Physica A 463 (2016) 131–138

Contents lists available at ScienceDirect

Physica A

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

A dynamic network model for interbank market

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HIGHLIGHTS

- We construct a dynamic network model based on agent behavior for interbank market.
- We investigate the impact of credit lending preference on network topology.
- We investigate the evolution of interbank market network.
- We analyze shocks to the stability of interbank market.

ARTICLE INFO

Article history:
Received 23 September 2015
Received in revised form 14 June 2016
Available online 21 July 2016

Keywords:
Interbank market
Agent behavior
Dynamic network
Risk preference
Shock

ABSTRACT

In this paper, a dynamic network model based on agent behavior is introduced to explain the formation mechanism of interbank market network. We investigate the impact of credit lending preference on interbank market network topology, the evolution of interbank market network and stability of interbank market. Experimental results demonstrate that interbank market network is a small-world network and cumulative degree follows the power-law distribution. We find that the interbank network structure keeps dynamic stability in the network evolution process. With the increase of bank credit lending preference, network clustering coefficient increases and average shortest path length decreases monotonously, which improves the stability of the network structure. External shocks are main threats for the interbank market and the reduction of bank external investment yield rate and deposits fluctuations contribute to improve the resilience of the banking system.

1. Introduction

Interbank market permits liquidity exchanges among financial institutions through facilitating the allocation of the liquidity surplus to illiquid banks. Complex network relationships are formed through interbank lending, payment and settlement, discount and guarantee. On one hand, the complex debtor–creditor relationships between banks provide channels for interbank liquidity exchanges, but on the other hand, they also become potential paths for financial contagion, which may trigger the domino effect. For example, the US sub-prime mortgage crisis broke out in August 2007, resulting in large number of bank failures (such as Lehman Brothers, Washington Mutual Bank, Colombia Trust, etc.), which quickly evolved to a global financial crisis and greatly damaged the global financial system.

Complex network theory is an important tool for complex system modeling and its common topologies include Erdős–Rényi random graph [1], small world network [2,3], scale-free network [4], etc. Multi-agents methods can be used to model and analyze the behavior of agents. Interbank market has shown a high degree of complexity and intelligence and owns a variety of network structures [5,6] (such as money center structure, complete market and incomplete market, etc.).

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http://dx.doi.org/10.1016/j.physa.2016.07.013
0378-4371/

There has been large number of empirical literature on interbank market network structure. Souma, Fujiwara, Aoyama [7] found that the Japanese business network had scale-free property through empirical results. The work of Boss, Elsinger, Summer et al. [8] showed that the Austrian interbank network followed power-law distribution, interbank liability network owned a community structure, a low clustering coefficient and a short average path length. The structure of Italian interbank market proved to be a random network, changed over time [9], and consisted of two communities, one mainly composed of large and foreign banks, the other composed of small banks [10]. Brazilian interbank network structure emerged as a weak community structure and with high heterogeneity [11]. Tabak, Cajueiro and Serra [12] constructed the Brazilian interbank network with minimum spanning tree method and they discovered that the private and foreign banks tended to form clusters within the network and that banks with different sizes were also strongly connected and tended to form clusters. Soramäki, Bech, Arnold et al. [13] found that the US interbank market network had a low average path length and low connectivity, and the degree distribution was scale free over a substantial range. Craig, Von Peter [14] developed a coreperiphery model and found evidence of tiering in the German banking system. Peltonen, Scheicher, Vuillemey [15] suggested the CDS network exhibited a "small world" structure and a scale-free degree distribution.

Recently, scientists tried to use simulation modeling methods to explore the formation mechanism of interbank market network structure. Wan, Chen, Liu [16] developed a growth network model to explain the phenomenon of two-power-law distribution of banking system. Inaoka, Takayasu, Shimizu et al. [17] proposed a procedure to construct a network structure from a set of records of transactions, which was followed by a power-law degree distribution. Li, He and Zhuang [18] introduced an interbank market network model based on interbank credit lending relationships and showed typical structural features such as a low clustering coefficient and a relatively short average path length, community structures, and dual power-law distribution of out-degree and in-degree.

Through the above analysis, we summarize the following disadvantages for current simulation models to construct a interbank market network: The structure of the interbank network constructed by current models is static, which does not change with bank dynamic behavior over time; Building processes of interbank market by the current models are relatively simple, usually by assuming the interbank market to be a particular network architecture, such as a random network, a small-world network or a scale-free network, which does not take the bank's own behavioral characteristics (such as asset liabilities) into consideration. But empirical results have demonstrated that the actual interbank market network structure evolves over time [9], the establishment of an interbank lending relationship is associated with bank credit lending scales, banks with different credit lending scales tend to establish strong connections and easily form cluster structures [12]. In this paper, we build a dynamic bank balance sheet to describe the bank dynamic behavior and develop a model to construct interbank market network based on bank behaviors. Moreover, the evolution of the structure of interbank market network is analyzed. Finally, we investigate the effects of fluctuations of deposit and investment yield on the stability of the interbank market network.

The remainder of this paper is organized as followed. The interbank market network model is introduced in Section 2, simulation experiments and relative analysis are presented in Section 3, further discussions are made in Section 4, and conclusions are given in Section 5.

2. The model

In this paper, a directed graph $G = (V, E)$ is used to denote the interbank market, where the parameter V represents the set of all of banks and the parameter E is the collection of all credit links between banks. A directed edge $e_{i,j}$ exists between nodes $i, j \in V$, if and only if bank i is the creditor of bank j. We assume the number of total banks $|V| = N$, N_i denotes a collection composed of neighbors of bank i, and matrix $X = (x_{ij})_{N\times N}$ represents credit lending scales of banks, where x_{ij} denotes the credit lending of bank i to bank j. L_i is the lending scale of bank i, satisfying $L = \sum_{1\le i\le N} L_i$, $L_i = \sum_{j:j\neq i} x_{ij}$. The behavior of each bank agent is described through its balance sheet, which varies dynamically over time. Moreover, it is assumed that the connections of credit lending links between banks only rely on the latest bank balance sheet, since interbank credit lending only satisfies short-term liquidity exchanges among banks. The processes of the construction of initial bank balance sheet, bank balance sheet update and the construction of interbank market network are listed below.

2.1. Initial bank balance sheet

To formulate the actual bank balance sheet, we assume the items of assets of bank j include bank external investments I_j, interbank loans L_j and liquid assets M_j and liabilities involve deposits D_j, interbank borrowing B_j and equities E_j. From the accounting equation, we can get $I_j + L_j + M_j = D_j + B_j + E_j$. Furthermore, the initial deposits D_j^0 are assumed to account for α of the total initial assets, and the ratio of interbank borrowing B_j and liquid assets M_j to the total assets is β and γ, respectively. The detailed process to construct balance sheet of bank j is listed below.

- Interbank loans and borrowing. Initial interbank borrowing B_j^0 of bank j is generated through power law distribution: $P(l) \sim l^{-\tau}$, where τ is the parameter of power law distribution [8]. Interbank credit lending scales matrix $X = (x_{ij})_{N\times N}$ can be computed through the interbank market network built by the algorithm in Section 2.3, with $x_{ij}^0 = B_i^0 B_j^0 / \sum_{k:j\in N_k} B_k^0$. Then, the initial interbank loans can be calculated as $L_j^0 = \sum_k x_{jk}^0$.