Mobility Analysis of Chinese Stock Market Filtered Network

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Abstract: The mobility of stock prices is greatly influenced by redundant information in the market and overall market trends. This paper uses the random matrix theory to filter the market factors, and the minimum spanning tree method to construct the filtered network of Chinese stock market, and compares the evolution of Chinese stock market structure in different periods from the perspective of mobility. It is found that the filtered network has different characteristics from the original network during the financial crisis and the Chinese stock market disaster. The mobility of weighted degree centrality is robust to market factors, and the closeness centrality is highly sensitive to the crisis and the stock market disaster. These centralities are very important for analyzing the structural changes of the Chinese stock market in special periods.

1. Introduction

Stock market is an important platform which reflects the financial information and economic development status, and the mobility of stock market can reflect the activeness of the overall financial market. In stock market, there are many factors may cause excessively strong correlations between stock price volatility, which affects the analysis of the stocks' own interactions. In 2011, Namaki[1] et al. used the random matrix theory (RMT) to define the overall effect on all stocks of the largest eigenvector in the stock market cross-correlation matrix as the market factor, and filtered the market factors via the Capital Asset Pricing Model(CAPM). They found that most parts of the cross-correlation are generated by the market factors. Kwapień[2] et al. found that after removing the market factors, the eigenvalues in the range predicted by RMT contain not only the random information, but also some important information that describes the cross-correlations between the stocks themselves.

With the extensive use of complex network methods in financial markets, many work[3][4][5] combined RMT methods with stock market cross-correlation networks and found that there are a large number of random factors in the empirical data of the stock market. The factors will greatly affect the topological nature of the stock cross-correlation network, and cover the correlation between the stocks themselves.

In order to remove the impact of the overall market trend on the mobility of stock market, this paper adopts the RMT method to filter out the market factors, and then uses the minimum spanning tree method to construct a stock market filtered network based on the cross-correlation matrix of stock price return rate. By analyzing the topological nature of the network, this paper explores the performance characteristics of the stock market mobility in different economic periods.

2. Data process

The data of this paper comes from Guotaijunan Database. We select 503 stocks in the Shanghai A Shares from 2001 to 2016, and take their daily closing price of 3876 trading days from January 2, 2001 to December 30, 2016. In order to obtain a quantitative correlation between each two stocks, we first calculate the stock's log yield:

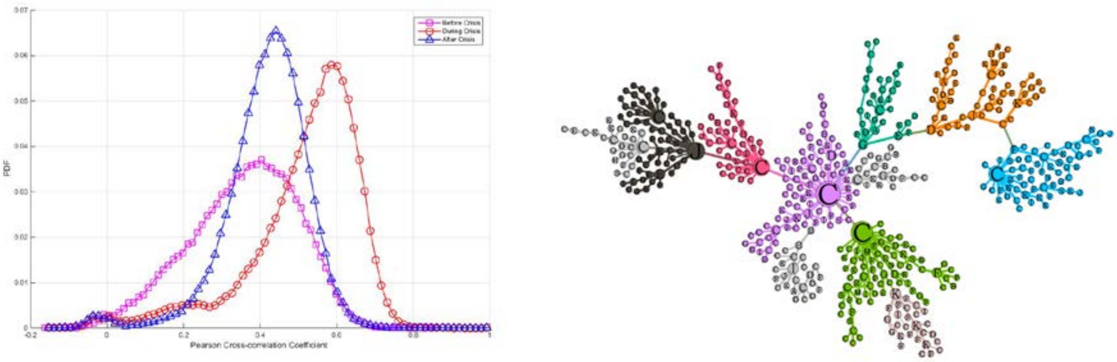
$$r_i(t) \equiv \ln S_i(t + \Delta t) - \ln S_i(t) \tag{1}$$

Of which, $S_i(t)$ denotes the price of stock i in t time. Δt denotes the time interval, which is one day in this paper. Then, we caculate the Pearson Cross-correlation Coefficient for the sequence of logarithmic returns of every two stocks:

$$C_{ij} = \frac{\langle r_i r_j \rangle - \langle r_i \rangle \langle r_j \rangle}{\sigma_i \sigma_j} \tag{2}$$

$\langle \cdot \rangle$ denotes mean. $\sigma_i = \langle {r_i}^2 \rangle - \langle r_i \rangle^2$ denotes the logarithmic return variance of stock i. According to the definition of Pearson Cross-correlation Coefficient, $-1 \leq C_{ij} \leq 1$ .Matrix $\boldsymbol{C} = (C_{ij})$ is the stock price logarithmic return rate correlation matrix. According to the method of Ashadun Nobi et al. who studied the Korean stock market[6], we divide the time series data into 6 periods, BEFORE THE CRISIS,DURING THE CRISIS,AFTER THE CRISIS ,BEFORE THE DISASTER, DURING THE DISASTER, and AFTER THE DISASTER. The probability distribution of the correlation during the financial crisis is shown in Figure 1(a).

3. Construct the Stock Price Return Cross-correlation Network



(a) (b)

Figure 1 PDF of Cross-correlation (a) and MST of Cross-correlation matrix(b)

In this paper, we use the minimum spanning tree method (MST) which is commonly used in financial markets to construct stock market network. The method was first applied by Mantegna to analyze the financial markets and now the MST method has been widely used in various financial markets. The reason is that the MST method can remove a large amount of redundant data in the data and catch the most important information of stock cross-correlation. In order to construct the minimum spanning tree network for the cross-correlation of stock price returns, we first transform the cross-correlation matrix into a distance matrix:

$$d_{ij} = \sqrt{2(1 - C_{ij})} \tag{3}$$

Of which, C_{ij} is the Pearson cross-correlation coefficient of stocks. The elements in the correlation distance matrix D satisfy $0 \leq d_{ij} \leq 2, d_{ij} = d_{ji}$, and the stronger the correlation between stocks, the closer the distance. And then based on the correlation distance matrix, we construct the cross-correlation network of the stock market with the MST Prim algorithm.

Figure 1(b) shows the Chinese stock market cross-correlation network during the financial crisis. Nodes represent stocks, the color represents the community. The edge weights indicate the distance between stocks. The letters represent the industry of each stock, and C represents manufacturing.

4. Topology of Filtered Network in Chinese Stock Market

In order to excavate the interaction mechanism among the stocks, this paper uses the RMT method adopted by Namaki et al. in the related work [1] to filter the market factors. We found that after filtering the market factors, the cross-correlation falls to the mean value around 0, which means that during the financial crisis, the correlation between stocks is mostly caused by the impact of the financial crisis.

Table 1 Topology Nature of MST in Different Periods

	BEFORE FC	DURING FC	AFTER FC	BEFORE SD	DURING SD	AFTER SD
AWD	1.814	**1.515**	1.721	1.866	**1.329**	1.676
AWD(filtered)	2.401	2.346	2.336	2.247	2.154	2.262
APL	6.772	7.626	8.455	9.219	8.04	8.212
APL(filtered)	15.551	**20.901**	16.221	19.325	**16.075**	19.771
ND	19	20	20	20	24	23
ND(filtered)	37	**53**	41	50	**38**	53

Further, this paper constructs networks of stock cross-correlation matrix before and after filtering market factors, and analyzes the differences of the topological properties such as the average weighted degree(AWD), the average path length(APL), and the network diameter(ND) of network in each period. We found that before filtering market factors, the AWD during the financial crisis (1.515) and the stock market disaster (1.329) are lower than that of other periods (1.676~1.814), reflecting that the high correlation between the stocks in the special period. After filtering, cross-correlations among different periods have no significant differences, but the APL and ND reflecting significant differences of network compactness, the network compactness during the crisis is significantly lower than other periods, and it is opposite in stock market disaster. The reason for this phenomenon is that the financial crisis and the stock market disaster have different impacts on the Chinese stock market. These phenomena did not appear before filtering the market factors, because the overall movement of the stock market during the crisis and the stock market disaster produced by impact has covered the changes in the self-interaction mechanism between stocks.

5. Mobility Analysis of Filtering Network in Chinese Stock Market

According the above results, we select four centralities which are the weighted degree centrality, closeness centrality, eigenvector centrality and the eccentricity centrality to analyze the network mobility. Previously, scholars used the mobility sorting method and found that there is a constant scale between the mobility of daily closing price, volume, and return rate of stocks with the sampling interval[7]. This paper uses the same method to calculate the mobility of each centrality indicators:

Step 1. Calculate the network node centralities of all stocks in time t and $t+\Delta t$

Step 2. Rank stocks according to the centralities and get the $R_{k,t}$ of each stock

Step 3. Calculate the mobility indicator RM of the ranking sequence in time t and $t+\Delta t$

$$RM_{(t,\Delta t)} = \frac{1}{N^2}\sum_{k=1}^{N}\left|R_{k,t} - R_{k,t+\Delta t}\right| \tag{4}$$

N denotes the number of stocks. The t is the start time of mobility, Δt is the sampling interval, $R_{k,t}$ represents the order of the stock k in time t. If two networks are independent, the mean of RM is close to 1/3. Figure 2 shows the ranking mobility RM of each centrality. We can see that as the time interval Δt increases, the mobility trends to be the 0.33, which reflects the weak long-term correlation. However when $\Delta t < 60$, the RM of centralities(such as weighted degree) with Δt reveal a power law relationship which is ubiquitous in data of all years.

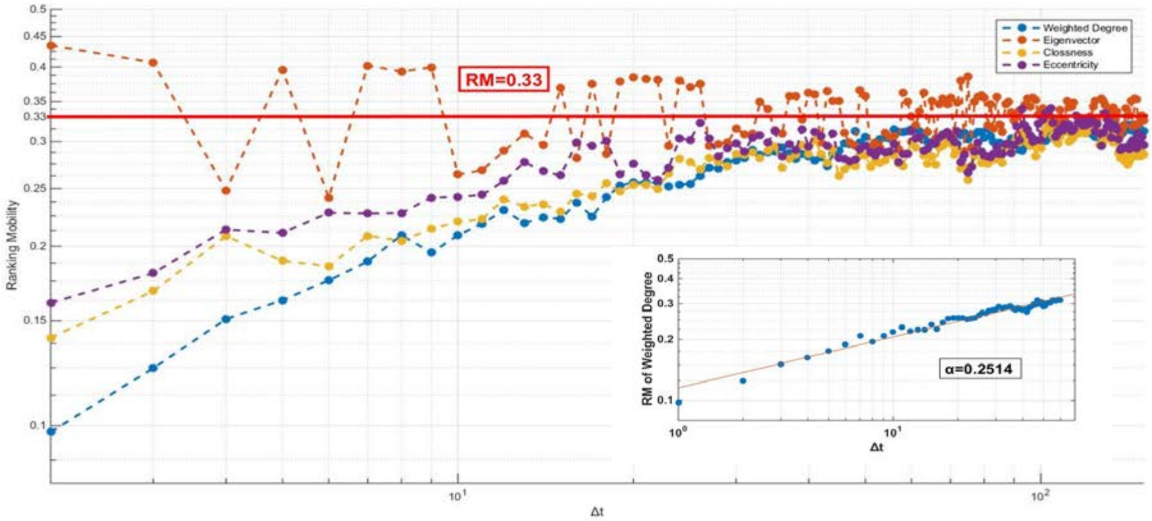


Figure 2 Evolution of Centralities with the Increase of Δt

In figure 3 we can see that during the financial crisis or the stock market disaster, there are obvious differences in the curves of the ranking mobility of weighted degree and closeness with time interval. The ranking mobility of the weighted degree gradually decreased with the occurrence of the crisis and disaster, and the ranking mobility of the closeness reached the lowest level during the crisis and disaster, and gradually recover after them. Compared with other centralities, weighted degree centrality and closeness centrality can be more stable to describe changes in the Chinese stock market network at the time of financial events. The closeness to the center can clearly demonstrate the differences of Chinese stock market network in the special period, which is of great significance for us to analyze the financial market.

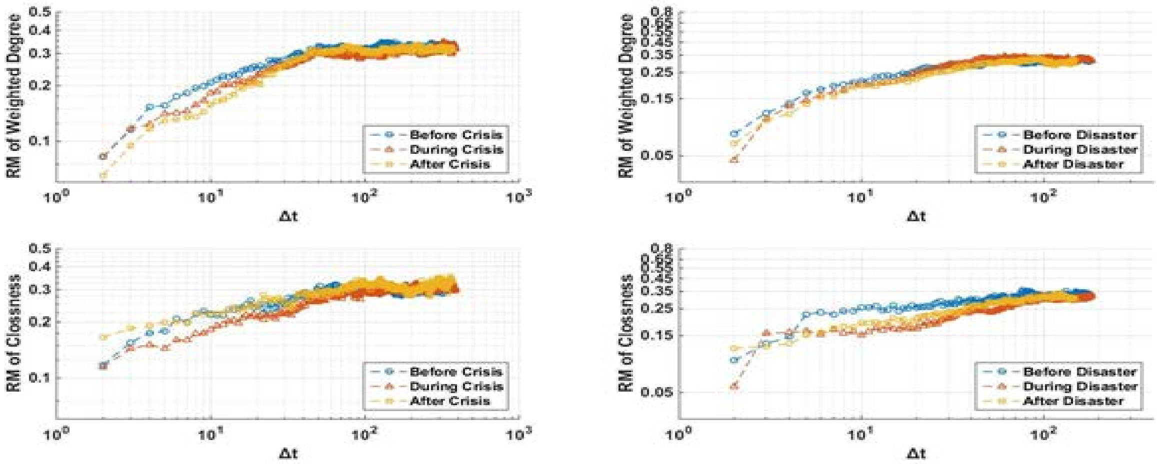


Figure 3 RM of Centrality during the Financial Crisis and Stock Market Disaster

After filtering the market factors, we found that the scale invariance of weighted degree centrality is robust to the market factors, and the power index α=0.2465, which is similar to the one before filtering, but the power index of other indicators gradually approaches to 0. We also found that those other indices become closer to the average of 0.33, indicating that after removing the influence of the overall market trend, the mobility of central indicators in the network of Chinese stock market is closer to that of random networks, but at this time, there still is a clear difference between network mobility and completely random networks. Therefore, the information contained in these indicators is related to the interaction mechanism of stocks themselves.

6. Conclusions

This paper uses the RMT to filter out the market factors, and then constructs the cross-correlation matrix and the MST network of the stock price return rate in order to remove the influence of the overall trend of the Chinese stock market, and explore the interaction mechanism between the stocks.

We found that after filtering the market factors, the cross-correlation network of Chinese stock market showed some different characters which the original cross-correlation networks did not have, that is the less compactness of the filtered network during the financial crisis and the greater compactness of the filtered network during the Chinese stock market disaster, reflecting the different results of the impact caused by these two financial events to the Chinese stock market. On the other hand, the weighted degree centrality of network is robust to the influence of market factors, there is no significant differences before and after filtering; the closeness centrality is not robust to market factors but with high sensitivity to financial events, can better reflect the state of China's stock market network in special periods; the eigenvector centrality and eccentricity centrality are too volatile to be good choices to be used for the analyzing of the mobility. Moreover, after filtering the market factors, the mobility of centralities become much closer to the random network except for the weighted degree centrality. But on the other hand, the part being different from the random network after filtering, contains important information, which is important for us to carry out research and analyze changes in the structure of the Chinese stock market in a special period in the future.

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