Financial Networks and Systemic Risk in China's Banking System

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Abstract: In this paper, using two alternative methods, we investigate the contagion effects and systemic risk in China's commercial banks system based on the balance sheet data and the estimation on interbank exposures. First, we calculate various indicators in terms of the balance sheets of individual commercial banks to quantify contagiousness and vulnerability for China's banking system without considering the detailed topology of interbank networks. Second, we estimate the detailed bilateral exposures matrix of the interbank network to examine the domino effects and snowball effects of financial contagion. The simulation results from two alternative approaches are consistent. Both suggest that the contagious risk arising from an assumed bank failure is trivial in Chinese banking system, whereas the amplification effects of the losses due to the financial interlinkage are non-trivial. In particular, we identify the systemic important banks in terms of a relative contagion index and the measures capturing the topological features of the interbank networks, respectively. Our study provides insights for the prevention of systemic risk and the implementation of macroprudential oversights in China's banking system.

Keywords: Balance Sheets; Interbank Networks; Financial Contagion; Systemic Risk; China's Banking System

JEL Code: D85, G21, G28

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1. Introduction

The "too connected to fail" (TCTF) problem in modern financial system has attained more and more concerns from academics and policymakers recently, because the financial interlinkages stemming from both asset and liability sides of financial institutions' balance sheets would spread and amplify the damage effects of various shocks by creating channels of financial contagion, and thereby yields systemic risk and financial disruptions at macro level. The interbank markets across the countries, especially in advanced economies, have been the focuses of the studies on financial contagion that could lead to systemic risk due to their typical financial interconnected structure[2], whereby the systemic important financial institutions are identified and the insights for macroprudential regulation are developed. Concentrating exclusively on China's interbank markets in this paper, we investigate the topological features of China's banking system, and measure the systemic contagion effects of financial networks when a bank failure occurs under an idiosyncratic shock which wipes out its outside assets. Our study complements the existing literature by applying two alterative methodologies in assessing the contagion risk and identifying the systemically important banks, thereby sheds lights on the prevention of systemic risk and the implementation of macroprudential policy for China's financial stability.

Our study and the contributions to the literature can be summarized in several respects. First of all, following the methodology proposed by Glasserman and Young (2015, 2016), we use the balance sheet data of China's commercial banks to examine the contagious effects and systemic risk in the interbank market without considering the detailed topological structure of Chines interbank markets. In doing so, we find that the probability of contagion arising from the failure of one bank is minimal or

[2] See, the related literature in Section 2.

almost impossible in terms of our sample. Nevertheless, the calculated multiplying factors show that the amplification effects of the losses stemming from a bank default through the channel of interbank interconnectedness are non-trivial, reaching approximately 2.73 times. Second of all, we define a relative contagion index, which is calculated in terms of the structural variables of a bank's balance sheet, reflecting the financial connectivity and the outside leverage of a bank, With this relative contagion index, we identify the systemic important banks in China. Third of all, we employ the maximum entropy approach to estimate the bilateral exposures matrix of the interbank network, and then analyse the topological features of Chinese banking system by applying k-clique, partitioning, and hierarchical clustering techniques. The results demonstrate that Chinese interbank network presents a typical core-periphery structure. In addition, we find that the network centrality coefficients of banks are significantly correlated with the interbank assets, interbank liabilities and total assets, and therefore closely connected with the abovementioned relative contagion index. Fourth of all, we simulate the contagion effects and systemic risk with the estimated topological matrix by calculating the number of banks that default by contagion and the losses as a fraction of the total assets caused by an assumed bank failure due to an idiosyncratic shock. The simulation results in terms of the round-by-round algorithm show that, the contagious possibility of a bank failure through the interbank network is very low, whereas the losses amplified suffered from the bank failure through the interbank network are relatively high in China. Finally, our study illustrates that the simulation results from two approaches[3] are consistent. In sum, our empirical simulations suggest that the domino effects of financial contagion in Chinese banking system are trivial, whereas the amplification effects of financial contagion due to the

[3] As abovementioned, one only uses the balance sheet data without considering the detailed topological structure, another one needs to estimate the bilateral exposures matrix.

financial interconnectedness are non-trivial. Therefore, the systemic risk in Chinese interbank market should attain proper concern by the policymakers and prudential regulators.

The rest of the paper proceeds as follows. Section 2 discusses the progress in related literature. Section 3 presents the data and the stylized facts of Chinese banking system. Section 4 describes the methodology. Section 5 simulates the financial contagion and calculates the systemic losses arising from a bank default without considering the detailed topology of China's interbank networks. Section 6 investigates contagion risk and systemic losses through the transmission channels of estimated interbank networks. Section 7 makes the conclusive remarks.

2. Related Literature

In the aftermath the global financial crisis of 2008, there is growing interest in the analysis of financial contagion and the relevant systemic risk, particularly using network models. Banks are highly interdependent and closely linked together via bilateral exposures in the interbank market, forming a typical financial network, which promotes the efficiency of banking system by sharing the risk and reducing the costs on one hand, provides spreading and propagation channels of systemic risk within the financial system on the other hand. Thus, the interbank networks have commanded the attention of much of academic literature and have dominated the discussion on the financial instability and the macroprudential regulation.

In a foundational research, Allen and Gale (2000) show that the pattern of interconnectedness of the banking sector or the topological structure of interbank markets is crucial for the possibility of financial contagion. They suggest that a "complete" structure of interbank network enhance the ability of withstand shocks to the banking system than an incomplete structure, where every bank doesn't have symmetric linkages with all other banks in the financial system. Unfortunately, the actual structure of the interbank networks is unknown in most countries because national authorities and banks do not release the relevant data[4]. A solution to this problem is to estimate the adjacent matrix of the bilateral claims and obligations by maximum entropy in terms of bank balance sheet data. Following this methodology, vast studies on various interbank markets across countries contribute to the growing body of literature: Sheldon and Maurer (1998) for the Swiss banks; Upper and Worms (2004) for the German banking system; Boss et al. (2004) for the Austrian interbank market; Wells (2004) for the UK-resident banks; van Lelyveld and Liedorp (2006) for the Dutch banking sector; Elsinger et al. (2006a, b) for the Austrian banking system; Mistrulli (2011) for Italian interbank market. Although the maximum entropy method is optimal and extensively applied when the true network structure is unknown, some inherited drawbacks, in particular the assumption of complete interbank linkages, could lead to misleading results or biases because the real interbank networks are typically sparse and relationship-oriented. As such, alternative methods are developed for estimating the topological structure of interbank networks, including the transfer entropy method proposed by Li et al. (2013), and the minimum density approach developed by Anand et al. (2014). The former builds the interbank market structure by calculating the transfer entropy matrix using bank stock price sequences. The latter loads the most probable links with the largest exposures consistent with the total claims and obligations of each bank to produce the interbank network topology. Liang et al. (2016) find that the simulations based on the results from the transfer entropy and from the maximum entropy are consistent when applied to Chinese banking system. In contrast, Anand et al. (2014) show that the maximum-entropy method

[4] Germany, Italy and Brazil are ones of few exceptions, where the true bilateral exposures are reported to the monetary authorities. See, for example, Memmel et al. (2012), Craig and von Peter (2010), Mistrulli (2011), and Cont et al. (2012).

underestimates the contagion risk, whereas the minimum-density method may overestimate it when used in a stress-testing context.

A second methodology for investigating financial contagion in the interbank markets is proposed by Glasserman and Young (2015, 2016), which assess the contagion risk without considering the detailed topology of the interbank networks, instead only use the balance sheets data including the aggregate bilateral exposures[5]. Our study firstly employs their theorems to quantify the contagion risk and identify systemic important institutions for Chinese banking system, and then compare the results with the results from the simulation by estimating the topology of Chinese banks with the maximum entropy method.

Generally, network models examine the contagion and systemic risk by calculating the number of institutions that defaults by contagions and the losses as a fraction of the total assets that arise from an assumed bank default in the banking system. In simulating the effects of the financial contagion among a fraction of US banks, Furfine (1999, 2003) firstly developed the round-by-round algorithm (or sequential default algorithm named by Upper, 2011), in which a bank failure due to an idiosyncratic shock is assumed and then the losses of other banks that have exposures to the failed bank are calculated and compared with their capitals. If the losses are greater than its capital for any bank, the relevant bank fails and drops from consideration. The simulation is then iterated by assessing if banks fail in each round make other banks fail in later round, the iteration procedure continues until no bank failure. This algorithm is extensively employed by researchers[6]. A second algorithm is the fictitious defaults algorithm with the clearing vector proposed by Eisenberg and Noe (2001), which investigate the path of contagion from the trigger to the first and

[5] This method derives from the fictitious defaults algorithm proposed by Eisenberg and Noe (2001), we will describe it in Section 5 in detail.
[6] See, the Appendix 1 in Upper (2011).

higher rounds of contagion. The difference between two algorithms, according to Upper (2011), lies in how to deal with the simultaneity problem. The round-by-round method does not consider the impact of higher order defaults on the losses of previously failed banks, whereas the fictitious defaults algorithm does. Our simulations in Section 6 follow the sequential default approach.

At least three mechanisms of financial contagion[7] through the banking networks have been observed and simulated in literature: the first is the “Domino effect” (the failure of a single bank can potentially trigger a whole chain of subsequent failures) or the knock-on effect through the direct spread channel of lending exposures in the interbank, which measures the possibility of contagion. The second is the “Snowball effect” or the amplification effect through the propagation of contagious damaging within interbank networks, which calculates the severity of contagion. The third one is the “Spiral effect” or fire sale externality, in which liquidity shortage in the interbank market caused by two abovementioned effects leads to the fire sale of banks’ outside assets to satisfy the capital requirements and the interbank exposures, forcing the vicious fall in the price of assets and thus the losses-given-default, which introduces other banks to sell non-liquid assets under distress, eventually enhance a small shock into a spiralling chain of sales and losses by a positive feedback circle[8].

The insights provided by the empirical works with network model include: first, the interbank network does affect the overall level of systemic risk within the financial system due to the spread and propagation effects of contagion in the system. Second, contagious risk occurs with low probability[9] in most economies but produces high costs once it happens. Third, the bank-specific features and the topological

[7] See, a detailed discussion on the channels of financial contagion, for example, the survey by Upper (2011).
[8] See, for example, the discussions by Aldasoro et al. (2016).
[9] Cont et al. (2012), however, show that the contagions are more frequent than previous studies when examining the actual the network structure of the Brazilian financial system.

structure of interbank networks determine the transmission channels of financial contagion and thereby uncover the formation mechanism of systemic risk in the banking system, should therefore be attained more concerns by the policy makers and prudent regulators.

3. Data and China's Interbank Market

In broad terms, China's interbank markets consist of FX spot market, money market, bond market, and derivative market. This paper restricts it to the money market in which financial institutions conduct bilateral trading. The participants in China's interbank market contain policy banks, commercial banks, cooperatives, insurance companies, security companies, trustees, financial funds, and other financial companies. Given that commercial banks dominated the bilateral transactions in the interbank market and banking activities in China's banking sector (Figure 1 presents China's banking sector), we focus on three categories of commercial banks in our study: 5 big state-owned commercial banks, 12 joint-stock commercial banks and 133 city commercial banks[10]. The total assets of these three types of commercial banks account for approximately 88.45% of the aggregate assets owned by all commercial banks, and account for approximately 69.14% of the assets owned by all banks. Our sample data of banks' balance sheet source from the Wind database (hereafter Wind) and China Banking Regulatory Commission (hereafter CBRC). Due to the data availability for 2015, 124 rather than 133 city commercial banks are adopted in our sample, besides all the big state-owned commercial banks and the joint-stock commercial banks.

Figure 2 depicts the changes in the total assets and total liabilities of the commercial banks for the period of 2003-2015. At the end of 2015, the total assets of

[10] The other two types of commercial banks are rural commercial banks and foreign commercial banks.

the banking sector reached 199,345.4 billion yuan (RMB, China's national currency), which is approximately 7.21 times the level of 2003, with the average annual growth rate at 47.75%. On the other hand, the total liabilities and the net assets of the banking sector are 184,140.1 and 15,205.3 billion yuan, which are approximately 6.92 and 14.29 times the levels of 2003, respectively.

Figure 1 China's Banking Sector

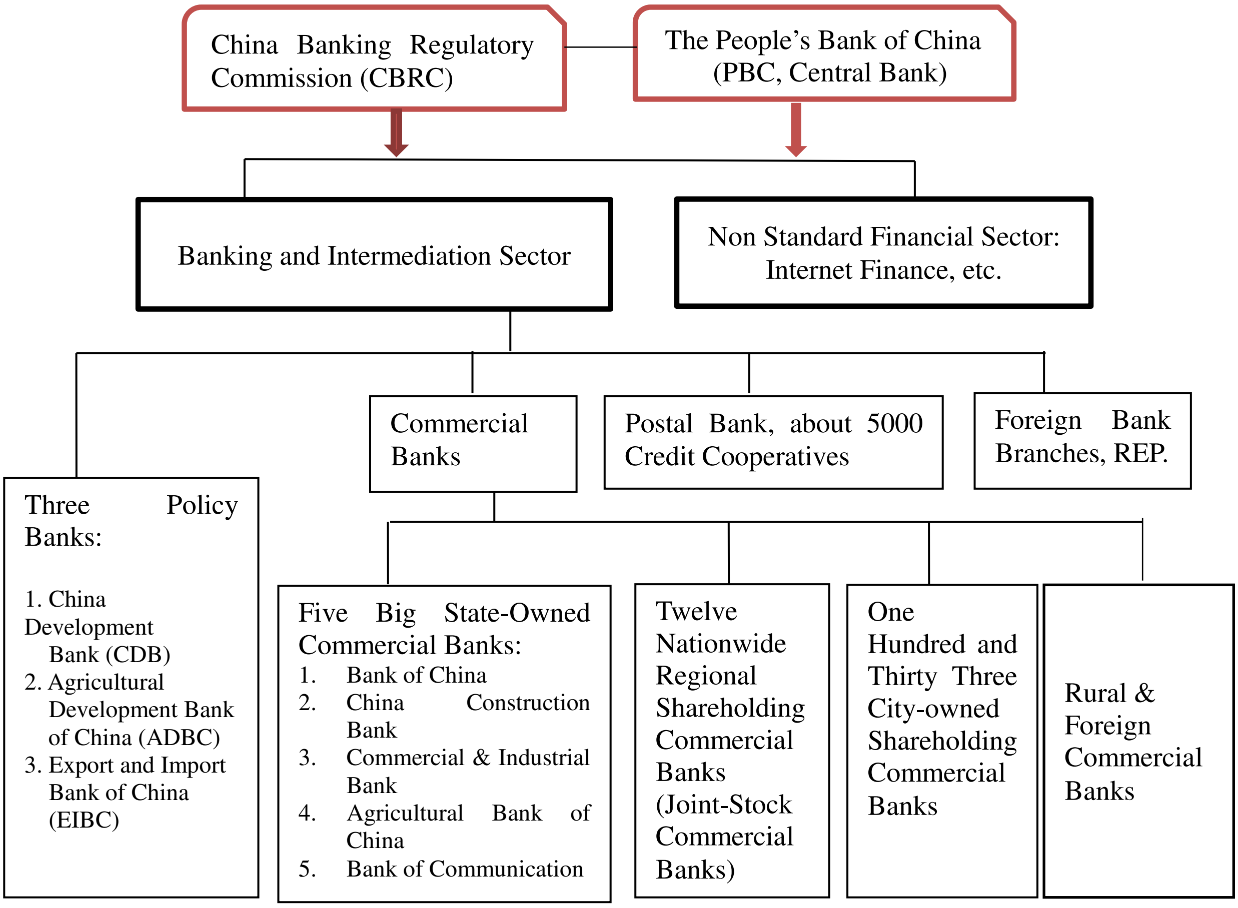
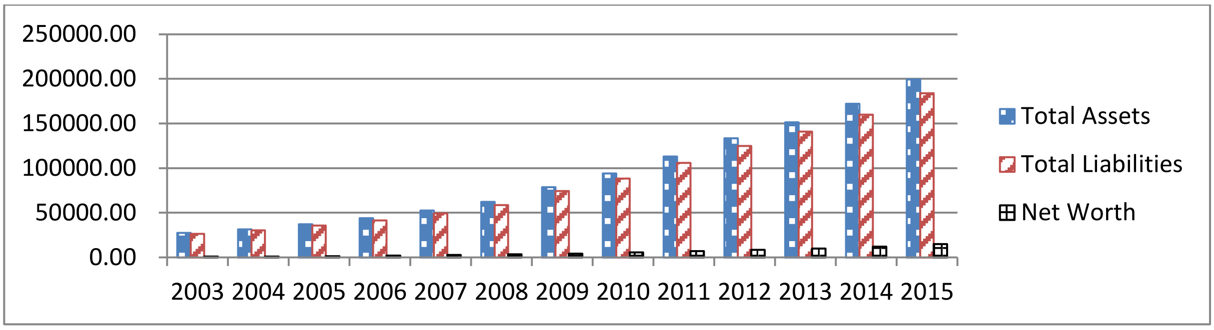


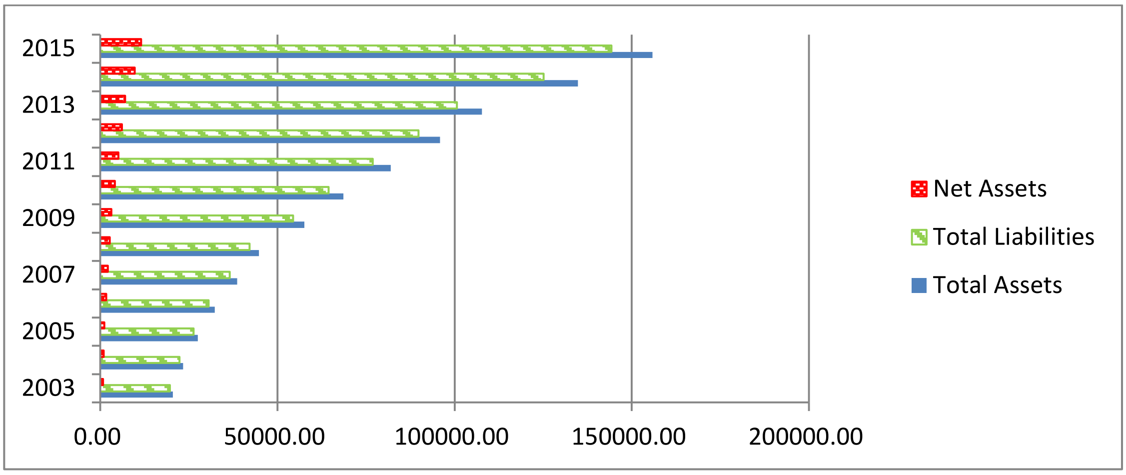
Figure 2, Changes in the Balance Sheets of the Banking Sector (Unit, Billion Yuan)



Source: CBRC

The total assets, total liabilities and net assets of the commercial banks are plotted in Figure 3 for the period of 2003-2015. The total assets, total liabilities and net assets grew by average annual rates at 51%, 49%, and 104% during 2003-2015, reaching 155,825.7, 144,268.2, and 11,557.5 billion yuan at the end of 2015, respectively.

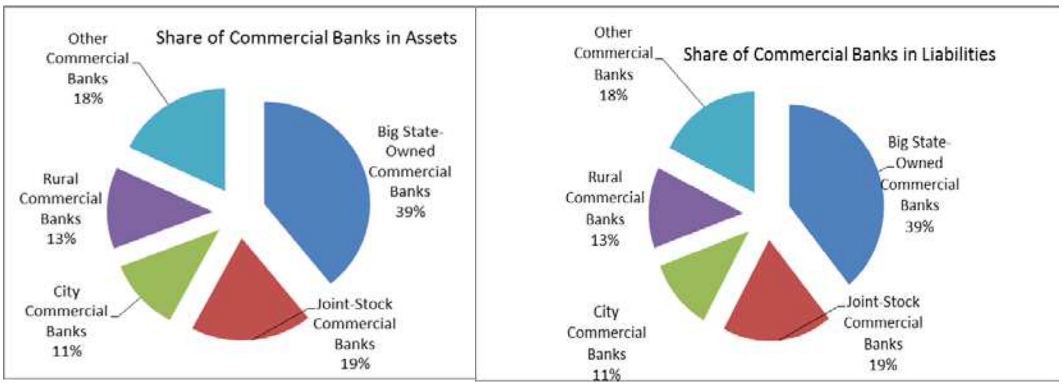
Figure 3 Changes in Balance Sheets of the Commercial Banks (Unit, Billion Yuan)



Source: CBRC

Figure 4 presents the changes in the shares of balance sheet data for each category of commercial banks in the banking sector at the end of 2015. It indicates that the three categories of commercial banks in our sample account for approximately 70% of the banking sector.

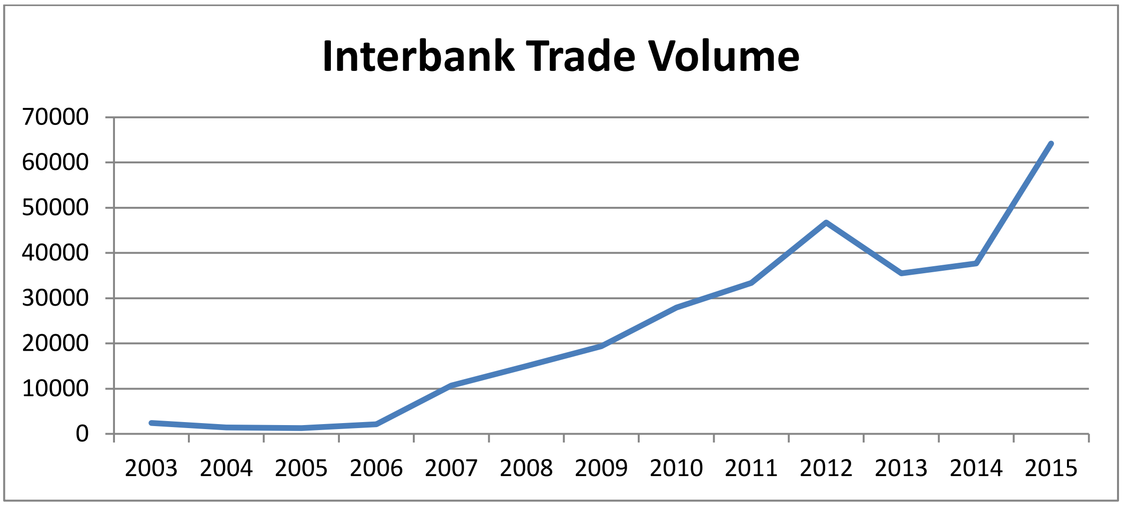
Figure 4 Shares of Each Category of Commercial Banks at the end of 2015



Source: CBRC

The evolution of trade volumes in China's interbank market during 2003-2015 is illustrated in Figure 5. At the end of 2015, the interbank market borrowings attained 64,200 billion yuan, which is approximately 93.17% of current GDP. Despite its rapid growth, China's interbank market is still under developing and needs time to mature.

Figure 5 Trade Volumes in China's Interbank Market (Unit: Billion Yuan)

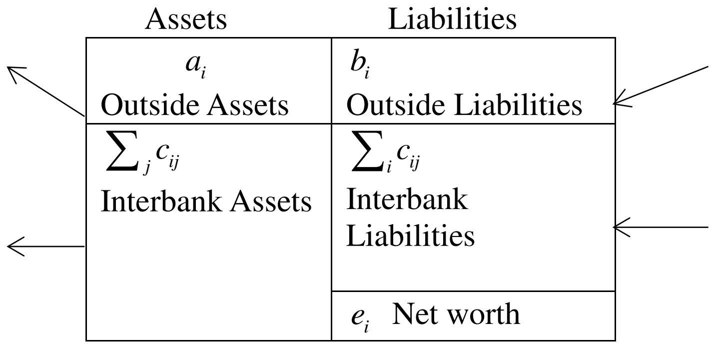


Source: Wind.

4. Balance Sheets and Interbank Networks-Methodology

Following Allen and Gale (2000), Glasserman and Young (2015, 2016), the stylized balance sheet of an individual commercial bank i is depicted in Figure 6, in which the bank's assets compose of the outside (interbank market) assets (denoted by a_i) and the interbank assets (denoted by $\sum_j c_{ij}$). The former is the claims of bank i on entities such as loans and equities outside the interbank market. The latter represents the claims of bank i on other financial institutions in the interbank market. Similarly, the bank has two types of liabilities: outside liabilities (denoted by b_i), which are obligations to entities such as deposits from the households outside the interbank market; and interbank liabilities (denoted by $\sum_i c_{ij}$), which are obligations to other financial institutions in the interbank market. The difference between the bank's assets and liabilities are the net worth (denoted by e_i)

Figure 6 Stylized Balance Sheet of a Bank



The interbank claims and obligations (c_{ij} s in Figure 6) connect the commercial bank together and formulate a financial network, in which an individual bank is represented by a *vertex*, and the *links* (directed edges or arcs) between banks show the bilateral exposures relationships. Specifically, in an interbank network we use outwards arrowed lines to represent the claims (interbank assets) that the starting vertex owed to the ending vertex (the arrow pointing to), and the inward arrowed lines to represent the obligations that the ending vertex owes to the starting vertex. In addition, the sizes of the bilateral exposures between banks are defined by *weights* and shown by the *strength* of the lines in the network. Therefore the interbank networks in our study are *weighted directed networks,* in which the number of the bilateral connections in a directed network is identified by the *in-degree* and *out-degree* of vertices, respectively, in terms of the edges' direction.

More specifically, a *weighted directed network*[11] can be described by an *adjacency matrix* C with entries c_{ij} , where c_{ij} denotes the exposure of bank j towards bank i, or the claims that bank i towards bank j. For N banks, we have

[11] More detailed discussions on the complex networks, see, for example, Newman (2010), Chen et al. (2015), and Sun and Shi (2015).

following adjacency matrix

$$C = \begin{bmatrix} c_{11} \cdots c_{1j} \cdots c_{1N} \\ \vdots \\ c_{i1} \cdots c_{ij} \cdots c_{iN} \\ \vdots \\ c_{N1} \cdots c_{Nj} \cdots c_{NN} \end{bmatrix}$$

where the sum of the elements in a given row i: $\sum_{j=1}^{N} c_{ij}$, denotes the total interbank assets owned by bank i, and the sum of the elements in a given column j: $l_j = \sum_{i=1}^{N} c_{ij}$, denotes the total interbank liabilities of bank j. Straightforwardly, the diagonals of the matrices C are all zeros.

The balance sheets and the interbank topology provide a framework by which we can simulate the financial contagion and systemic events to prevent the occurrence of the financial fluctuation. In what follows, we will flesh out this framework with the balance sheets data and interbank structure of China's commercial banks, and then examine the contagion risk and systemic losses of Chinese banking system through the interbank channels of propagation and amplification subjects to an idiosyncratic shock by using two alternative approaches.

5. Measuring Contagion and Systemic Risk without Considering the Detailed Interbank Structure

Glasserman and Young (2015, 2016) developed the following theorems to assess the contagiousness and vulnerability of financial institutions without knowing the details of the entire interbank network structure.

Glasserman and Young Theorem 1[12] *Assume the shocks are i.i.d., beta distributed, and that the net worth of every vertex is initially nonnegative. Let* D *be a nonempty subset of vertices and let* $i \notin D$*, contagion from* i *to* D *is impossible if*

$$\sum_{j \in D} e_j > e_i \rho_i (\theta_i - 1) \qquad (1)$$

and it is weak if

$$\sum_{j \in D} e_j > e_i \rho_i \sum_{j \in D} (\theta_i - 1) / \theta_j \qquad (2)$$

where ρ_i denotes the *financial connectivity* of bank i, measured by the proportion of bank $i's$ liabilities to other entities in the financial system: $\rho_i = l_i / (b_i + l_i)$. θ_i denotes the leverage of bank $i's$ outside assets: $\theta_i = a_i / e_i \geq 1$.

Note that the right-hand side of (1) is defined as *contagion index* of bank i by Glasserman and Young (2016). The contagion index calculates the currency amount of bank i's obligations to other banks, and thus the potential impact on the rest of the banking system if i defaults. A higher contagion index implies that the relevant bank is more susceptible to failure (due to high leverage) that has large consequences (due to its size) and potentially large impacts on the rest of the banking system (due to its high financial connectivity) (Glasserman and Young, 2016).

The total leverage of bank i (denoted by θ_i^*) equals to its total asset divided by its net worth, producing $\theta_i^* = (b_i + l_i + e_i) / e_i, \theta_i^* \geq \theta_i$. The condition that bank j is relatively immune to a shock from bank i satisfy

$$c_{ji} / e_j < (\theta_i^* - 1) / (\theta_i - 1) \qquad (3)$$

Theorem 1 developed by Glasserman and Young (2015) implies that the financial contagion in a financial system depends on some critical parameters, such as

[12] On the proofs of the regarding theorems, see, Glasserman and Young (2015).

the financial connectivity, the net worth, and the degree of leverage of bank i, rather than on the distribution of shocks or on the topology of the network.

Glasserman and Young Theorem 2. *Let* $N(a,b,e,\overline{P})$ *be a financial system and let* N^O *be the analogous system with all the connections removed. Assume that the shock distribution is homogeneous in assets and IFR*[13]*. Let* $\rho^+ = \max_i \rho_i < 1$ *and let* $\sigma_i = P(\varepsilon_i \geq e_i)$. *The ratio of expected losses in the original network to the expected losses in* N^O *is at most*

$$\frac{\overline{L}}{\overline{L}^o} \leq 1 + \frac{\sum \sigma_i a_i}{(1-\rho^+)\sum a_i} \tag{4}$$

where σ_i is the probability of default for bank i. If introducing the marginal probability of default σ, the $m = 1 + \frac{\sigma}{1-\rho^+}$ can be defined as the amplification factor of the financial networks.

Using the balance sheet data of China's commercial banks at the end of 2015, which are composed of 5 big state-owned commercial banks, 12 joint-stock commercial banks, and 133 city commercial banks[14], we calculate the contagion indices for the banks and assess the contagion risk in China's interbank market. Table 1 in Appendix summarizes the results.

Columns 4-9 in Table 1 present the components of balance sheets of commercial banks. Column 10 calculates the proportion of bank liabilities to other entities in the financial system (ρ_i), or the measurement of *financial connectivity* of banks. The ratios of interbank liabilities range from 0.00 to 0.42 with the average at 0.14, which is close to the average value at 0.149 for the 50 largest of European banks, estimated

[13] IFR: increasing failure rate. In general a random variable with distribution function G and density g is said to have an increasing failure rate (IFR) distribution if $g(x)/[1-G(x)]$ is an increasing function of x. All normal, exponential, and uniform distributions are examples of IFR distributions (Glasserman and Young, 2016).

[14] Due to the data availability, only 115 city commercial banks are included in our sample.

by Glasserman and Young (2015).

Column 11 reports the leverage of outside assets (θ_i). The average of θ_i is 13.68 for 132 Chinese commercial banks (ranging from 7.65 to 21.23), which is far lower than the average of θ_i for the 50 largest of European banks at 24.9. This reflects that most Chinese commercial banks have sound capital adequacy ratios.

Columns 12 and 13 calculate the contagion index and the sum of net worth for other commercial banks, respectively. Comparing the results from column 12 and column 13 in terms of Theorem 1, we conclude that the probabilities of contagion risk arising from the hypothetical failure of some single institution are minimal for most banks, in other words, the contagious defaults (domino effects) are relatively unlikely in Chinese banking system in terms of our present data sample.

The total leverages for all banks in our sample are shown in column 14, in which the maximum is 21.49 and the minimum is 8.15 with the average at 14.47.

We define a relative contagion index by setting the maximum value of contagion index as 100. Such a definition yields the relative contagion indices for other banks, which are measured by the ratios of relevant contagion indices of the banks to the maximum value of the contagion index. Column 15 reports the relative contagion indices, in terms of which we identify the systemically important banks in China's interbank market, because it is an essential prerequisite of prudential regulation besides measuring systemic risk. We identified those banks with relative contagion indices greater than 50 as the systemically important banks, which consist of, without surprising, the five big state-owned commercial banks (from No. 1 to No. 5) and one joint-stock commercial bank (No. 11, the industrial bank co. ltd). For those banks that their relative contagion indices are between 20 and 50, we classified them as potentially important banks, which mainly include five joint-stock commercial banks.

Those with their relative contagion indices lower than 20 are defined as non-systemic banks. Obviously, most joint-stock commercial banks and all the city commercial banks are non-systemic banks in China.

To estimate the amplification factor of Chinese interbank networks by applying Theorem 2, we assume the different scenarios for different marginal probabilities of defaults, given that the ρ^{+} is 0.42 from Table 1, the amplification factors in expression (4) are calculated and summarized in Table 2.

Table 2 Amplification Factors for Different Marginal Probabilities of Defaults

Probabilities of Defaults	1%	5%	10%	50%	75%	100%
Amplification Factors	1.017	1.086	1.172	1.862	2.293	2.724

6. Simulating the Contagion and Systemic Risk with the Estimated Interbank Structure

Because the actual data of bilateral exposures among China's commercial banks in the interbank market are unavailable, we employ the maximum entropy approach with iterative proportional fitting (IPF) algorithm[15] to estimate the interbank bilateral exposures[16] matrix from above bank balance sheet data, and then analyse topological structure of China's commercial banks linkages in Subsection 6.1. The simulation of contagion and systemic risk for china's banking system in terms of the estimated interbank topological structure is conducted and summarized in Subsection 6.2.

[15] The maximum entropy method assumes that banks distribute their claims as evenly as possible among all the other banks by maximizing the entropy of interbank linkages. See, the discussion on the estimation methodology with IPF in Upper and Worms (2003).

[16] When estimating, we introduce an agent representing the other financial institutions (OFIs) to complete the interbank market. However, we ignore the OFIs in the later discussions because our study focuses on China's commercial banking system.

6.1 The Topological Features of China's Commercial Banks Networks

Obviously, the estimated network by the maximum entropy method produces a complete regular network[17], in which every vertex (bank) is connected with every other vertex. Using *k-clique*[18] technology, firstly, we depict the topological structure of China's commercial banks networks (weighted directed network) in terms of the estimated bilateral exposures (the adjacent matrix) in Figure 7 (a), in which the size of the vertex (bank) reflects the sum value of the interbank assets and interbank liabilities stemming from the bank's balance sheet. As illustrated, Figure 7 (a) exhibits a typical core-periphery structure[19] of China's commercial banking network, where the big five state-owned commercial banks and the Industrial Bank Co. Ltd. are in the core positions, the joint-stock banks and some big city banks (such as the Bank of Beijing) lie in the semi-periphery, and most other city commercial banks locate in periphery positions. Specifically, we partition China's commercial banks into 5 *clusters* in terms of the interbank transaction volumes (the interbank assets plus interbank liabilities) in Figure 7 (b): the banks that have more than 1.5 trillion yuan transaction volumes are classified into the first cluster in which the vertices are marked with yellow colours, these are core-banks. Those banks whose transaction volumes are between 500 billion yuan and 1.5 trillion (lower than) yuan belong to the second cluster where the banks are marked with green colours; the banks in the third cluster with red colours have transaction volumes among 100 billion yuan and 500 billion (lower than) yuan; The banks in the second and third clusters belong to the semi-periphery. Those banks that are marked with blue colours in the fourth cluster hold transaction volumes between 10 billion and 100 billion yuan; the remaining

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[17] Discussions on a complete market structure of financial networks, see, for example, Allen and Gale (2000).
[18] A clique is a subnetwork with maximum density.
[19] More characteristics about the core-periphery structure of financial networks, see, for example, Craig and von Peter (2010), Fricke and Lux (2012).

banks with transaction volumes below 10 billion yuan in the fifth cluster are marked with orange colours. The banks in the latter two clusters are periphery banks. Note that the core-banks in the first cluster consists of the “big five” state-owned banks and the Industrial Bank Co. Ltd, which are identified as systemic important banks in terms of the relative contagion indices in Section 5.

Figure 7 (c) plots the topological structure of the commercial banks that are also partitioned into 5 clusters in terms of their net worth, where the classification standards are: more than 1 trillion for yellow first cluster, from 100 billion to 1 trillion for green second cluster, among 10 billion and 100 billion for red third cluster, from 2 billion to 10 billion for the blue fourth cluster, and the fifth orange cluster for banks whose net worth below 2 billion yuan. Figure 7 (d) presents the topological structure of China’s commercial bank network by *hierarchical clustering* technique[20] after partition on the basis of their net worth.

Using the estimated adjacent matrix, secondly, we examine the centralities of the interbank network with Page Rank algorithm. The results are shown in Figure 8. Not surprisingly, the “big five” state-owned commercial banks (from No.1 to No. 5) and the Industrial Bank Co. Ltd. (No. 11) hold the largest centrality coefficients (from 0.05 to 0.1) among all commercial banks, suggesting their central significant positions in China’s banking system. Interestingly, and worthily of highlighting, these six banks are also identified as systemic important banks in terms of the relative contagion index method in Section 5 (See Table 1 in Appendix). In addition, the centrality coefficients for the potential important banks (5 joint-stock banks including Nos. 6-9, 12) that are identified in Section 5 are between 0.02 and 0.05, and for non-systemic banks their coefficients are below 0.02. Therefore, the relative contagion index

[20] The hierarchical clustering groups vertices that are most similar, then groups the next pair of vertices or clusters that are most similar, and continues until all vertices have been joined.

introduced in the paper does reflect the topological features of the commercial banks networks of China's interbank market.

Furthermore, we find that the centrality coefficients of banks are significantly correlated with the interbank assets, interbank liabilities and total assets, and therefore closely connecting with the relative contagion index (Table 3). This finding suggests that those banks that have more total assets and conduct more interbank transactions (a metrics represented by the sum of interbank assets and liabilities) generally play central roles in the interbank networks. This supports the conclusion from Glasserman and Young (2015) that without knowing the detailed topological structure we can identify the systemically important banks and quantify the contagion risk in terms of banks' balance sheet information[21], especially in terms of the interbank transaction information. Moreover, it exhibits that the systemic significance of a bank does associate with the size of its balance sheet variables and its interbank position.

Table 3 Correlations among Centralities, Balance Sheets Variables and Relative Contagion Index

	Centrality	Interbank Assets	Interban Liabilities	Total Assets	Relative Contagion Index
Centrality		0.866662	0.999767	0.921165	0.998968
Interbank Assets			0.859053	0.929628	0.84932
Interban Liabilities				0.919653	0.999631
Total Assets					0.918718
Relative Contagion Index					

6.2 Simulating Results of the Contagion and Systemic Risk with the Estimated Interbank Networks

In this subsection, given the estimated network structure, we examine how the failure

[21] See, also, Craig and von Peter (2010), who show that the core-periphery positions of the banks can reliably be predicted by means of a regression that uses only balance sheet variables. That is, the observed interbank network structure is driven by factors that are reflected in bank balance sheets.

of one or a certain banks impacts other banks' solvency via direct effects and chain reactions in the banking system, that is, assess the possibility of default cascades and the amplification effects of potential contagion by simulation. In the simulation process, we assume that banks cannot react to any shock by, for example, raising capital or getting bail-outs from the governments to compensate for the losses suffered from the failure of their interbank counterparts. Considering the special situations of Chinese banking system, where most commercial banks are state-owned or the dominating shareholders are governments, we define a bank failure when its losses in assets exceed its net worth, in contrast with the previous studies in which the bank default refers to the scenario that the losses in assets exceed its Tier 1 capital.

Our simulation methodology follows Furfine (2003) and Upper and Worms (2004). They examine the possibility of contagion by letting banks go closeness one at a time and calculate the number of banks that fail due to their exposures to the failing bank. Specifically, we consider the following three failure scenarios[22]: the failure of one of the systemic important bank, the failure of one of the potential-important bank, and the failure of one of the non-systemic bank. Based on the relative maximum sizes of interbank liabilities, we choose the Industrial & Commercial Bank of China (ICBC, top 1 among the global 1000 banks in 2015), Shanghai Pudong Development Bank (SPD), and the Bank of Tianjin (Tianjin) as the first default banks, respectively.

For simplicity, we assume that both the rate of loss given default (LGD, denoted by δ), and the external capital loss (denoted by μ, due to the fire sale externality) are constant. The methodology of the round-by-round algorithm can be described by the following steps:

A. By assumption an initial bank i defaults.

[22] Because of the weak possibility of interbank contagion and the limitation of space, we only consider three representative banks rather than all banks as the first default bank. Actually, the results for considering all banks are similar with the illustrative results.

B. Any bank j defaults if its losses suffered from the bilateral exposures versus the Bank i and from the external equity loss exceed its net worth. The default condition for the first round contagion is given by:

$$\delta c_{ji} + \mu e_j > e_j, \quad (5)$$

C. In a possible second round of contagion, any bank k defaults if its losses suffered from the bilateral exposures versus the Bank i and the bank j and from the external equity loss exceed its net worth. So the default condition for the second round of contagion is

$$\delta(c_{ki} + c_{kj}) + \mu e_k > e_k, \quad (6)$$

D. Contagion stops if no further bank defaults. Otherwise, the third round of contagion occurs. This process continues until no additional bank defaults.

Tables 4 and 5 summarize the number of bank defaults and total losses of banking system under three assumed scenarios for the different values of LGD ratio and external capital loss coefficients. Column 1 in Tables 4 and 5 presents the initial defaulted bank, whereas columns 2 to 7 report the total number or the total losses of the defaulted banks arising from financial contagion for respective LGD ratio and external equity loss coefficients.

Table 4 suggests that the probability of contagion within Chinese banking system is minimal even if the initial failed bank is the biggest bank around the world with a 100% LGD ratio. This result is consistent with the results that we obtained in Section 5 following the method provided by Glasserman and Young (2016), in which the detailed topological structure of the banking system is not considered in assessing the possibility of financial contagion.

The intuitions underpinning our results in which a failure of one systemic important bank does not trigger the cascade of bank failures in Chinese banking system comprise, first, the interbank bilateral exposures are significantly lower relative to their outside assets despite the interbank markets closely connect the banks togehter. Second, most Chinese commercial banks maintain sound and relatively high levels of the net worth. Third, the model of profits earning for Chinese commercial banks mainly depends on the spread between the interest rates for loans and deposits, hence, their main activities are retail banking, which reduces the demand for interbank transactions. Fourth, Chinese interbank market is underdevelopment, and the instruments for transactions are few. These limit the size and scope of Chinese interbank markets.

Nevertheless, the losses of Chinese banking system arising from an initial bank failure through the channel of the banks network are not trivial (Table 5). In the extreme case when the ICBC fails with a 100% LGD ratio, the total losses of the banking system reach 6,558.87 billion yuan, which accounts for 4.76% of the total assets held by Chinese commercial banks (excluding the rural commercial banks and foreign commercial banks) at the end of 2015.

Table 4 Number of bank defaults due to contagion in 2015

$\mu = 0.5$							
	$\delta = 0.1$	$\delta = 0.25$	$\delta = 0.5$	$\delta = 0.75$	$\delta = 0.9$	$\delta = 1$	Remark
ICBC	1	1	1	1	1	1	No contagion
SPD	1	1	1	1	1	1	No contagion
TIANJIN	1	1	1	1	1	1	No contagion
$\mu = 0.25$							
	$\delta = 0.1$	$\delta = 0.25$	$\delta = 0.5$	$\delta = 0.75$	$\delta = 0.9$	$\delta = 1$	Remark
ICBC	1	1	1	1	1	1	No contagion
SPD	1	1	1	1	1	1	No contagion
TIANJIN	1	1	1	1	1	1	No contagion
$\mu = 0$							
	$\delta = 0.1$	$\delta = 0.25$	$\delta = 0.5$	$\delta = 0.75$	$\delta = 0.9$	$\delta = 1$	Remark
ICBC	1	1	1	1	1	1	No contagion
SPD	1	1	1	1	1	1	No contagion
TIANJIN	1	1	1	1	1	1	No contagion

Table 5 Losses of Banking System by a Bank Default (Unit, RMB Billion Yuan)

$\mu = 0.5$							
	$\delta = 0.1$	$\delta = 0.25$	$\delta = 0.5$	$\delta = 0.75$	$\delta = 0.9$	$\delta = 1$	Remark
ICBC	5271.19	5485.80	5843.49	6201.18	6415.79	6558.87	
SPD	5192.44	5288.93	5449.75	5610.57	5707.07	5771.39	
TIANJIN	5137.91	5152.61	5177.11	5201.61	5216.31	5226.11	
$\mu = 0.25$							
	$\delta = 0.1$	$\delta = 0.25$	$\delta = 0.5$	$\delta = 0.75$	$\delta = 0.9$	$\delta = 1$	Remark
ICBC	2707.13	2921.75	3279.44	3637.12	3851.74	3994.81	
SPD	2628.38	2724.88	2885.70	3046.52	3143.01	3207.34	
TIANJIN	2573.86	2588.56	2613.06	2637.56	2652.26	2662.06	
$\mu = 0$							
	$\delta = 0.1$	$\delta = 0.25$	$\delta = 0.5$	$\delta = 0.75$	$\delta = 0.9$	$\delta = 1$	Remark
ICBC	143.08	357.69	715.38	1073.07	1287.68	1430.76	
SPD	64.33	160.82	321.64	482.46	578.96	643.28	
TIANJIN	9.80	24.50	49.00	73.50	88.20	98.00	

In addition, we calculate the possibility of the failure of any bank i given the assumed three defaults scenarios according to equation (3), in contrast with the results from the above round-by-round algorithm. The results in Table 6 show that all the banks are immune to the failure of the ICBC. This is consistent with the results from the round-by-round simulation.

6.3 Robust Tests

We conduct robust tests using the balance sheets data of our sample at the end of 2014. We apply two approaches and obtain similar results. Based on the limitation of space, we do not present the results of our robust tests, which are provided on the request.

Table 6 Immunity of Banks under Assumed Three Default Scenarios*

The initial failed bank is the ICBC, so the $(\theta^{*}-1)/(\theta-1)$ =1.03							
	c_{ji}/e_j		c_{ji}/e_j		c_{ji}/e_j		c_{ji}/e_j
BOC	0.08	JINSHANG	0.00	MINTAI	0.11	GUANGZHOU	0.03
CCB	0.05	CHANGZHI	0.04	CHOUZHOU	0.01	HUARUN	0.10
ABC	0.11	JINCHENG	0.03	NINGBOCB	0.05	DONGGUAN	0.02
JCB	0.11	DATONG	0.19	HAIXIA	0.02	NANYUE	0.12
CMB	0.08	JILIN	0.05	XIAMEN	0.06	HUAXING	0.03
SPD	0.09	SHENGJING	0.22	QUANZHOU	0.14	BEIBUWAN	0.01
CITIC	0.07	JINZHOU	0.06	XIAMENINTER	0.10	LIUZHOU	0.02
EVERBRIGHT	0.11	HULUDAO	0.06	NANCHANG	0.04	GUILIN	0.20
HUAXIA	0.07	DALIAN	0.04	JIUJIANG	0.05	CHONGQING	0.23
INDUSTRIAL	0.04	ANSHAN	0.08	GANZHOU	0.01	SANXIA	0.08
MINSHENG	0.12	FUSHUN	0.15	SHANGRAO	0.08	CHENGDU	0.26
PINGAN	0.12	DANDONG	0.09	QILU	0.01	DAZHOU	0.23
GUANGFA	0.12	YINGKOU	0.10	JINING	0.04	MIANYANG	0.03
HENGFENG	0.02	FUXIN	0.16	QINGDAO	0.03	ZIGONG	0.16
BOHAI	0.03	LIAOYANG	0.04	LINSHANG	0.01	PANZHIHUA	0.13
ZHESHANG	0.07	CHAOYANG	0.01	ZAOZHUANG	0.04	DEYANG	0.02
BEIJING	0.33	YANHAI	0.27	DONGYING	0.03	LUZHOU	0.10
TIANJIN	0.14	HARBIN	0.09	WEIFANG	0.09	LESHAN	0.20
HEBEI	0.15	LONGJIANG	0.02	YANTAI	0.02	NANCHONG	0.13
TANGSHAN	0.00	SHANGHAI	0.14	WEIHAI	0.05	YIBIN	0.02
QINHUANGDAO	0.16	NANJING	0.06	QISHANG	0.06	LIANGSHAN	0.15
CANGZHOU	0.00	JIANGSU	0.10	TAIAN	0.22	GUIYANG	0.03
CHENGDE	0.03	CHANGJIANG	0.00	RIZHAO	0.02	FUDIAN	0.02
HANDAN	0.16	SUZHOU	0.11	LAISHANG	0.01	QUJING	0.08
BAODING	0.14	HANGZHOU	0.17	ZHENGZHOU	0.08	XI'AN	0.22
LANGFANG	0.18	NINGBO	0.04	LUOYANG	0.03	CHANG'AN	0.13
ZHANGJIAKOU	0.40	WENZHOU	0.05	JIAOZUO	0.05	LANZHOU	0.04
HENGSHUI	0.01	JIAXING	0.02	ZHONGYUAN	0.02	GANSU	0.23
BAOSHANG	0.14	HUZHOU	0.02	HUISHANG	0.08	QINGHAI	0.00
NEIMENGGU	0.05	SHAOXING	0.06	HANKOU	0.01	NINGXIA	0.05
WUHAI	0.08	JINHUA	0.06	HUBEI	0.01	WULUMUQI	0.00
ORDOS	0.05	TAIZHOU	0.04	CHANGSHA	0.03	KUNLUN	0.31
		TAILONG	0.04	HUARONG	0.14		

*We only report the results for the scenario of assumed ICBC default. The results are same for another two scenarios, which are provided on the request due to the limited space.

7. Conclusion

Relying on the balance sheet data of Chinese commercial banks, we examine the contagion effects and systemic risk in China's interbank market. Two approaches are employed in our study: one only uses the balance sheet variables without considering the detailed topological structure of the interbank network; another one needs to estimate the bilateral exposures matrix. The simulation results from two methods are consistent, and both suggest that the domino effects of Chinese interbank networks arising from an assumed bank default are minimal, whereas the amplification effects (snowball effects) of losses through the channel of interbank networks are non-trial. Comparing two methods, we feel that the former is straightforward and insightful, and the latter is more intuitive and extensively applicable, helps analyse the microstructure of the banking system and the transmission channels of financial contagion in the banking system.

In particular, using a relative contagion index, we identify the systemic important banks for China. The measures that capture the topological features of the interbank networks by applying k-clique, partition and hierarchical clustering techniques support our identifications.

Despite the possibility of financial contagion in China's banking system is trial, the systemic losses stemming from a hypothetical bank failure due to the financial network are non-trivial. Thus, the systemic risk in Chinese interbank markets should attain proper concern by the policy makers and prudential regulators.

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Appendix

Table 1 Balance Sheets and Contagion Risk of China's Commercial Banks (Unit: Million RMB Yuan)

Category	No. & Bank Name	Abbreviation	Outside Assets	Interbank Assets	Total Assets	Outside Liabilities	Interbank Liabilities	Net Worth	ρ_i	Leverage of Outside Assets θ_i	Contagion Index	Net Worth of other Banks	Total Leverage	Relative Contagion Index
Big State-Owned Commercial Banks	1.Bank of China Limited	BOC	15884372.00	931225.00	16815597.0	13429226.0	2028766.00	1357605.00	0.13	11.70	1906548.47	8898616.25	12.39	87.06
	2.Industrial & Commercial Bank of China (The)	ICBC	21525987.00	683793.00	22209780.0	18143401.0	2265860.00	1800519.00	0.11	11.96	2189944.50	8455702.25	12.34	100.00
	3.China Construction Bank Corporation Joint Stock Company	CCB	17685744.00	663745.00	18349489.0	15143299.0	1761107.00	1445083.00	0.10	12.24	1691957.81	8811138.25	12.70	77.26
	4.Agricultural Bank of China Limited	ABC	16589218.00	1202175.00	17791393.0	15041848.0	1537660.00	1211885.00	0.09	13.69	1426164.75	9044336.25	14.68	65.12
	5.Bank of Communications Co. Ltd	JCB	6620463.00	534899.0	7155362.00	5161216.00	1456054.00	538092.00	0.22	12.30	1338355.64	9718129.25	13.30	61.11
Joint-Stock Commercial Banks	6.China Merchants Bank Co Ltd	CMB	5225506.00	249472.0	5474978.00	4222888.00	890332.00	361758.00	0.17	14.44	846893.05	9894463.25	15.13	38.67
	7.Shanghai Pudong Development Bank	SPD	4795158.00	249194.0	5044352.00	3583215.00	1142537.00	318600.00	0.24	15.05	1082289.79	9937621.25	15.83	49.42
	8.China CITIC Bank Corporation Limited	CITIC	4922713.00	199579.0	5122292.00	3684814.00	1117792.00	319686.00	0.23	15.40	1071340.59	9936535.25	16.02	48.92
	9.China Everbright Bank Co Ltd	EVERBRIGHT	2949038.00	218672.0	3167710.00	2342292.00	601371.00	224047.00	0.20	13.16	556697.75	10032174.25	14.14	25.42
	10.Hua Xia Bank Co., Ltd	HUAXIA	1940138.00	80466.00	2020604.00	1567875.00	334341.00	118388.00	0.18	16.39	320197.98	10137833.25	17.07	14.62
	11.Industrial Bank Co Ltd	INDUSTRIAL	5200197.00	98683.00	5298880.00	3112118.00	1869385.00	317377.00	0.38	16.38	1832352.70	9938844.25	16.70	83.67
	12.China Minsheng Banking Corporation	MINSHENG	4190043.00	330645.00	4520688.00	3220130.00	990775.00	309783.00	0.24	13.53	912978.23	9946438.25	14.59	41.69
	13.Ping An Bank Co Ltd	PINGAN	2321467.00	185682.00	2507149.00	2022400.00	323249.00	161500.00	0.14	14.37	297660.55	10094721.25	15.52	13.59
	14.China Guangfa Bank Co Ltd	GUANGFA	1730466.00	106121.10	1836587.10	1288436.82	450610.11	97540.17	0.26	17.74	423112.73	10158681.08	18.83	19.32
	15.China Hengfeng Bank	HENGFENG	1056389.39	11766.28	1068155.67	823231.54	187956.10	56968.03	0.19	18.54	185769.02	10199253.22	18.75	8.48
	16.China Bohai Bank	BOHAI	754766.18	9469.26	764235.44	481571.89	247106.55	35557.00	0.34	21.23	243895.37	10220664.25	21.49	11.14
	17.China Zheshang Bank Co. Ltd	ZHESHANG	998204.75	33445.64	1031650.39	654940.51	327052.81	49657.06	0.33	20.10	315913.75	10206564.19	20.78	14.43

	18.Bank of Beijing Co Ltd	BEIJING	1490003.00	354906.00	1844909.00	1299917.00	428178.00	116814.00	0.25	12.76	340241.32	10139407.25	15.79	15.54
	19.Bank of Tianjin	TIANJIN	521428.67	44239.06	565667.73	379403.73	153016.29	33247.70	0.29	15.68	140302.09	10222973.55	17.01	6.41
	20.Bank of Hebei	HEBEI	199652.32	22986.28	222638.60	190875.72	15997.59	15765.28	0.08	12.66	14220.05	10240455.97	14.12	0.65
	21.Bank of TangShan	TANGSHAN	124747.57	116.61	124864.18	99120.70	17593.52	8149.96	0.15	15.31	17575.94	10248071.29	15.32	0.80
	22.Bank of QinHuangDao	QINHUANGDAO	33117.74	3196.86	36314.60	34184.28	5.41	2124.91	0.00	15.59	4.90	10254096.34	17.09	0.00
	23.Bank of CangZhou	CANGZHOU	83523.96	25.72	83549.68	78716.47	59.11	4774.10	0.00	17.50	59.09	10251447.15	17.50	0.00
	24.Bank of ChengDe	CHENGDE	63519.03	932.56	64451.59	58023.26	2581.91	3846.42	0.04	16.51	2542.18	10252374.83	16.76	0.12
	25.Bank of HanDan	HANDAN	101996.84	9334.18	111331.02	100948.71	4288.87	6093.44	0.04	16.74	3908.46	10250127.81	18.27	0.18
	26.Bank of BaoDing	BAODING	316744.51	35850.83	352595.34	260413.09	65947.15	26235.10	0.20	12.07	58702.82	10229986.15	13.44	2.68
	27.Bank of LangFang	LANGFANG	118411.58	11352.31	129763.89	91870.70	31206.60	6686.59	0.25	17.71	28328.19	10249534.66	19.41	1.29
	28.Bank of ZhangJiaKou	ZHANGJIAKOU	96286.05	28724.64	125010.69	94740.62	22745.12	7524.95	0.19	12.80	17184.06	10248696.30	16.61	0.78
	29.Bank of HengShui	HENGSHUI	33462.92	166.45	33629.37	64248.79	14.65	2843.50	0.00	11.77	6.98	10253377.75	11.83	0.00
	30.BaoShang Bank	BAOSHANG	316744.51	35850.83	352595.34	260413.09	65947.15	26235.10	0.20	12.07	58702.82	10229986.15	13.44	2.68
City Commercial Banks	31.Bank of NeiMengGu	NEIMENGGU	102868.34	3905.33	106773.67	84804.14	12939.24	9030.30	0.13	11.39	12422.25	10247190.95	11.82	0.57
	32.Bank of WuHai	WUHAI	32660.63	2474.42	35135.05	24219.32	7833.08	3082.65	0.24	10.59	7228.37	10253138.60	11.40	0.33
	33.Ordos Bank	ORDOS	57816.32	3572.75	61389.07	43020.02	11377.57	6991.49	0.21	8.27	10630.31	10249229.76	8.78	0.49
	34.JinShang Bank	JINSHANG	156912.13	330.50	157242.63	117066.93	31178.77	8996.93	0.21	17.44	31109.26	10247224.32	17.48	1.42
	35.ChangZhi Bank	CHANGZHI	23900.08	523.86	24423.94	18722.04	4148.77	1553.13	0.18	15.39	4053.74	10254668.12	15.73	0.19
	36.JinCheng Bank	JINCHENG	64317.83	1362.10	65679.93	44827.15	15442.65	5410.13	0.26	11.89	15093.65	10250811.12	12.14	0.69
	37.Datong Commercial City Bank	DATONG	29070.13	2917.38	31987.51	30394.41	0.00	1593.11	0.00	18.25	0.00	10254628.14	20.08	0.00
	38.Bank of JiLin	JILIN	347636.35	9897.28	357533.63	283265.25	53639.98	20628.40	0.16	16.85	52064.20	10235592.85	17.33	2.38
	39.ShengJing Bank	SHENGJING	615992.83	85635.67	701628.50	547925.93	111987.62	41714.95	0.17	14.77	97455.21	10214506.30	16.82	4.45
	40.Bank of JinZhou	JINZHOU	346055.56	15604.35	361659.91	215181.61	120206.99	26271.31	0.36	13.17	114614.22	10229949.94	13.77	5.23
	41.Bank of HuLuDao	HULUDAO	44264.04	2136.53	46400.57	40621.53	1780.68	3998.36	0.04	11.07	1690.96	10252222.89	11.60	0.08
	42.Bank of Dalian	DALIAN	236652.35	7707.22	244359.57	183065.67	42821.78	18472.12	0.19	12.81	41360.71	10237749.13	13.23	1.89
	43.Bank of AnShan	ANSHAN	87273.07	5868.35	93141.42	84812.23	980.51	7348.68	0.01	11.88	913.44	10248872.57	12.67	0.04
	44.Bank of FuShun	FUSHUN	46956.06	5352.06	52308.12	37513.85	11146.32	3647.95	0.23	12.87	9920.35	10252573.30	14.34	0.45
	45.Bank of DanDong	DANDONG	59549.01	4110.15	63659.16	49038.49	10033.85	4586.82	0.17	12.98	9335.71	10251634.43	13.88	0.43

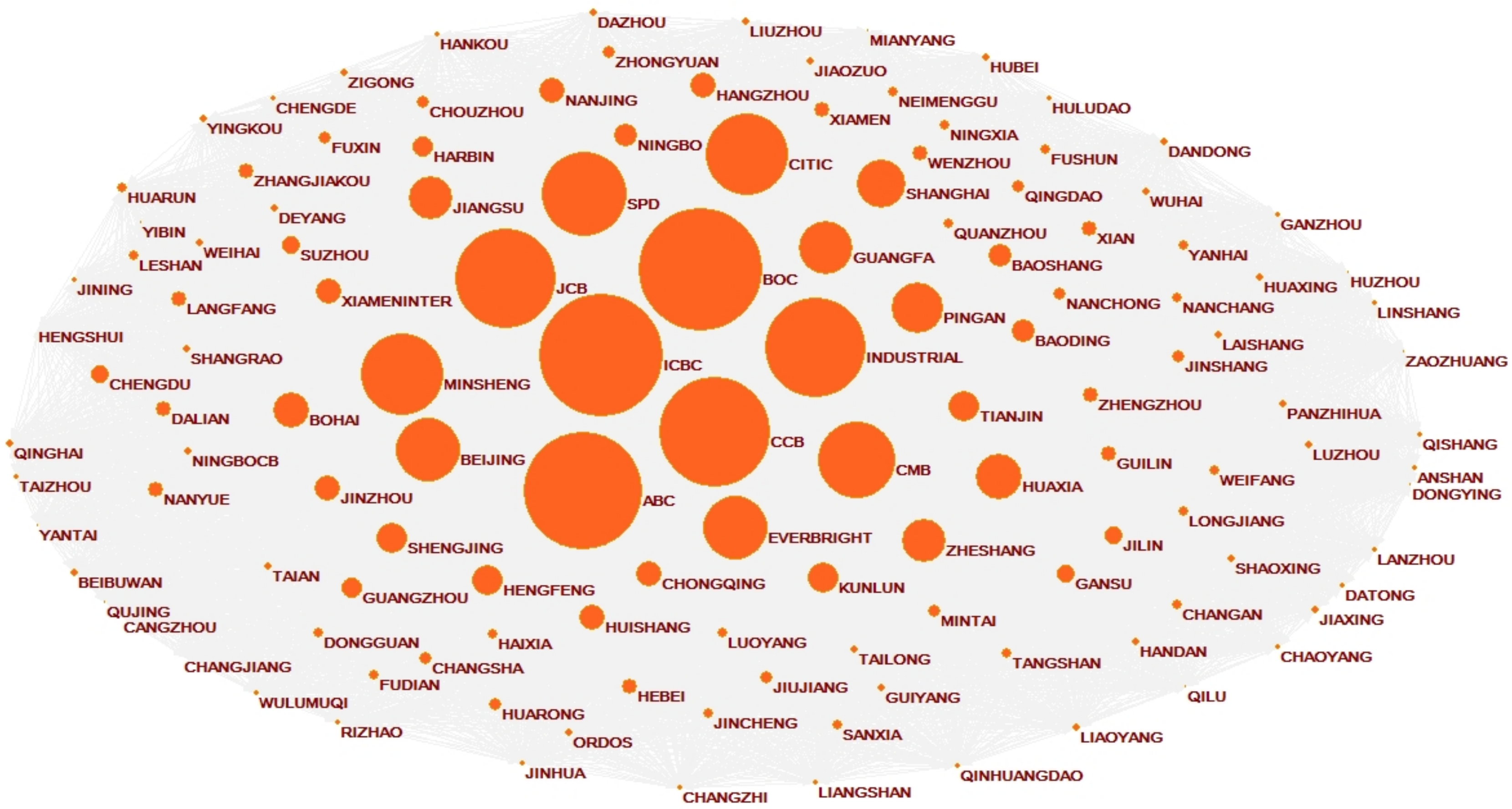
	46.Bank of YingKou	YINGKOU	97566.31	7573.34	105139.65	94337.71	2524.58	8277.36	0.03	11.79	2327.19	10247943.89	12.70	0.11
	47.Bnak of FuXin	FUXIN	92004.09	11305.06	103309.15	78039.87	17719.39	7549.88	0.19	12.19	15627.49	10248671.37	13.68	0.71
	48.Bank of LiaoYang	LIAOYANG	89932.81	2646.65	92579.46	79035.54	6544.89	6999.03	0.08	12.85	6342.48	10249222.22	13.23	0.29
	49.Bank of ChaoYang	CHAOYANG	50180.79	450.48	50631.27	43990.12	2645.90	3995.25	0.06	12.56	2620.34	10252226.00	12.67	0.12
	50.Yingkou Yanhai Bank Co. Limited	YANHAI	48917.85	6406.33	55324.18	40058.56	12786.90	2478.72	0.24	19.74	11236.77	10253742.53	22.32	0.51
	51.Harbin Bank	HARBIN	414816.21	30035.06	444851.27	358974.38	52028.93	33847.96	0.13	12.26	48226.79	10222373.29	13.14	2.20
	52.LongJinag Bank	LONGJIANG	213710.30	2249.98	215960.28	181032.87	21875.78	13051.62	0.11	16.37	21633.21	10243169.63	16.55	0.99
	53.Bank of ShangHai	SHANGHAI	1330795.09	118345.40	1449140.49	994737.56	361568.53	92834.40	0.27	14.34	330019.62	10163386.85	15.61	15.07
	54.Bank of NanJing	NANJING	773428.59	31591.65	805020.24	649160.98	103445.33	52413.92	0.14	14.76	99103.08	10203807.33	15.36	4.53
	55.Bank of JiangSu	JIANGSU	1230585.84	59747.50	1290333.34	921969.45	302829.32	65534.56	0.25	18.78	288056.86	10190686.69	19.69	13.15
	56.Jiangsu Changjiang Commercial Bank	CHANGJIANG	17103.02	44.36	17147.38	16058.50	0.00	1088.87	0.00	15.71	0.00	10255132.38	15.75	0.00
	57.Bank of SuZhou	SUZHOU	209667.82	21233.56	230901.38	160330.25	50947.37	19623.76	0.24	10.68	45827.12	10236597.49	11.77	2.09
	58.Bank of HangZhou	HANGZHOU	492516.90	52797.67	545314.57	439454.70	73965.42	31894.44	0.14	15.44	66359.17	10224326.81	17.10	3.03
	59.Bank of NingBo	NINGBO	700883.53	15581.12	716464.65	582534.21	88833.12	45097.32	0.13	15.54	86771.48	10211123.93	15.89	3.96
	60.Bank of WenZhou	WENZHOU	151136.36	4930.45	156066.81	109143.49	37014.91	9908.41	0.25	15.25	35766.26	10246312.84	15.75	1.63
	61.Bank of JiaXing	JIAXING	49318.91	739.25	50058.16	39109.39	7659.20	3289.58	0.16	14.99	7538.13	10252931.67	15.22	0.34
	62.Bank of HuZhou	HUZHOU	32932.66	393.68	33326.34	30538.73	235.65	2551.96	0.01	12.90	232.64	10253669.29	13.06	0.01
	63.Bank of ShaoXing	SHAOXING	84107.25	2439.47	86546.72	72877.24	9066.57	4602.91	0.11	18.27	8796.66	10251618.34	18.80	0.40
	64.Bank of JinHua	JINHUA	53031.70	2259.16	55290.86	49715.34	1839.99	3735.53	0.04	14.20	1759.36	10252485.72	14.80	0.08
	65.TaiZhou Bank	TAIZHOU	119593.73	3805.92	123399.65	112644.48	305.99	10449.19	0.00	11.45	295.68	10245772.06	11.81	0.01
	66.Zhejiang Tailong Commercial Bank	TAILONG	105754.79	2961.65	108716.44	92165.27	9514.04	7037.14	0.09	15.03	9236.92	10249184.11	15.45	0.42
	67.Zhejiang Mintai Commercial Bank	MINTAI	97652.91	7352.96	105005.87	77886.35	20091.75	7027.77	0.21	13.90	18583.92	10249193.48	14.94	0.85
	68.Zhejiang Chouzhou Commercial Bank	CHOUZHOU	131661.90	1387.37	133049.27	91254.57	30541.88	11252.83	0.25	11.70	30193.98	10244968.42	11.82	1.38
	69.NingBo Commercial Bank	NINGBOCB	47190.11	3105.56	50295.67	35196.74	8928.95	6169.98	0.20	7.65	8300.53	10250051.27	8.15	0.38
	70.HaiXia Bank of Fujian	HAIXIA	132603.93	1079.55	133683.48	102141.80	24143.77	7397.90	0.19	17.92	23937.38	10248823.35	18.07	1.09
	71.XiaMen Bank	XIAMEN	155916.58	4403.56	160320.14	114048.77	38043.28	8228.09	0.25	18.95	36941.80	10247993.16	19.48	1.69

	72.Bank of QuanZhou	QUANZHOU	67275.40	6518.48	73793.88	57172.67	11615.56	5005.85	0.17	13.44	10514.82	10251215.40	14.74	0.48
	73.XiaMen International Bank	XIAMENINTER	432873.31	26331.38	459204.69	321877.90	109534.70	27792.09	0.25	15.58	102849.22	10228429.16	16.52	4.70
	74.Bank of NanChang	NANCHANG	205225.38	7862.37	213087.75	183801.47	9077.69	20208.59	0.05	10.16	8707.65	10236012.66	10.54	0.40
	75.Bank of JiuJinag	JIUJIANG	169253.80	5622.52	174876.32	137157.64	25144.15	12574.54	0.15	13.46	24273.10	10243646.71	13.91	1.11
	76.Bank of GanZhou	GANZHOU	89603.26	311.73	89914.99	80596.81	3277.92	6040.26	0.04	14.83	3265.74	10250180.99	14.89	0.15
	77.Bank of ShangRao	SHANGRAO	62245.70	3513.18	65758.88	49398.29	11503.75	4856.84	0.19	12.82	10840.15	10251364.41	13.54	0.49
	78.QiLu Bank	QILU	151494.27	1387.22	152881.49	141717.50	1112.48	10051.52	0.01	15.07	1101.68	10246169.73	15.21	0.05
	79.Bank of JiNing	JINING	44154.07	1326.73	45480.80	39767.29	1992.95	3720.57	0.05	11.87	1929.63	10252500.68	12.22	0.09
	80.Bank of QingDao	QINGDAO	182541.84	4693.41	187235.25	140233.74	30387.86	16613.65	0.18	10.99	29551.96	10239607.60	11.27	1.35
	81.LinShang Bank	LINSHANG	68222.83	408.60	68631.43	59298.42	3568.03	5764.98	0.06	11.83	3544.84	10250456.27	11.90	0.16
	82.ZaoZhuang Bank	ZAOZHUANG	13343.57	409.35	13752.92	12621.00	151.41	980.51	0.01	13.61	146.56	10255240.74	14.03	0.01
	83.DongYing Bank	DONGYING	54797.82	1169.27	55967.09	50239.85	1049.01	4678.23	0.02	11.71	1025.09	10251543.02	11.96	0.05
	84.Bank of WeiFang	WEIFANG	85703.74	6081.96	91785.70	73332.09	11351.84	7101.77	0.13	12.07	10536.56	10249119.48	12.92	0.48
	85.YanTai Bank	YANTAI	52539.42	829.53	53368.95	47126.71	1409.72	4832.53	0.03	10.87	1385.63	10251388.72	11.04	0.06
	86.WeiHai City Commercial Bank	WEIHAI	147091.29	4186.43	151277.72	130570.74	11437.12	9269.86	0.08	15.87	11099.95	10246951.39	16.32	0.51
	87.QiShang Bank	QISHANG	78962.02	4267.23	83229.25	75609.65	538.12	7081.47	0.01	11.15	507.96	10249139.78	11.75	0.02
	88.TaiAn Bank	TAIAN	47234.23	5515.07	52749.30	41699.43	8432.46	2617.41	0.17	18.05	7504.79	10253603.84	20.15	0.34
	89.Bank of RiZhao	RIZHAO	90302.05	1686.05	91988.10	82690.96	1722.21	7574.93	0.02	11.92	1687.81	10248646.32	12.14	0.08
	90.LaiShang Bank	LAISHANG	63639.12	556.55	64195.67	47529.18	11458.73	5207.75	0.19	12.22	11350.62	10251013.50	12.33	0.52
	91.Bank of ZhengZhou	ZHENGZHOU	252424.00	13199.00	265623.00	220526.00	27273.00	17824.00	0.11	14.16	25820.31	10238397.25	14.90	1.18
	92.Bank of LuoYang	LUOYANG	163544.77	3162.73	166707.50	133983.88	19394.50	13329.11	0.13	12.27	18994.58	10242892.14	12.51	0.87
	93.JiaoZuo City Commercial Bank	JIAOZUO	39240.22	2145.15	41385.37	27447.77	9705.90	4231.70	0.26	9.27	9145.51	10251989.55	9.78	0.42
	94.ZhongYuan Bank	ZHONGYUAN	299219.96	6927.21	306147.17	243123.67	29895.84	33127.66	0.11	9.03	29137.31	10223093.59	9.24	1.33
	95.HuiShang Bank	HUISHANG	604856.96	31273.66	636130.62	496588.01	97197.35	42345.26	0.16	14.28	92078.13	10213875.99	15.02	4.20
	96.HanKou Bank	HANKOU	182008.75	1133.33	183142.08	160984.64	6274.78	15882.66	0.04	11.46	6232.26	10240338.59	11.53	0.28
	97.HuBei Bank Co. Ltd.	HUBEI	153188.43	1515.71	154704.14	137066.95	6577.33	11059.86	0.05	13.85	6507.93	10245161.39	13.99	0.30
	98.Bank of ChangSha	CHANGSHA	280492.73	4927.74	285420.47	235740.81	31815.44	17864.22	0.12	15.70	31229.48	10238357.03	15.98	1.43

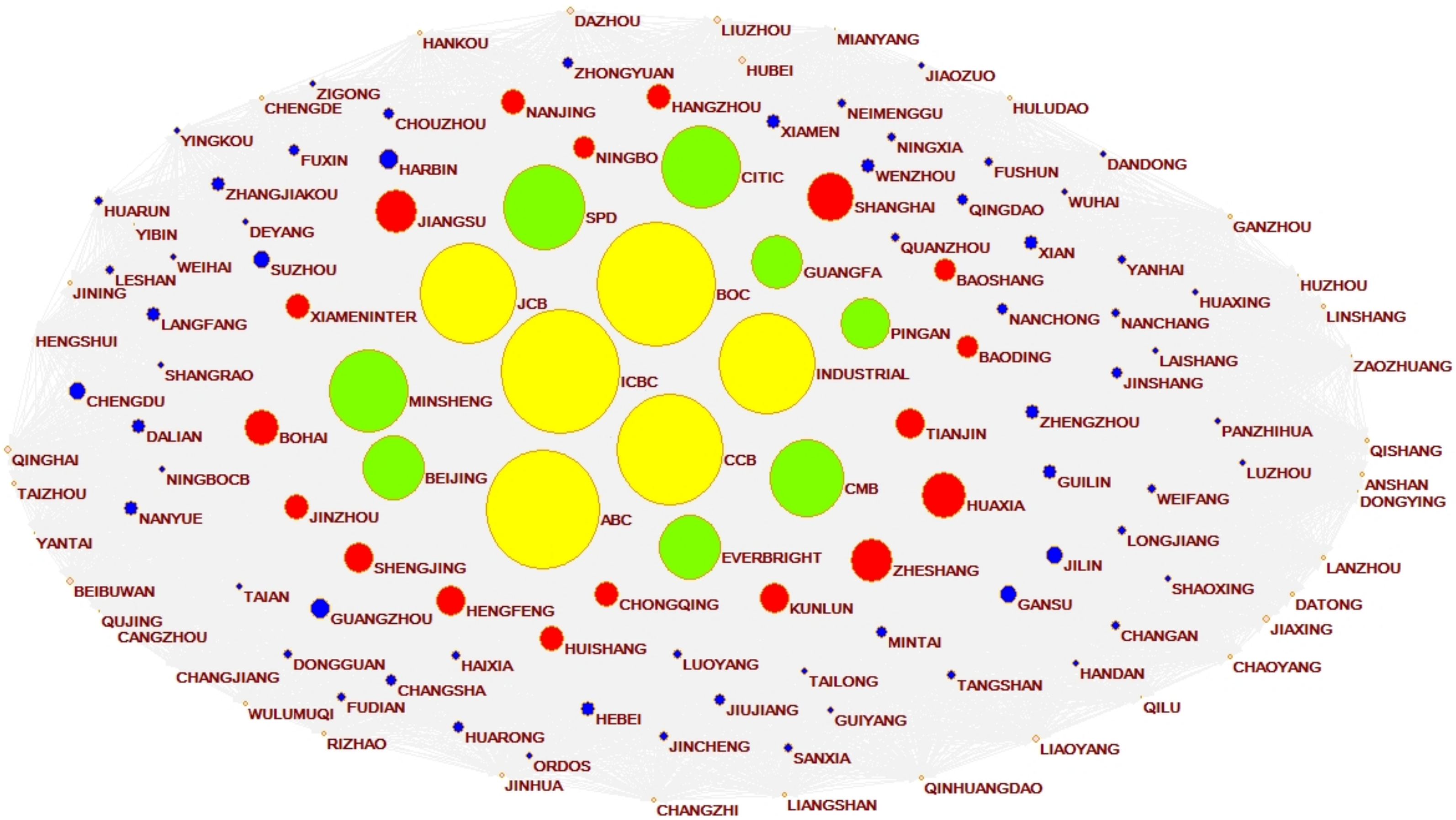
	99.Huarong XiangJiang Bank	HUARONG	194515.96	16608.56	211124.52	182229.85	16015.57	12879.10	0.08	15.10	14673.82	10243342.15	16.39	0.67
	100.Bank of GuangZhou	GUANGZHOU	410228.26	4964.08	415192.34	314865.46	80514.21	19812.67	0.20	20.71	79503.34	10236408.58	20.96	3.63
	101.China Resources Bank	HUARUN	107622.08	8771.76	116393.84	93650.65	13897.62	8845.57	0.13	12.17	12764.11	10247375.68	13.16	0.58
	102.Bank of DongGuan	DONGGUAN	189846.17	2215.45	192061.62	154595.62	22305.57	15160.43	0.13	12.52	22026.22	10241060.82	12.67	1.01
	103.Guangdong Nanyue Bank	NANYUE	154445.46	11539.79	165985.25	121020.85	34423.83	10540.57	0.22	14.65	31868.30	10245680.68	15.75	1.46
	104.Guangdong Huaxing Bank	HUAXING	104453.84	1578.50	106032.34	85976.34	14184.80	5871.20	0.14	17.79	13961.25	10250350.05	18.06	0.64
	105.Guangxi Beibu Gulf Bank	BEIBUWAN	112363.22	664.50	113027.72	94039.00	8004.13	10984.60	0.08	10.23	7952.01	10245236.65	10.29	0.36
	106.Bank of LiuZhou	LIUZHOU	88283.87	1642.54	89926.41	73424.26	8124.48	8377.68	0.10	10.54	7960.84	10247843.57	10.73	0.36
	107.GuiLin Bank	GUILIN	127408.73	16227.38	143636.11	100817.49	34406.57	8412.06	0.25	15.15	30277.65	10247809.19	17.08	1.38
	108.Bank of ChongQing	CHONGQING	273951.43	45856.56	319807.99	225279.44	73235.55	21292.99	0.25	12.87	61985.43	10234928.26	15.02	2.83
	109.Chongqing Three Gorges Bank	SANXIA	124692.98	7936.76	132629.74	112794.15	9945.43	9890.16	0.08	12.61	9302.32	10246331.09	13.41	0.42
	110.Bank of ChengDu	CHENGDU	270661.20	50784.14	321445.34	290372.71	10793.55	20279.08	0.04	13.35	8973.49	10235942.17	15.85	0.41
	111.Dazhou City Commercial Bank	DAZHOU	18253.50	4778.65	23032.15	16210.19	4640.78	2181.17	0.22	8.37	3577.20	10254040.08	10.56	0.16
	112.Mianyang City Commercial Bank	MIANYANG	51663.77	1032.87	52696.64	47750.23	1032.49	3913.92	0.02	13.20	1010.63	10252307.33	13.46	0.05
	113.ZiGong Commercial Bank	ZIGONG	36704.56	5508.23	42212.79	30997.99	7515.22	3699.58	0.20	9.92	6440.38	10252521.67	11.41	0.29
	114.Panzhihua City Commercial Bank	PANZHIHUA	56468.87	6342.60	62811.47	49223.84	8407.18	5180.45	0.15	10.90	7481.93	10251040.80	12.12	0.34
	115.Greatwall Bank	DEYANG	82269.18	926.22	83195.40	67417.11	10437.17	5341.12	0.13	15.40	10313.00	10250880.13	15.58	0.47
	116.Luzhou City Commercial Bank	LUZHOU	28489.63	2983.72	31473.35	21271.89	7079.66	3121.81	0.25	9.13	6334.59	10253099.44	10.08	0.29
	117.Leshan City Commercial Bank	LESHAN	61552.60	10906.08	72458.68	56794.69	9926.64	5737.35	0.15	10.73	8304.06	10250483.90	12.63	0.38
	118.Nanchong City Commercial Bank	NANCHONG	127847.16	13300.10	141147.26	118983.27	24820.51	10643.58	0.17	12.01	20229.32	10245577.67	13.26	0.92
	119.Yibin City Commercial City Bank	YIBIN	28570.61	653.94	29224.55	24606.22	1164.42	3453.91	0.05	8.27	1134.87	10252767.34	8.46	0.05

	120.Liangshan Prefectural Commercial Bank	LIANGSHAN	20085.09	3000.63	23085.72	20991.32	3.36	2091.04	0.00	9.61	2.88	10254130.21	11.04	0.00
	121.GuiYang Bank	GUIYANG	233877.66	4318.89	238196.55	215320.51	8742.16	14133.88	0.04	16.55	8573.65	10242087.37	16.85	0.39
	122.Fudian Bank	FUDIAN	151969.79	2065.64	154035.43	124389.97	15570.35	14075.11	0.11	10.80	15340.55	10242146.14	10.94	0.70
	123.Qujing City Commercial Bank	QUJING	26475.19	1204.91	27680.10	24762.84	1235.17	1682.08	0.05	15.74	1177.92	10254539.17	16.46	0.05
	124.Bank of Xi'an	XI'AN	179988.16	30035.44	210023.60	183535.78	12068.94	14418.88	0.06	12.48	10215.73	10241802.37	14.57	0.47
	125.Chang'an Bank	CHANG'AN	148006.65	11885.59	159892.24	137220.36	12767.80	9904.08	0.09	14.94	11756.03	10246317.17	16.14	0.54
	126.Bank of LanZhou	LANZHOU	200282.40	5291.53	205573.93	189455.24	1860.56	14258.13	0.01	14.05	1809.10	10241963.12	14.42	0.08
	127.Bank of GanSu	GANSU	183609.76	26573.77	210183.53	166336.64	31516.94	12329.95	0.16	14.89	27283.89	10243891.30	17.05	1.25
	128.Bnak of QingHai	QINGHAI	70285.46	149.96	70435.42	56816.69	7950.00	5668.73	0.12	12.40	7931.59	10250552.52	12.43	0.36
	129.Bank of NingXia	NINGXIA	114509.15	4488.67	118997.82	94736.32	14665.33	9596.16	0.13	11.93	14063.62	10246625.09	12.40	0.64
	130.Bank of Urumqi Co Ltd.	WULUMUQI	103197.93	241.43	103439.36	88343.82	7280.94	7814.60	0.08	13.21	7262.56	10248406.65	13.24	0.33
	131.Bank of KunLun	KUNLUN	222444.57	67734.00	290178.57	154553.14	112684.67	22940.77	0.42	9.70	84123.65	10233280.48	12.65	3.84

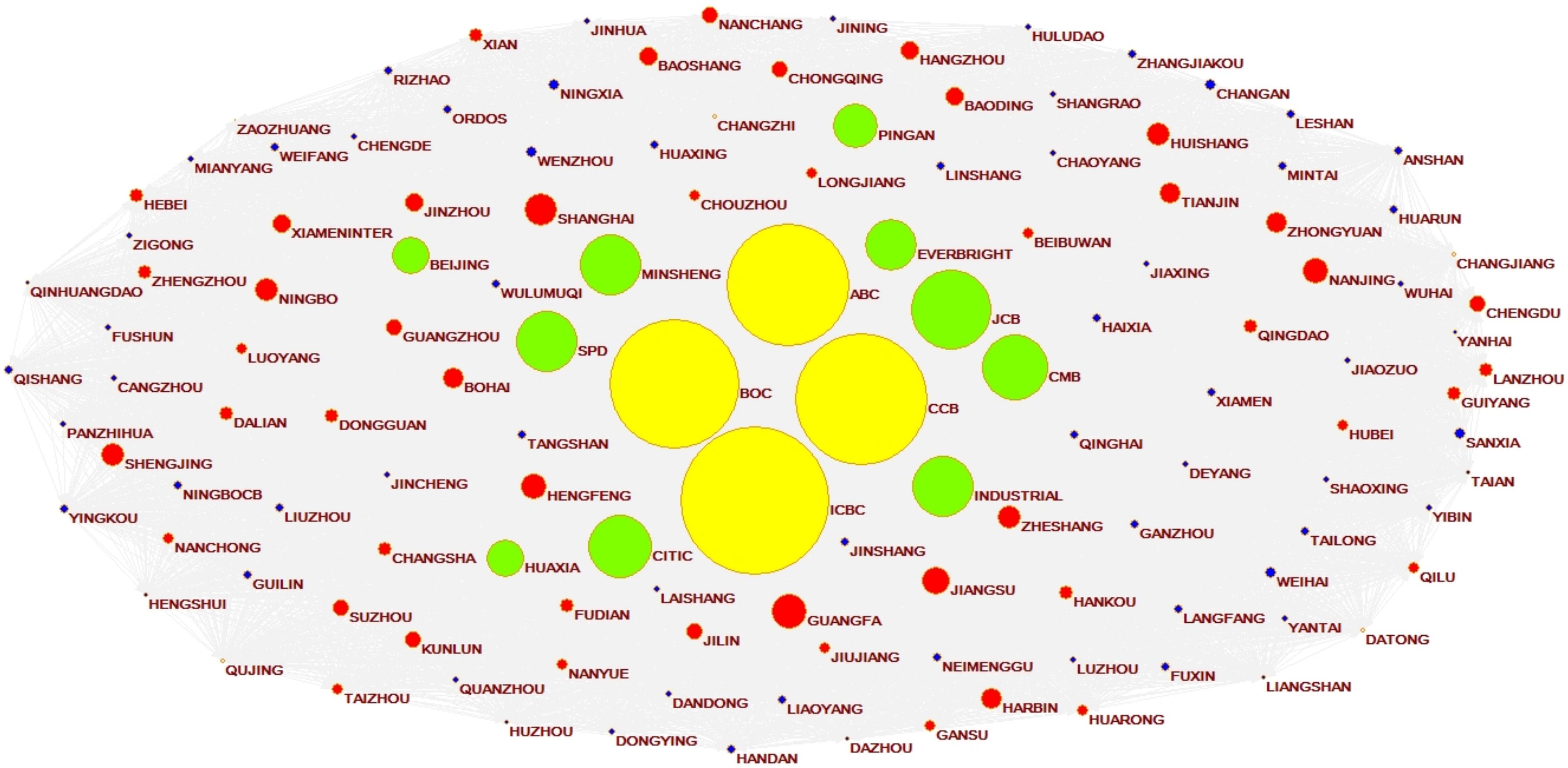
Figure 7 Topological Structure of China's Commercial Banks Networks



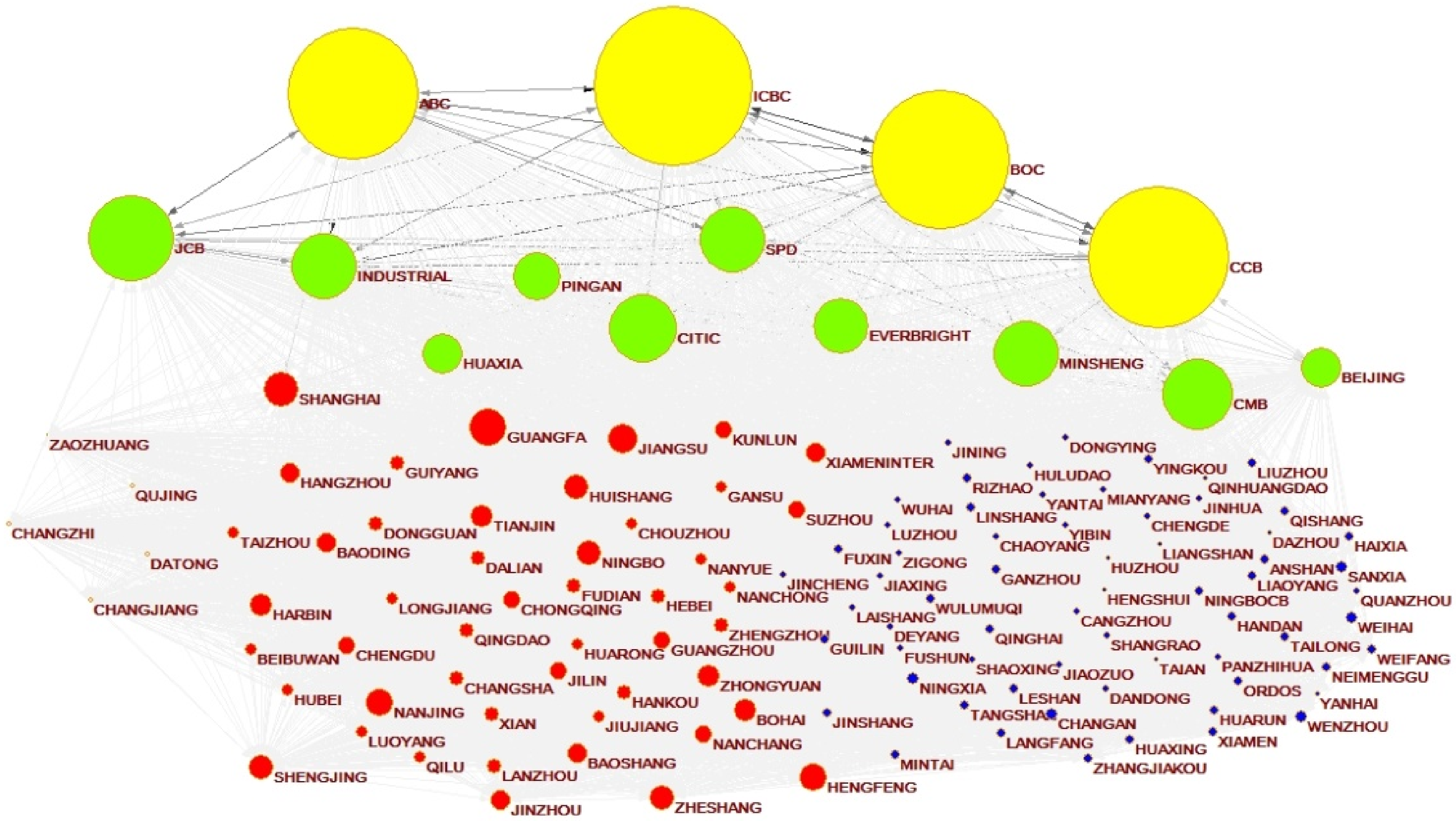
(a) Partition by k-clique technology, the size of the vertex (bank) is quantified by the sum of interbank claims and liabilities



(b) Clustering in terms of the sum of interbank assets and interbank liabilities



(c) Clustering in terms of the net worth



(d) Hierarchical clustering in terms of the net worth

Figure 8 Centralities of Commercial Banks in China