the interbank market

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ABSTRACT

This work introduces a network model of an interbank market based on interbank credit lending relationships. It generates some network features identified through empirical analysis. The critical issue to construct an interbank network is to decide the edges among banks, which is realized in this paper based on the interbank's degree of trust. Through simulation analysis of the interbank network model, some typical structural features are identified in our interbank network, which are also proved to exist in real interbank networks. They are namely, a low clustering coefficient and a relatively short average path length, community structures, and a two-power-law distribution of out-degree and in-degree.

1. Introduction

After the innovative researches on small-world networks by Watts and Strogatz [1] and scale-free networks by Barabasi and Albert [2], the study of complex networks has received increasing attention. Complex networks have become a general method for studying common properties of complex systems in the real world, and have penetrated into statistical physics, social sciences, biological sciences and many other fields. Applications of network theory in economic systems can be useful in considering explicitly the relations among economic agents. Many empirical analyses of economic systems have been constructed with the application of network tools, such as the world trade web [3,4], e-commerce [5], the correlation network of stock price returns [6–8], and commercial credit among firms, financial credit from banks to firms and interbank credit [9].

In the banking system, an intricate web of claims and obligations links the balance sheets of a wide variety of intermediaries, such as banks and hedge funds, into the structure of a network. As for the banking system, there is abundant theoretical economic literature on contagion risk and systemic risk which suggest various topological structures of the banking system, such as the complete and incomplete interbank structures [10], the 2-D directed lattice [11], money-center structure [12], a random network [13–15], and so on. In addition, some literature drew the conclusion that the banking system stability depended on its structure [16–19]. Therefore, it is of great importance to understand the structure of the real banking system. However, the structure of the real banking system is not completely in accord with the theoretical structure those scholars postulated.

There is a large literature on the study of the structure of the real banking systems, too. A case in point is the research on the banking systems in Japan, Austrian, UK, Germany, Hungary, the US, Italy and Brazil. With regard to the Japanese banking network constructed by banks and other financial institutions, the empirical analysis suggests that its network is scale-free and that its degree distribution follows a two-power-law distribution [20]. Boss et al. [21] analyzed the network structure of the Austrian interbank market, and found that: the degree distribution of the interbank network included two pronounced power-law regions; the interbank network had a small-world property; the interbank network also showed a community

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structure and a tiered structure. Similarly, tiered structures were found in many other banking systems, including that in the United Kingdom [22] and that in Germany [23].

For the topology of the Hungarian large-value transfer system, Lubloy [24] defined seven centrality indices for different aspects on the payment topology in order to analyze the permanency of the network over time, and found that the structure of the payments was permanent in June 2005. He also suggested that the Hungarian payment system could be characterized as a structure with multiple liquidity centers. Soramaki et al. [25] explored the network topology of the interbank payments transferred between commercial banks over the Fedwires Funds Service in the US, and found that the network had both a low average path length and low connectivity and that the degree distribution was scale-free over a substantial range. They also found that the properties of the network changed considerably in the immediate aftermath of the event of September 11, 2001.

For the Italian interbank market, it was proved to be a random network and its structure was suggested to be in evolution year after year over the period 1999–2002 [26]. The interbank network was changing with time, which was also found in the Brazilian interbank market [27]. Besides, the Italian interbank network was found to be highly heterogeneous, and large banks might lend funds from small banks. Also, a recent study [28] found that the Italian interbank market had two different communities, with one consisting of foreign banks and large banks, and the other composed of small banks. It indicated that the interbank market had a clear community structure. In addition, the Brazilian interbank network had been found bearing a weak evidence of a community structure and a high heterogeneity [29]. For the Brazilian banking network, Tabak et al. analyzed its topological properties by building the minimum spanning tree, and found that the private banks and foreign banks tended to form clusters within the network and banks with different sizes were also closely connected and tended to form clusters [30].

According to the above literature, the banking system is a complex network. As for the features of the banking network, scholars have been trying to explain their formation. For instance, Inaoka et al. constructed a growing model for banking networks to explain that a power law distribution is a self-organized critical phenomenon [31]. Vivier-Lirimont analyzed a model of interbank lending through a network of interbank relations, and then explained the densification of banking networks since the financial liberalization process that began in the 1980's so as to give a theoretic foundation to the small-world phenomenon [32]. De Masi et al. put forward a banking network model to analyze the formation of the community characteristic of the Italian interbank market [33]. In addition, a network growth model was proposed to theoretically explain the phenomenon of a two-power-law degree distribution in undirected banking networks [34].

Since previous studies mainly focus separately on the formation of one of the banks' structural features, this paper aims to construct a directed network model to make it close to the real interbank market structure, and to explain some emerging phenomena of interbank networks, namely, a community structure, a small world property and a two-power-law degree distribution. The model allows us to deeply and correctly understand the formation as well as the evolution mechanism of real interbank networks. This paper is organized as follows. The approach to construct interbank networks is introduced in Section 2. The simulation analysis is conducted in Section 3. And the conclusion is drawn in Section 4.

2. The model

The interbank market emerges as a consequence of the banks' needs to manage their liquidity. Since the loans are originated out of the fact that every bank needs liquidity in order to satisfy the demands of its customers, credit lending relationships exist among banks. In this paper, a network model of an interbank market is constructed based on interbank credit lending relationships. An interbank network can be described as $G(V, E)$, which consists of a non-empty set of banks V called notes and a list of unordered pairs of elements called edges E. If i and j are nodes of G, an edge from i to j is said to join or connect i and j, where the edge denotes the interbank credit lending relationships.

In order to explain the formation of the interbank network, we suggest a setup for a network model of the interbank market, though in real life it is much more complex. In our interbank network model, we postulate that it is easy for homogeneous banks that belong to the same type or have similar sizes to establish interbank credit lending relationships. In addition, the second postulate we set is that a bank decides its credit lending relationships with other banks depending on its credit degrees to other banks. Provided with these two postulates, our interbank network model is addressed as follows:

(i) *Categorizing banks in the interbank market*. Supposing that the number of banks in the interbank market is N, we categorize all the banks into l different groups according to a certain characteristic of the banks (such as their sizes or types). Let n_i denote the number of banks in group i ($i = 1, 2, \ldots, l$), where $n_1 + n_2 + \cdots + n_l = N$.

(ii) *Fixing the trust vector*. Generally, there are no sponsion or mortgages in the credit lending relationships, for they are fully established out of credit. Let $(w_{i1}, w_{i2}, \ldots, w_{iN})$ denote the trust vector of bank i to other banks, where $w_{ii} = 0$ and w_{ij} follows a normal distribution.

(iii) *Deciding interbank credit relationships in the same group*. In group l_i, there is credit lending relationships between bank i and bank j if $w_{ij} \geq \tau_i$, where bank i is the creditor bank and bank j is the debtor bank. Normally, different banks have different trust thresholds, so here we let τ_i be at intervals of $[a, b]$, where τ_i is the trust threshold of bank i.

(iv) *Deciding interbank credit relationships in different groups*. For group l_i and group l_j, we select randomly r_{ij} banks from group l_i, and then decide their credit lending relationships with banks in group l_j. For bank s in r_{ij} banks, we decide its credit lending relationships with banks in group l_j according to step (iii). But the sum of the credit relationships $n_{ij}(s)$ is