Analysis of Time Series Based on Threshold Network Model

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ABSTRACT
In order to explore the structural changes of financial networks at different time scales and different time scales, the state provides reliable theoretical basis for determining international economic relations and policies. Based on complex scientific theory, cross-correlation matrix eigenvectors are used. When the component of eigenvectors is greater than the threshold value of 0.4, the nodes are netted. Link builds connection. Firstly, the stock data are arranged in the order of total assets from large to small, and the interaction between stocks in the financial network is analyzed. At different times, the core stock of the network is constructed by banking stocks, and the network basically presents a stable structure, not changing with time. The interaction between financial networks will undergo drastic changes during the financial crisis or bubble. The construction of threshold network nodes is more robust and safe. The experimental results show that the research can help the government formulate *and improve the macro-economy.*

Keywords: *Network, Threshold, Cross-correlation matrix, Bank, Assets.*

1. INTRODUCTION

Complex networks have experienced four stages: regular network [1]–[3], random network,[4] small world network [5], [6] and scale-free network. With the discovery of the small world effect and scale-free nature of complex networks, the research of complex networks has attracted wide attention from the scientific community. The basic theory of complex networks has gradually become a hot topic in various fields of science, from mathematical science to life science, engineering science and even social science[7]–[12]. In recent years, there are two ways to analyze financial market networks: minimum spanning tree and planar maximum filtering graph. Threshold network can also be regarded as a special kind of network. The threshold network is also proposed in recent years. Network research, based on threshold, although still in the stage of model construction and description, has received extensive attention from researchers in various fields, and many researchers are also working in this field.

Mantegna [13] use the minimum spanning tree (MST) of the network to find the directed network of the stock, and the smallest spanning tree can also reveal the hierarchical structure of the network, and the article provides useful information for the economic factors. Jiang [14]-[16] use plane filtering to establish a network method and discuss the changes of time series network nodes with the average correlation in the plate is positive, the correlation between the plates is negative, and the time evolution of the plate interaction structure is deep, find that the local interaction structure will change sharply during the golden thawing crisis or the bubble. Lee take 200 stocks in Korean securities market, and use the cross correlation matrix theory to establish a scale-free network with a threshold of 0.45. The correlation coefficient proposes the concept of threshold value, and the index of the scale-free network depends on the threshold.

2. METHODOLOGY

2.1 Cross-correlation Matrix

The data in this article was collected from the Yahoo website in China (http://www.yahoo.com)[17]–[21]. The data we use

is the daily closing price of US stocks. Thirty stocks of United States were listed from January 3, 1994 to December 31, 2013, corresponding to T = 5036 days. Here i is the stock serial number. Table 1 lists the company names and their abbreviations corresponding to the 30 constituent stocks in the US Dow Jones Index. The total value of each bank's stock assets is available on the Fortune website (http://www.fortune.com). If a stock is missing the closing price data for a particular day, the data for the previous day's closing price will be filled. In this way, processing data does not cause human bias.

In order to observe the different stock price trends of the cross-correlation matrix, we first divide the independent time period to analyze the cross-correlation matrix stock price fluctuation results. If p(t) is the closing price of the stock, i is the stock serial number, t means the time, there are 30 US stock closing prices.

The closing time of the bank's stock closing price is indicated by Δt;

$$R_i(t,\Delta t) \equiv \ln P_i(t,\Delta t) - \ln P_i(t) \quad (1)$$

$$r_i(t,\Delta t) = \frac{R_i - \langle R_i \rangle}{\sigma_i} \quad (2)$$

$$C_{ij} = \frac{\langle r_i r_j \rangle - \langle r_i \rangle \langle r_j \rangle}{\sigma_i \sigma_j} \quad (3)$$

The yield of the r_i th stock volatility is expressed; here is $\sigma_i \equiv \sqrt{\langle R_i^2 \rangle - \langle R_i \rangle^2}$ the standard deviation, $\langle \cdots \rangle$ which represents the average value of the stock price for a period of time; finally, the cross-correlation matrix $C = (C_{ij})$; we calculate the elements in the eigenvectors of the cross-correlation matrix C_{ij} of the same time, examined i is each point of the time series, and j is the stock price representing each group; and then analyzing the US stock $C_{30\times30}$.

A feature vector λ and a corresponding eigenvalue [22], [23];

$$C u = \lambda u \quad (4)$$

$C_{30\times30}$represents the 30 component stocks in the Dow Jones Index, and the eigenvectors for $C_{30\times30}$cross-correlation matrix.

2.2 *Threshold Network Establishment Steps*

1) First, create an $C_{30\times30}$ empty matrix. The first line number is arranged by arranging the connection order from 1 to 30[24]–[27]. Each column is assigned the same value, and the value is equal to the first number in each column. 30 columns of links to synthesize a column, this column we set it as the new first column;

2) Creating an $C_{30\times30}$ empty matrix, assign a consecutive sequence of 1 to 30 to each column in the 30 columns of the matrix, and combine 30 columns into one column to set it as the new second column;

3) Setting the threshold size $u \geq 0.3$, the value of the component of the cross-correlation matrix $C_{30\times30}$feature vector is less than the threshold value is set to 0, and the component of the 30-column feature vector is combined into one column, and it is set as the new third column;

4) The weight of the cross-correlation matrix $C_{30\times30}$, and the matrix 30 columns are linked into one column to be the new fourth column;

5) The new fourth column, when the weight is 1, is set to 0, 30 columns are combined into one column, and this column is the new fifth column;

6) Delete all the five columns with the value 0, assign consecutive values, and connect them to build a threshold network; draw with Gephi tool.

3. RESULTS

"Figure 1" shows the stock closing price trend chart. The X axis represents time and the Y axis represents price; Figures 1(a)-(c) show the maximum, intermediate and minimum weights of the three stocks.

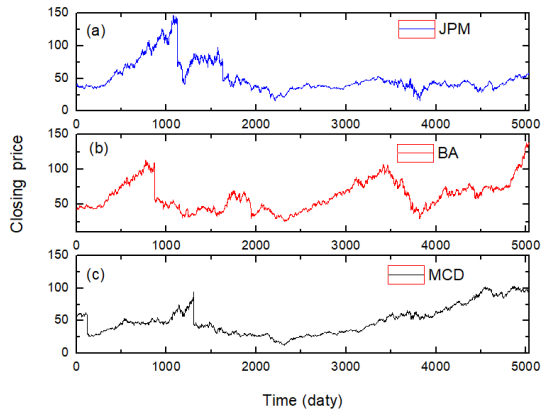


Figure 1 Stock closing price trend chart; (a-c) JPM, BA and MCD stock closing prices.

"Figure 2" shows the composition of the two time windows in the first half of 2013 and the second half of 2013; we introduce a threshold $u \geq 0.3$ when the eigenvector component of the cross-correlation matrix is greater than the threshold value of the connection. Obviously, the network characteristics presented by the interaction of windows at different times have a stable structure in the first half of the year. The network connection in the second half of the year presents a linear structure. The core nodes of the network are 28 and 23 stocks. These two stocks are at the network center node. It proves that the network was more stable in the first half of the year. "Figure 2". Window (A) from 2013.7 to 2013.12; window (B) from 2013.1. to 2011.6; window (A) (B) change in the first half of 2013 and the second half of 2013; threshold $u \geq 0.3$.

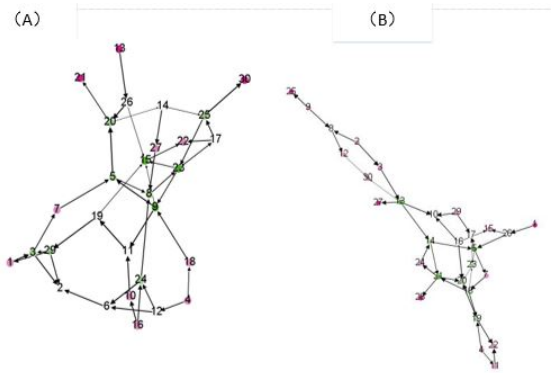


Figure 2 The network diagram of the US market correlation matrix changes in the first half of 2013 and the second half of the two periods.

"Figure 3" Window (A) from 2013.1 to 2013.12; window (B) from 2012.1 to 2012.12. Window (A) (B) asset changes, different in 2013 and 2012; threshold $u \geq 0.3$; "Figure 3". Stocks are arranged according to the order of assets by size, and are arranged by the stock price of 2013 and 2012 in different years; the time network established in these two years, the network is basically stable and does not change with time.

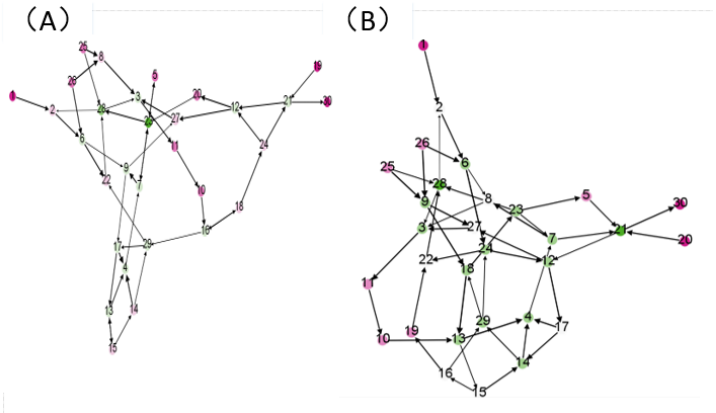


Figure 3 Network diagram of the US market association matrix.

"Figure 4" To further verify the above conclusions [28]–[31],The interaction structure between stocks in the subprime crisis. Window (A) from 2007.10 to 2008.11; window (B) from 2008.12 to 2010.1; window (A) peak period of subprime mortgage crisis; threshold $u \geq 0.3$;we analyze another set of data sets, all from the US market from October 2007 to November 2008. This period corresponds to the peak period of the subprime mortgage crisis. Window (B) filed for bankruptcy and bankruptcy protection from 2008.12 to 2010.1 banks; they all appeared again as relatively simple interaction structures.

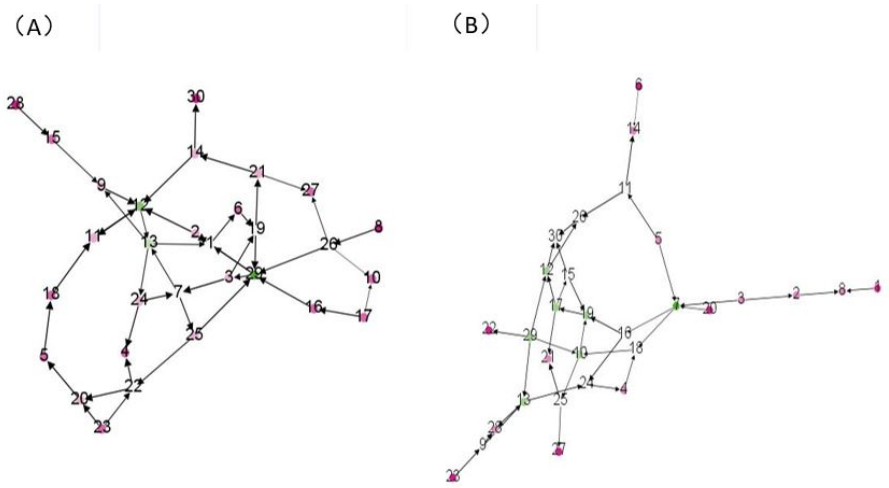


Figure 4 Network diagram of the US market correlation matrix.

"Figure 5". Window (A) from 1990.1 to 1994.3; window (B) from 1994.4 to 1998.6; window (C) from 1998.7 to 2002.9; window (C) during network foam; threshold $u \geq 0.3$; We then divide the data of the US financial market into three time periods: window (a)-(c), where window (a) is a regular time period, and neural network images appear; and window (c) contains a typical securities market bubble event from 1998.7 to 2002.9.

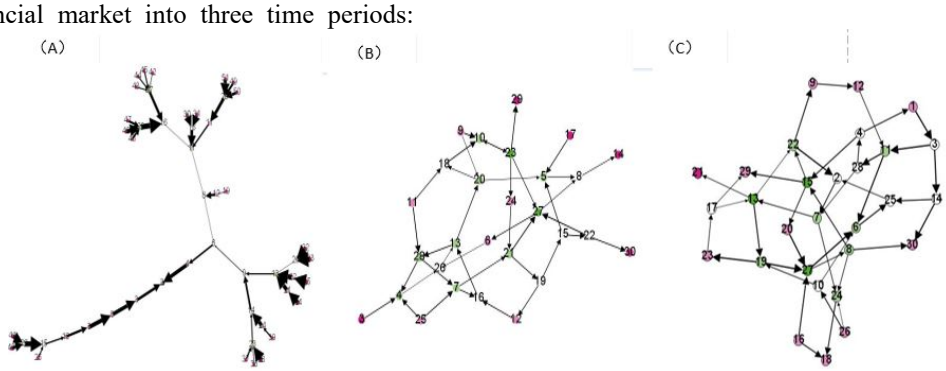


Figure 5 Interaction structure of the US market correlation matrix in the network bubble.

4. CONCLUSION

The interaction between the networks established by the threshold method is basically stable and does not change over time. In particular, during the securities market bubble or financial crisis, the structure is dominated by a certain stock, which is the economic form at the time and closely related to the background. The organization structure of the matrix is adjusted according to the weight. According to the theory of cross-correlation matrix and the cooperation between stocks, a threshold network diagram is established. This research can help understand the changing laws of many networks in nature and society.

REFERENCES

[1] Song C., Koren T., 2010. Nat. Phys., vol. 6, no. 10, pp. 818–823.

[2] Garlaschelli,D. Capocci,A. 2006. Nat. Phys., vol. 3, no. 11, pp. 813–817.

[3] Gao J., Buldyrev S. V., 2011. Phys. Rev. Lett., vol. 107, no. 19, pp. 1–5.

[4] Joshi,A. Smet R. De2009 Bioinformatics, vol. 25, no. 4, pp. 490–496.

[5] Jia T. and Barabási A.-L., 2013Sci. Rep., vol. 3, p. 2354.

[6] Gao J., Liu Y.-Y., 2014Nat. Commun., vol. 5, p. 5415.

[7] Beg,Q. Vazquez K. A., 2007 Proc. Natl. Acad. Sci. U. S. A., vol. 104, no. 31, pp. 12663–12668.

[8] Vidal M., Cusick M. E., 2011 Cell, vol. 144, no. 6, pp. 986–998.

[9] B. Barzel and aacute A.-L. 2013Nat. Biotechnol., vol. 31, no. 8, pp. 720–725.

[10] Yang J.-S., Kim J., 2013 Nat. Sci. Reports, vol. 3, no. 1403, pp. 1–9.

[11] Liu Y.-Y., Slotine J.-J2011 Nature, vol. 478, no. 7369, pp. E4–E5.

[12] Jiang Z.-Q., Xie, W.-J 2013. Proc. Natl. Acad. Sci. United States Am. Sci., vol. 110, no. 5, pp. 1600–1605.

[13] Lux T. and Marchesi M., 1999 Nature, vol. 397, no. February, pp. 498–500.

[14] Jiang X. F. and Zheng B., 2012Papers, vol. 97, no. 4, p. 48006–48011(6).

[15] Jiang X. F., Chen T. T., 2014. Sci Rep, vol. 4, p. 5321.

[16] Lee K. E., Lee J. W., 2007 Comput. Phys. Commun., vol. 177, no. 1–2, p. 186.

[17] Tan L., Chen J. J., 2016 PLoS One, vol. 11, no. 2, pp. 1–13.

[18] Münnix M. C., Shimada, T. 2012 Sci. Rep., vol. 2, p. 644.

[19] ShizhaoZHU, 2015.CPB: vol. 24, no. 5, pp. 634–638.

[20] Plerou V., Gopikrishnan P., 1999 Papers, vol. 83, no. 7, pp. 1471–1474.

[21] Shen J. and Zheng, B. 2012. vol. 86, no. 4.

[22] Balcan D. and Vespignani A., 2011. Nat. Phys., vol. 7, no. 7, pp. 581–586.

[23] Wang D., Tong H., 2011 Hum. Factors, vol. 82, pp. 735–744.

[24] Vespignani A., 2010 Nature, vol. 464, no. 7291, pp. 984–985.

[25] Segal E., Raveh-Sadka T 2008. Nature, vol. 451, no. 7178, pp. 535–540.

[26] Sharma A., Gulbahce N. 2013. Mol. Cell. Proteomics, vol. 12, no. 11, pp. 3398–408.

[27] Vazquez A., Dobrin, 2004. Proc. Natl. Acad. Sci., vol. 101, no. 52, pp. 17940–17945.

[28] Bollen J., Mao, H. 2011 J. Comput. Sci., vol. 2, no. 1, pp. 1–8.

[29] Huang X. Vodenska I. 2012. Sci. Rep., vol. 3, p. 13.

[30] Petersen A M and Tenenbaum,J. 2012.Sci. Rep., vol. 2, p. 313.

[31] May R M., Levin. S a 2008. Nature, vol. 451, no. February, pp. 893–895.