Research on the Risk Contagion Effect between the Network Structure and Commercial Banks - Based on the Data of 25 Banks ' Inter-bank Lending

Chongzhen Huang[1], Mingzhe Li[2*]

[1]Harbin Engineering University,145 Nantong Street, Nangang District, Harbin, China
[2]Harbin Engineering University,145 Nantong Street, Nangang District, Harbin, China

Huangcz.2007@163.com[1];1025469929@qq.com[2*]

Abstract. Based on the network structure model, this paper studies the risk contagion of central banks under malicious attacks. Based on this, we first select the inter-bank lending data of 25 commercial banks, use the matrix method to construct the inter-bank lending matrix and modify the matrix, draw the network structure diagram, and analyze the network node degree and network core structure. Finally, we simulate the risk contagion effect between the whole banks when the core layer banks are maliciously attacked, and analyze the retention rate of transaction scale in the network. The research results show that the 25 banks are divided into three hierarchical network structures, and the central layer banks occupy the main position. The malicious attacks on the central banks have a huge impact on the entire inter-bank network, and the transaction scale retention rate is only about 10 %. The empirical results provide a theoretical basis for the financial regulatory authorities to formulate policies to prevent and control financial risks.

Keywords: network structure; commercial banks; risk contagion

1 Introduction

From the beginning of the U.S. subprime mortgage crisis to the current bankruptcy of Silicon Valley banks, the risk between commercial banks caused by the turbulent international financial environment has spread through the network on a large scale, which has brought a severe impact on the entire banking system. The banking system plays an important role in the financial market. Therefore, in view of the complex international financial environment, China 's General Administration of Financial Supervision actively implements macroeconomic policies to reduce the large-scale contagion of inter-bank risks, maintain the stable development of the financial system, and better serve the real economy. Foreign scholars have found that the bank network structure of some countries presents the characteristics of hierarchical multi-core banks. Agnes Lubloy found that the Hungarian banking network is a multi-center banking structure with 15 banks as the network center[1]. Degryse and Nguyen found that the Belgian

L. Moutinho et al. (eds.), *Proceedings of the 2023 International Conference on Management Innovation and Economy Development (MIED 2023)*, Advances in Economics, Business and Management Research 260,
https://doi.org/10.2991/978-94-6463-260-6_11

inter-bank network is a typical central structure with banks whose asset size occupies the main position in the banking industry as the network center[2]. Veld et al. and Langfield et al found that in the Dutch-British inter-bank market network structure, large banks are the core of the network structure, and other banks are scattered around the core layer[3-4]. Kobayashi et al found that the German inter-bank market network is divided into two levels, and the lower-level banks only have lending relationships with a small number of large banks[5-6].Domestic scholar Ma Junlu et al found that China 's banking network is a structure with Bank of China as the core and Construction Bank as the sub-center [7]. Chen Shaowei and Li Yang believe that China 's inter-bank network is based on the core bank to build a currency center, and other banks are distributed in the second and third layers of the network structure [8]. Li Zhi and Niu Xiaojian found that banks with larger assets constitute the center of China 's banking industry, but the status of banks is not static[9]. A large number of literature studies have shown that the inter-bank lending network structure has an impact on inter-bank risk contagion : He Dexu believes that the initial small-scale growth of inter-bank linkage will increase the contagion effect in the financial market, but the subsequent growth can enhance the impact resistance of the financial system [10].Liu Zhiyang empirically concluded that the banking network structure is the main bearer of risk contagion in small and medium-sized banks[11]. Tang Wenjin studied the vulnerability of the network structure from the essence of the network structure to prevent the impact of overseas financial events on China 's financial market [12]. Liu Chao found that there is a complex correlation between network structure factors and systemic risk contagion [13]. In summary, some literatures study the hierarchical structure of the network, and other literatures focus on the characteristics of the network structure. Few literatures study the risk contagion effect from the malicious attack of the central bank. Therefore, this paper can study the network risk contagion from the malicious attack on the central bank. The possible marginal contributions of this paper are as follows: First, this paper uses the asset-liability data to construct the inter-bank lending matrix, and obtains the inter-bank network structure diagram through the matrix. Identify the hierarchical structure in the banking network structure and analyze the network structure hierarchically. Secondly, this paper analyzes the process of inter-bank risk contagion from the perspective of network structure, and studies the impact on the entire banking network system when the central bank in the network structure is attacked.

2 Network structure model construction and inter-bank risk contagion analysis

2.1 Matrix method theory and construction of network structure model

Based on the fact that the loan relationship between banks in the actual market is two-way, this paper assumes that the total number of sample banks selected is n. By constructing a matrix of n×n to represent the relationship between inter-bank lending, the matrix is standardized, and the inter-bank lending assets and liabilities of each sample bank are calculated. The proportion of the total amount and negative total amount of

inter-bank lending assets of all sample banks makes the sum of each element in the matrix equal to 1, that is:

$$\sum_j \sum_i c_{ij} = 1, \begin{cases} a_i = \sum_j c_{ij} \\ l_j = \sum_i c_{ij} \end{cases} \tag{1}$$

$$C = \begin{bmatrix} c_{11} & \cdots & c_{1j} & \cdots & c_{1n} \\ \vdots & \ddots & \vdots & \iddots & \vdots \\ c_{i1} & \cdots & c_{ij} & \cdots & c_{in} \\ \vdots & \iddots & \vdots & \ddots & \vdots \\ c_{n1} & \cdots & c_{nj} & \cdots & c_{nn} \end{bmatrix} \begin{matrix} a_1 \\ \vdots \\ a_i \\ \vdots \\ a_n \end{matrix} \tag{2}$$

$$\begin{matrix} l_1 & \cdots & l_j & \cdots & l_n \end{matrix}$$

2.2 Core-edge analysis of node degree and network structure.

In the network structure model, there is a distribution function P (k), P (k) represents the ratio of the number of nodes with node degree k to the number of all nodes in the network, and the distribution of node degree is represented by this function. The cumulative degree distribution function P (k) is used to represent the ratio of the number of nodes with a degree of not less than k to the total number of nodes. The expression is:

$$P(k) = \sum_{i=k}^{\infty} P(i) \tag{3}$$

According to the matrix method, the relationship matrix of inter-bank lending is obtained to draw the network structure topology map. The core-periphery analysis of the network structure is carried out. The core-periphery structure divides the rows and columns of the inter-bank lending matrix into two parts. In the core-periphery structure, the core bank has a dominant position in the transaction with the peripheral bank.

2.3 Simulation of transaction scale survival rate after inter-bank risk contagion

Through the network structure diagram obtained above, we further study the prevention of risk contagion when banks encounter malicious attacks. This paper assumes that the bank at the network center level is maliciously attacked. In order to compare the stability of the network after deleting the center level and compare the network stability of each year, this paper sets the index survival rate as:

$$S = \frac{A'}{A} \tag{4}$$

However, this is only considering the connection relationship between networks. When the weight of the edges in the network is also included in the measurement factor, the retention rate of the index transaction scale is re-set:

$$S_w = \frac{A_w{}'}{A_w} \tag{5}$$

3 Empirical Analysis of Inter-bank Risk Contagion

3.1 Sample bank data acquisition and inter-bank risk matrix correction

This paper selects 25 representative banks with large inter-bank lending scale from 2016 to 2021 as samples for research. According to the balance sheets disclosed by these banks every year, relevant data are obtained. The sample includes A1-A6 representative state-owned commercial banks ; B1-B2 represent policy banks ; C1-C12 represents joint-stock commercial banks ; D1-D4 represents urban commercial banks and a rural commercial bank ; E1 represents foreign banks established in China. According to the matrix method, the inter-bank lending matrix of 25 banks from 2016 to 2021 is constructed, and the matrix is solved by the program in Lingo software.

3.2 Network structure diagram construction

In this paper, Gephi software is used to draw the inter-bank lending network structure from 2016 to 2021. As shown in the graph, according to the network structure diagram of the six years, it can be seen that the network structure presents an obvious hierarchical structure, which extends from the center of the network structure to the outside, forming the central level, the second level and the peripheral level in turn. The second level of the network structure is constantly changing. Most of the edges of each node in the peripheral level are dotted lines with lighter colors, which represent the smaller amount of inter-bank borrowing, and most of these edges are connected to the nodes of the central level and the second level. There is basically no interconnected relationship between most nodes in the peripheral level.

3.3 Network node degree analysis and network core structure analysis

As shown in Fig. 1 network structural diagram. From 2016 to 2021, Bank of China, Industrial and Commercial Bank of China, Construction Bank, Bank of Communications and Agricultural Bank of China have been ranked in the top ranks. This shows that China 's large state-owned commercial banks have been in an important position in the inter-bank market. Although the ranking of the node degree of joint-stock banks has not changed significantly, the node degree of banks represented by Industrial Bank, Shanghai Pudong Development Bank and Minsheng Bank has been growing. The node degree of urban banks has been relatively small, maintaining a relatively stable trend of floating. The difference between the out-degree and in-degree of each bank node is small, and there is no obvious characteristic. Using Ucinet software, the core-edge analysis of the inter-bank lending matrix is carried out. A1-A5 has been at the core of the network from 2016 to 2021. CITIC Bank and Industrial Bank are located in the core structure of the network in 2019 and 2021 respectively, while other banks have been at the edge of the network. These core banks are in a dominant position when conducting inter-bank lending transactions.

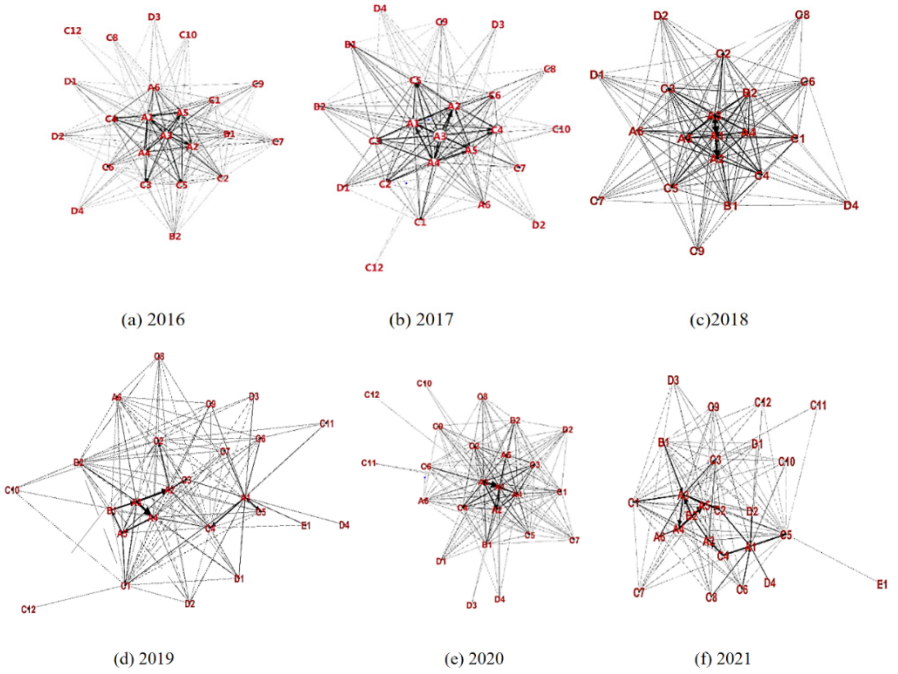

Fig. 1. network structural diagram

3.4 Analysis of the retention rate of transaction scale after inter-bank risk contagion

The four-year network of 2018, 2019, 2020 and 2021 is selected for research. The annual network comparison in the comprehensive graph shows that the network structure is most severely damaged when the central level is deleted. As shown in Fig. 2 Delete the center-level network diagram. The most serious damage is that four isolated nodes appear in 2020, two isolated nodes appear in 2021, a2nd one isolated node appears in 2019. It shows that the robustness of the risk contagion network has increased in the face of vicious attacks, but the network stability is still weak.

Comparing the retention rate of transaction scale in four years, according to Table 1, it is concluded that after deleting the central level, the scale of transactions retained in the network is very small. In 2019, the retention rate of transaction scale was only 10.60 %, indicating that the attack on the central-level bank would bring great damage to the overall network and the network structure would collapse. Although the transaction scale showed an increasing trend from 2016 to 2021, the highest value was only 24.89 %, and the transaction retention rate fell to 10.89 % in 2021. It shows that the contribution of other levels to the transaction scale in the network is increasing, the stability of the network as a whole has increased, but the stability is still weak, and the scale retention rate of inter-bank risk contagion.

The above research shows that the stability of China 's inter-bank lending network is weak, but the stability is gradually increasing. In the network, it is necessary to ensure the stable operation of the bank at the network center layer. If the bank at the network center layer is impacted, it will lead to the collapse of the entire network architecture.

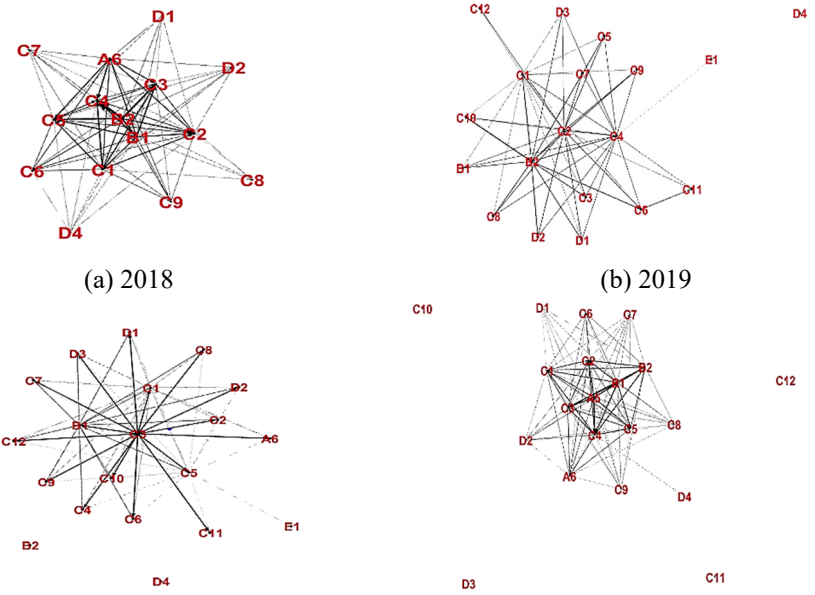

Fig. 2. Delete the center-level network diagram

Table 1. survival rate and transaction scale retention rate after malicious attack

	Network survival rate	The retention rate of transaction size
2016	30.51%	17.83%
2017	31.25%	18.08%
2018	41.41%	18.29%
2019	43.75%	10.60%
2020	47.97%	24.89%
2021	42.47%	10.89%

4 Conclusion

A large number of literatures start from the following perspectives, the characteristics of the inter-bank network, the hierarchical structure of the inter-bank network, and the central level that exists in the network. On the basis of previous studies, this paper selects the data of 25 listed commercial banks in China from 2016 to 2021 as an example, and uses the matrix method to construct the inter-bank lending matrix, so as to

construct the inter-bank network structure, and study the impact of malicious attacks on the entire risk contagion of central-level banks. In the process of simulating the malicious attack on the central bank, this paper finds that the stability of China 's interbank lending network is weak, but the network is increasing the degree of stability. The banks at the inter-bank center level have the greatest damage to the network structure when they are attacked, not only in the form of a significant reduction in the retention of transaction scale, but also in the form that some banks in the network will become isolated nodes, which will spread inter-bank risks on a large scale. Therefore, China 's financial regulatory authorities to increase the supervision of the central bank, can effectively prevent and control the risk of large-scale infection.

References

1. Lubloy A. The domino effect on the Hungarian interbank market [M]. Mimeo, 2005: 1-35. https://xueshu.baidu.com/usercenter/paper/show?paperid=ddee008395f36793edd1eea30e5f9472&site=xueshu_se
2. Dergyse H, Nguyen G. Interbank Exposure: An Empirical Examination of Systemic Risk in the Belgian Banking System[J]. International Journal of Central Bnaking, 2007, 3(2):123-171. DOI:10.2139/ssrn.1691645.
3. in't Veld, Daan, Van Lelyveld I. Finding the core: Network structure in interbank markets [J]. Journal of Banking & Finance, 2014, 49:27-40. DOI: 10.1016/j.jbankfin.2014.08.006.
4. Langfield S, Liu Z, Ota T. Mapping the UK interbank system[J]. Journal of Banking & Finance, 2014, 45:288-303. DOI: 10.1016/j.jbankfin.2014.03.031.
5. Craig B, Von Peter G. Interbank tiering and money center banks[J]. Journal of Financial Intermediation, 2014, 23(3):322-347. DOI: 10.1016/j.jfi.2014.02.003.
6. Kobayashi T, Takaguchi T. Social dynamics of financial networks[J]. Epj Data Science, 2018, 7(1):15. DOI:10.1140/epjds/s13688-018-0143-y.
7. Esti mating Bilateral Exposures in the China Interbank Market ： Is There a Syste mic Con tagion? [J]. Economic Research Journel,2007(01):68-78+142. DOI: CNKI: SUN: JJYJ.0.2007-01-005.
8. The Network Structure of Chinese Banking System: An Empirical Analysis Based on Com plex Network. [J]. On Economic Problems,2016(08):56-63. DOI: CNKI: SUN: JJWT.0.2016-08-012.
9. Research on Bank Network Models with Money-center Structures[J]. Management Review,2018, 30(04):12-19. DOI: CNKI: SUN: ZWGD.0.2018-04-002.
10. He Dexu, Zhang Xuelan. What kind of banking system is more conducive to financial stabi lity? -A review based on the international network structure[J]. Social Sciences Internatio nal, 2009(06)：29-36. DOI: CNKI: SUN: GWSH.0.2009-06-006.
11. Tang Wenjin, Li Shuang, Tao Yunqing. Research on systemic risk based on network structure model: current situation and prospect[J]. Financial Regulation Research,2020(06):100-114. 10.13490/j.cnki.frr.2020.06.007
12. The risk Analysis of Chinese Inter-bank Debt Default Contageion Under Network Structur e A-Two-dimensional Data Perspective of Inter-bank Debt and Finacial Marke[J]. Modern Economic Science,2020,42(03):69-79. https://kns-cnki-net-443.wvpn.hrbeu.edu.cn/kcms2/article/abstract?v=3uoqIhG8C44YLTlOAiTRKibYlV5Vjs7i8oRR1PAr7RxjuAJk4dHXouELcm5Jn9vhFs4mQthDXanckMKXzXRZd98XGzCUKdAq&uniplatform=NZKPT

13. Network Structure,Capital Buffer and Systematic Risk Contagion Effect of Banks –Data fr om 14 Listed Commercial Banks in China from 2007 to 2017[J]. Operations Research and Management Science,2022,31(12):143-149. https://kns-cnki-net-443.wvpn.hrbeu.edu.cn/kcms2/article/abstract?v=3uoqIhG8C44YLTlOAiTRKibYlV5Vjs7ioT0BO4yQ4m_mOgeS2ml3UPGtpcd5a4exnWvugVFrViHQnRLPFyuhOlAvJ3UJlVmI&uniplatform=NZKPT