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Research Article

Research on Correlation and Network Topologies in Asia-pacific Food-Price Stock Markets Network

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Abstract: Aiming at examining the effects of the 2008 global financial crisis on network structure evolution of Asia-pacific food-price stock markets during 2008-2009, 2011-2012, the complex network is established to measure correlations in fluctation among food-price stock indice returen series of 19 Asia-pacific countries. The network topologiy properties are studied and the empirical results show that Asia-pacific food-price stock markets are a small-world, without scale-free characteristics. Hong Kong, South Korea, Singapore act as central nodes. The advent of the financial crisis can make the food-price stock network structure more compact, enhance the corelations. In the stable period, the network volatility reduces and the network hierarchy is more compact. The influence of China food-price stock markets become more powerful, but its stability has declined.

Keywords: Complex network, community structure, food-price stock market, scale free

INTRODUCTION

The Asia-pacific food-price stock market is a typical complex system (Yang *et al*., 2013). There exist a large number of micro units in the system and they interact each other nonlinearly to push forward the structure evolution of the correlation effects among food-price stock markets across the Asia-pacific regions (Li and Wang, 2007). The research on the statistics and the variation characteristics of the structure evolution is very helpful to reveal the internal interactions and network dynamics behaviors of the Asia-pacific financial complex system (Jiang *et al*., 2014), which provides decision-making supports to the Portfolio optimization, international financial risk prevention, national financial security maintenance and the capital market open strategies (Lixia, 2013).

The food-price stock market correlations and their structure evolutions are the typical problems in the international financial field (Han and Wang, 2014). In terms of financial market structure, many researchers explored the correlation degree among region food-price stock markets by employing the measurement methods such as VAR (Shamila, 2011), GARCH (Chong *et al*., 2008), variance decomposition (Fang and Gui, 2010) and so on in the background of financial crisis. These traditional parameter analysis methods are born with the defect of inconsistent results due to the parameter and index diversity. Also, the methods usually need some assumptions that may not be fully satisfied by empirical data (Han and Wang, 2014).

Aiming at these defects and combining with the explanation and analysis capability of complex network on food-price stock market complex behaviors (Liu and Chi, 2012), some scholars tried to construct the international food-price stock market complex networks by using the food-price stock index as nodes and the correlation coefficients of food-price stock index return sequence as weighted ledges based on real food-price stock transaction data. They analyzed the correlation between the financial pattern of the international food-price stock market and the market by considering the topology structure properties of the network (Han and Wang, 2014). For example, (Nobi *et al*., 2014) analyzed the changes of the correlations between the Korean food-price stock index and the global food-price stock index as well as the network topology attributes by employing Jaccard similarity measurement and the food-price stock index data from 2000 to 2012. Their study showed that the average correlation of Korean food-price stock index decreased while that of the global food-price stock index increased and there is not significant correlation between the Korean food-price stock index and the global food-price stock index. By establishing the directed and weighted network, (Yang *et al*., 2014) analyzed the correlations among 26 global

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food-price stock index under the background of subprime mortgage crisis and European debt crisis. Their research results showed that the food-price stock index influences of China, United States and Japan were always significant during the crises.

Summarizing from the above literatures, we found the researches mainly focus on two aspects. One is the influence mechanism among the developed countries' food-price stock markets and the other is correlations between the food-price stock market of a specific region and that of the others (e.g., between Chinese food-price stock market and the global food-price stock market). The research area is limited. The correlations among the food-price stock markets of the developing countries are to be explored further. And the object and scientific evidence is lack to some extent when the correlations between Chinese food-price stock market and global food-price stock markets are only described by several limited food-price stock index under the financial crisis (Yang *et al*., 2014).

As the financial globalization is deepened and the Asia-pacific financial market is more open, the volatility spillover and the correlations among Asia-pacific food-price stock markets are gradually obvious. The financial crisis in 2008 attracted people's focus on the correlations among the Asia-pacific financial markets. So under the background of the financial crisis in 2008 and based on the food-price stock index data of the financial crisis period (2008-2009) and the stable period (2011-2012), this study comparatively analyzes the correlations and the structure evolution characteristics of the Asia-pacific food-price stock markets in the two periods. The research ascertains the correlation structures of the Asia-pacific food-price stock markets and the network positions of each food-price stock market.

MATERIALS AND METHODS

Complex network construction of Asia-pacific food-price stock markets data collection and preprocessing: Focusing on the food-price stock markets of 21 members of APEC, this study selected 19 food-price stock indices as the subjects. The number, affiliated country and name of the food-price stock index are: 1. Singapore Straits Times Index STI, 2. Korea Composite Index KS11, 3. China Hongkong's Hang Seng Index HIS, 4. Vietnam Hu Zhiming index VNINDEX, 5. Malaysia Kuala Lumpur Composite Index KLSE, 6. Philippines Manila Composite Index PSI, 7. Japan's Nikkei index N225, 8. Jakarta composite index JCI, 9. China mainland Shanghai Composite Index, 10. Chinese Taiwan Weighted Index TWII, 11. Thailand Composite Index SETI, 12. Chile 40 IPSA Index, 13. Mexico MXX Index, 14. New Zealand NZ50 Index, 15. Australian Average Index, AORD, 16. Russia RTS index, 17. Canada Toronto 300GSOTSE Index, 18. USA Dow Jones industrial index DJI, 19. USA National Association of Securities Dealers Automated Quotations NASDAQ.

To compare the variation characteristics of Asia-pacific food-price stock market network structure in the financial crisis period and financial stable period, we collected food-price stock index daily closing price data during two time periods through Wind Information and Yahoo Financial Channels. The first period is from March 25, 2008 to September 21, 2009 which is the financial crisis period and totally 390 days. The second period is from March 25, 2011 to September 20, 2012 which is the financial stable period and totally 390 days.

Network construction:

Step 1: Time window setting: A window value W and a sliding interval *interval* are set. Suppose the raw data size is m, then the data from No. 1 to No. W is constructed as window $M1$, the data from1+*interval* to W+*interval* which are derived by slide an data *interval* towards right direction is constructed as window $M2$, … and totally $\frac{m-W}{interval}+1$ windows can be constructed by analogy.

The sample internal size m is 780 days, the time windows is $W = 60$ and the sliding interval is $interval = 30$. The raw data in the two time periods are divided into 12 windows respectively in terms of the time sliding order.

According to the evolution process of the financial crisis in 2008, the time windows W1-W12 falls into four partitions: crisis emerging period W1-W2, crisis bursting period W3-W6, crisis adjustment period W7-W10 and crisis ending period W11-W12. The windows W13-W24 corresponds to the financial stable period after the financial crisis and will be compared with windows W1-W12.

Step 2: Calculating correlation coefficient matrix: For given food-price stock index i, the closing price is $S_i(t)$ at time t, then the logarithmic rate of return $r_i(t)$ of the food-price stock index I is denoted as:

$$r_i(t) = 100 \times \ln\left(\frac{S_i(t)}{S_i(t-1)}\right), (t = 1, 2, ..., n) \tag{1}$$

By using Eq. (1) to preprocess the raw daily closing price data, the sequence of rate of return can be derived as: $R_i(t) = \{r_i(t)\}$, $i = (1,2,\dots 19)$.

The correlation coefficient is a kind of statistics index that reflects the close degree of correlativity between variables. It scores the time tendency correlation between food-price stock i and j. the Pearson coefficient is adopted here, which is calculated as:

$$C_{ij} = \frac{\langle R_i R_j \rangle - \langle R_i \rangle \langle R_j \rangle}{\sqrt{\langle R_i^2 \rangle - \langle R_i \rangle^2}\sqrt{\langle R_j^2 \rangle - \langle R_j \rangle^2}} \tag{2}$$

where, $\langle R_i \rangle$ means the time average of R_i.

Step 3: Calculating the adjacent matrix and constructing the undirected and un weighted network: The adjacency matrix denotes the adjacent relationship between vertexes. It is the basis of constructing the undirected and unweighted network. In the adjacency matrix, if the correlation coefficient between two food-price stock index *Cij* is bigger than or equal to the predefined threshold value (Yang *et al*., 2014), then the fall and rise in the two food-price stocks are thought to be similar, that is $C_{ij} = C_{ji} = 1$, otherwise $Cij = Cji = 0$. Correspondingly in the undirected and un weighted network, the ledge between vertex *i* and vertex *j* connects, otherwise the ledge is non-existent.

According to the probability distribution of pairwise correlation coefficients of food-price stocks for W1-W24, the initial threshold value is predefined as 0.6. That is to say for a given time window and correlation coefficient matrices C19×19, if $Cij \geq 0.6$, then $ni\text{j} = 1$, otherwise $ni\text{j} = 0$. Then the corresponding matrices N19×19 of the adjacency matrices can be formed. Based on the 24 adjacency matrices for W1-W24, 24 undirected and unweighted networks are constructed by using Pajek.

Step 4: Calculating distance matrix and constructing undirected and weighted network: To constructing undirected and weighted networks, the distances between food-price stock indices should be measured. For the correlation coefficient *Cij* of the given food-price stock index *i* and *j*, the distance *dij* between *i* and *j* is calculated by:

$$d_{ij} = \sqrt{2(1-C_{ij})}, i, j = (1,2,...,19) \quad (3)$$

RESULTS AND DISCUSSION

Macro analysis on the market structure of Asia-pacific food-price stock market:

Analysis on network average degree and network diameter: The network average degree and network diameter describe the close degree of the network structure. The network average degree is the average value of all node degrees in an undirected and unweighted network. The network diameter measures the maximal value of path distances between arbitrary two nodes in an undirected and weighted network. Figure 1 and Figure depict the network average degrees and the network diameters of W1-W24.

Figure 1 shows that network average degrees fluctuate over W1-W12. They have a large increase at W3-W4 and reach the peak at W5. Then their fluctuations decrease. It means that the network connectivity grows gradually during the outbreak of the financial crisis period while descends during the later stage of the financial crisis. The network diameters take on a continual decline in a whole. They are at their highest at W2, suffer from a sharp drop from W2-W4 and attenuate continuously from W8-W12. Reviewing the development history of the 2008 economic crisis, we can see that the economic crisis diffused instantly from the United States to Asia-pacific region and then to the globe when it broke out in June, 2008 (W3). Then Governments over the world respond positively and it was controlled step by step. The whole process agrees with the fluctuations of the network average degrees and network diameters from W1 to W12.

But at the same time, there exist inconsistencies in the network average degrees and network diameters to some extent. They are not completely reverse correlation. They have certain homoplasy in the time intervals such as W4-W5 and W5-W6. This may be caused by the fact that the change amplitude of the correlations between food-price stock price indices doesn't meet to the threshold selection condition (the threshold is 0.6) in some time. In this case, the changes in the network diameters should be used as the benchmark because the threshold method calculating the network average degrees of adjacent matrices ignores a part of valid information. The network diameters based on distance matrices reflect the correlations between food-price stock indices more comprehensively.

Finally, the network average degree under W12 is bigger than that under W1 while the network diameter is quite the reverse. It exposes that in the later stage of the financial crisis, both the network connectivity and the closeness of food-price stock indices grow.

By comparing Fig. 2 with Fig. 1, it can be found that the values of network diameters in Fig. 2 are obviously smaller than the values in Fig. 1. On the contrary, the values of network average degrees in Fig. 2 are obviously bigger than the values in Fig. 1. This indicates that the network structure of Asia-pacific food-price stock index is more compact in the financial stable period than in the financial crisis period. The network average degrees in Fig. 2 fluctuate with certain rules and their fluctuation cycle is similar to that in Fig. 1, that is to say, the network average degrees rise from W14-W16 and fall from W18-W19. But their fluctuation cycle in Fig. 2 is a slightly longer than that in Fig. 1, which means that the impact of the financial crisis can strengthen the network connectivity of food-price stock markets quickly. In contrast with Fig. 1, the network diameters in Fig. 2 have no obviously tendency, but take on a kind of irregular fluctuations similar to white noises.

Figure 2, the fluctuation amplitude of network diameters and network average degrees under W21-W24 is bigger than that under W13-W16, but is smaller as compared with the same period in Fig. 1. Therefore,

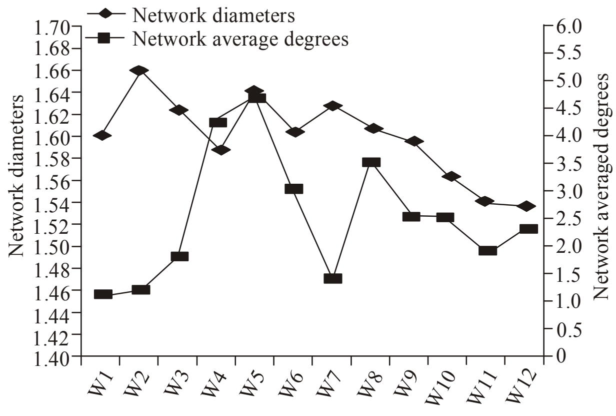

Fig. 1: Analysis on network average degrees and network diameters of W1-W12

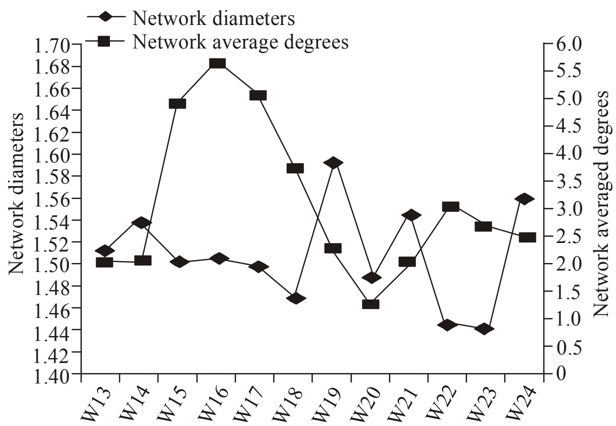

Fig. 2: Analysis on network average degrees and network diameters of W13-W24

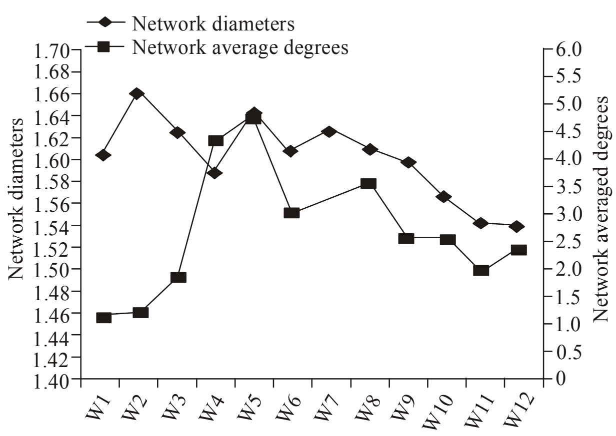

Fig. 3: Analysis on network average degrees and network diameters of W9-W12

it can be inferred that it is a kind of general trend that the network correlations of food-price stock markets become intense and the outbreak of financial crisis accelerates the evolution of the tendency, which is consistent with the economic globalization and the international financial market opening trend.

Furthermore, the fluctuation pattern of network clustering coefficients and critical path lengths under W13-W20 in Fig. 4 is similar to that under W1-W8 in Figure. But the difference appears in the later time windows. The changes of the network clustering coefficients and critical path lengths present certain same direction trend under W9-W12 in Fig. 3. However, the changes clearly keep the reverse direction trend under W21-W24 in Fig. 4. This implies that the outbreak of the financial crisis enhances the small-

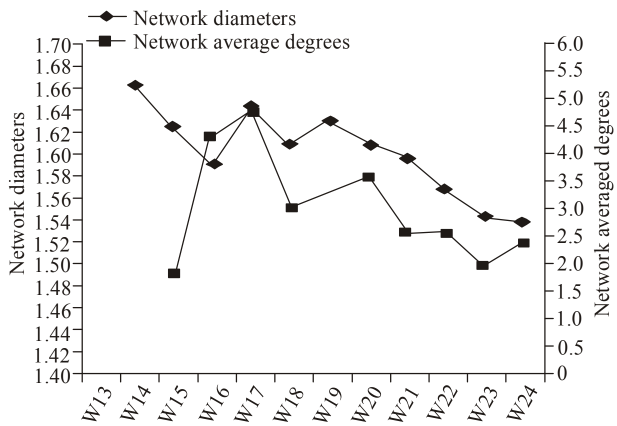

Fig. 4: Analysis on network average degrees and network diameters of W21-W24

world effect of Asia-pacific food-price stock index network, but the network renews back to the state of weak small-world effect after the financial crisis.

From the above analyses, it can be concluded that Asia-pacific food-price stock index network is a typical small-world network and has small-world effect. The financial crisis strengthens the small-world effect of Asia-pacific food-price stock index network. However, the fluctuation amplitude of the small-world effect of Asia-pacific food-price stock index network grows gradually as the international financial market tends to be stable.

Analysis on scale free property: The scale free property is a kind of intrinsic feature describing the serious non-uniform distribution of a complex system in a whole. Its mathematical expression of the power law is $P(k) \propto k^{-c}$, that is to say, the probability $P(k)$ of nodes with k degrees in the network is Proportional to *k*-c (C is a constant). To make the regression analysis more convenient, the power law expression can be transformed into:

$$\log(P(k)) \propto -c\log(k) \tag{6}$$

The scale free property of Asia-pacific food-price stock index network is calculated by using Eq. (6) under W1-W24. The significances of regression fitting under w1-w24 are listed in Table 1.

From the fitting results, it can be found that all linear regression results of logk values and logP(k) values corresponding to W1-W24 are not significant (R2<0.95) and there is no power-law distribution relation between K and P(k). This proves that there exists no scale free property for time windows W1-W24 in the undirected and unweighted network of Asia-pacific food-price stock index which is constructed on the adjacent matrices with threshold value equal to 0.6.

Table 1: Significances of scale free regression fitting

	Financial crisis period		Financial stable period
No.	R2	No.	R2
W1	-	W13	0.009
W2	0.214	W14	0.016
W3	0.005	W15	0.074
W4	0.000	W16	0.151
W5	0.003	W17	0.025
W6	0.001	W18	0.108
W7	0.912	W19	0.058
W8	-	W20	0.746
W9	0.001	W21	0.317
W10	0.000	W22	0.028
W11	0.436	W23	0.000
W12	0.119	W24	0.000

Sometimes the scale free property may be caused by a high threshold value which leads to a high frequency of K = 0. To eliminate such a bias on the scale free property, a series of tests were performed by setting the threshold value of adjacent matrices to 0.55, 0.5 and 0.45, respectively. The test results show that the drop of the threshold value makes the degree of each node increase and the occurrence probability of nodes with k = 0 reduce, but there is yet no power-law distribution relation between K and P(k) according to the fitting results of logk values and logP(k) values fromW1-W24 for the three tested threshold values. The tests verify the fact that Asia-pacific food-price stock index network has no scale free property both for financial crisis period and financial stable period.

However, why constructed Asia-pacific food-price stock index network has no significant scale free property in the two time intervals of W1-W12 and W13-W24? Is it caused by immature Asia-pacific food-price stock market or the small samples used to investigate the Asia-pacific food-price stock index network? The reason need be verified further by empirical studies.

CONCLUSION

Using the food-price stock indices of 19 countries in Asia-pacific region as research subjects, this study collected the food-price stock return sequence data from two time intervals, namely 2008-2009 and 2011-2012. With the complex network theories, the paper constructed the undirected and unweighted networks as well as the undirected and weighted networks and analyzed the structure evolution characteristics of Asia-pacific food-price stock markets both from the macro and micro viewpoints. The macro analysis results show that in the financial crisis period, there are definitely volatility in the network average degrees and a continuous decrease in the network diameter; in the later period of the financial crisis, the network connectivity and compact degree of food-price stock index network both strengthen; in the financial stable period, the network structure is more compact, the fluctuation cycle of network average degree is longer and the network diameter presents a kind of irregular fluctuation similar to the white noise. Both in the financial crisis period and stable period, the Asia-pacific food-price stock index network takes on the small-world effect but has no obvious scale free property. The small-world effect of the Asia-pacific food-price stock index network grows significantly in the financial crisis period and the fluctuation degree of the network's small-world effect becomes larger gradually in the financial stable period. These results provide cases and references for further empirical researches on the correlations of Asia-pacific financial markets, also are helpful for speeding up the opening process of the domestic capital market and the prevention of international financial market risks.

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