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Research Article

Systemic Risk in Chinese Commodity Futures Markets: A Graph Theory Analysis

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Abstract: This paper sets out to explore the contagion of systemic risk in Chinese commodity futures market based on specific tools of the graph-theory. More precisely, we use minimum spanning trees as a way to identify the most probable path for the transmission of prices shocks. In the sample of 30 kinds of Chinese commodity futures, we construct the MST and obtain the most probable and the shortest path for the transmission of a prices shock. We find that metal futures play an important role in commodity futures market and copper stands at the heart of the system (The core position of the system is very important for the transmission of system risk). And our results also reveal that when the risk occurs, the MST structure becomes smaller, leading to the most effective transmission path of risk becomes shorter.

Key words: Systemic Risk; Commodity Futures Markets

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1 Introduction

Futures market has the functions of price formation, resource allocation and systemic risk resolution, the leverage nature of futures trading determines that the risk of futures market is much greater than that of spot market. As for the risk transmission effect of commodity futures, most scholars focus on "the volatility transmission of the same commodity between futures market and spot market". Based on the GARCH model, Chan et al. (1992) empirically concluded that the S&P 500 index futures market and the spot market have two-way risk conductivity, and have the ability to predict the volatility of the other side. Lin and Tamvakis (2004) found that there is a two-way passive guiding relationship between the oil futures in the NYMEX market and the oil futures in the LIPE market. Xu and Fung (2005) found that there is a mutual guiding relationship between the risk of precious metal futures in Japan and the United States. Financial market risk transmission has been extensively studied in Chinese market, such as in stock market (Liangyu and Wang, 2014) , in energy market (He et al., 2013), in bank market (Feng et al., 2012) , however, there is surprisingly few research about the risk transmission of different commodity futures market.

Systemic risk refers to the risk of financial system collapse caused by partial or total damage of the financial system and which may have a serious negative impact on the real economy, the core of the system risk is the initial shock and contagion of risk (Nikolaus et al., 2013, Wu and Watts, 2002). More and more scholars are now applying complex network research methods to financial markets (A et al., 2010, Birch et al., 2016, Onnela et al., 2004) , complex network is the concept of graph theory, it takes each element inside a system as a node, and connects two nodes to form the edge of the graph under certain rules, thus forming a network system, that is, the network is a complex system contains a large number of individual nodes and interaction between individuals. Therefore, using graph theory to study the complex network system of the commodity futures market can provide investors and regulators with a more intuitive understanding of the commodity futures market system risk contagion path and dynamic changes in China.

The rest of the paper is organized as follows. Section 2 describes the data. Section 3 establishes empirical models. Section 4 discusses the empirical results. In Section 5 we conclude.

2 Data

For our empirical study, we selected futures markets corresponding to four sectors, namely metal, agriculture, chemical and energy futures. The dataset is from 2014 to 2019 including 1415 trading days, we obtain the daily price of main continuous contract of commodity futures form Wind. Table 1 is the research object of this article.

Table 1. Name of research object

Egg (1)	Corn (2)	Rapeseed meal (3)	Grain (4)	Soybean meal (5)
Soybean (6)	Soybean oil (7)	Rape oil (8)	Palm oil (9)	White sugar (10)
Cotton (11)	Rubber (12)	Copper (13)	Nickel (14)	Zinc (15)
Lead (16)	Aluminium (17)	Sliver (18)	Gold (19)	Screw thread steel (20)
Iron ore (21)	Steam coal (22)	coking coal (23)	Coke (24)	Glass (25)
Asphalt (26)	PTA (27)	Methanol (28)	Plastic (29)	PVC (30)

3 Empirical methodology

In order to study the contagion of risk among Chinese commodity futures, we rely on the graph-theory. We first decide to focus on the synchronous correlation of price returns, then we transform these correlations into distances, we are able to draw a fully connected graph of the prices system, where the nodes of the graph represent the time series of futures prices.

3.1 Synchronous correlation coefficients of price returns

The first step in the analysis of a complex network is the calculation of the price correlation synchronous correlation coefficient, which is defined as follows:

$$\rho_{ij}(t)=\frac{<r_i r_j>-<r_i><r_j>}{\sqrt{(<r_i^2>-<r_i>^2)(<r_j^2>-<r_j>^2)}} \tag{1}$$

where and represent two different commodity futures, and the daily logarithmic price difference represents the price return , is the price of the commodity futures at time , refers to the time series window, <.> represents the average of statistical data in other time windows. Then, we can calculate an correlation coefficient matrix containing all combination pairs , is a symmetrical matrix and contains the relationship coefficients of different combination pairs.

The graph theory approach requires that the data we cite be metric(metric), however, the relationship coefficient cannot represent the distance between and like, because it does not satisfy the three axioms defined by metric: We can convert the correlation coefficient into the distance by the following nonlinear transformation:

A distance matrix can be extracted from the correlation coefficient matrix by (2), but they are also different, can be positive or negative, but can only be positive. This distance matrix corresponds to a fully connected graph of commodity futures: it represents a network of all possible links in the price system.

3.2 From full connected graphs to Minimum Spanning Trees

In graph theory, if the overall network graph does not contain cyclic paths, we call the graph the tree structure of the network, which is the most obvious feature of a tree network. Spanning tree is defined as a subset of a network consisting of all nodes and partial connections in any given connected network. The minimum spanning tree is a special type of spanning tree, it is a sub-network of an associated network, the N nodes of the sub-network are connected by N-1 edges, and the sum of the distances of the N-1 edges reaches the smallest. The minimum spanning tree has the following properties:

1) The minimum spanning tree has N points and N-1 edges;

2) The minimum spanning tree is an acyclic structure;

3) The minimum spanning tree may not be unique.

Through a filtering procedure (the Prim Algorithm), the information space is reduced from to, the MST thus reveals the most relevant connections of each element of the system. In our study, it provides for the shortest path linking all nodes, thus, it can be seen as a way of revealing the underlying mechanisms of systemic risk: the minimal spanning tree indeed is the easiest path for the transmission of a prices shock.

4 Empirical results

In the first part of our study, we thus focus on the topology of the MST and its consequences for systemic risk. The second part is devoted to the dynamic behavior of the prices system.

4.1 The topology of the minimum spanning tree

In this first part of the study, we consider the whole time period as a single window and thus perform a static analysis.

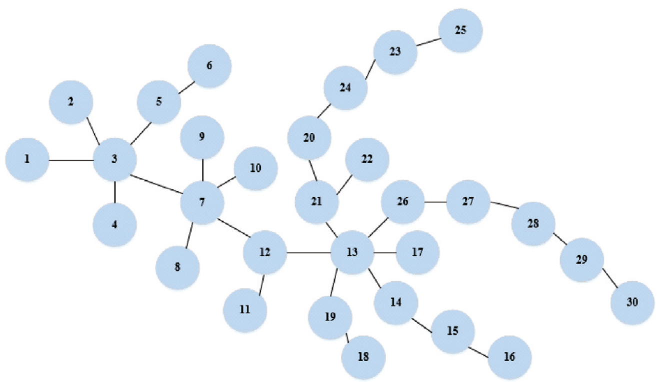

Figure 1. Static minimum spanning tree of commodity futures market, built from the correlation coefficients of prices returns.

In Figure 1, the metal sector and agricultural sector seem the most integrated, comparatively, the energy sector and chemical sector are distributed. The link between the agricultural and metal futures passes through rubber, and the link between the metal and energy (chemical) is screw thread steel (copper). The most connected node in the graph is copper, which makes it the best candidate for the transmission of price fluctuations in the tree, actually, we also find that the center of agricultural futures market are rapeseed meal and soybean oil, the center of metal futures market is copper, it is worth noting that the structure of energy and chemical market is linear, thus it is hard to say which commodity is at the center of energy and chemical market, but we can see that they are attached to the metal commodity. The surprise come from the steam coal and cotton, steam coal is more correlated to iron ore than to energy futures, cotton is more correlated to rubber than to agricultural futures.

The MST structure of commodity futures market in Chinese market is stellate, such a star-like organization leads to specific conclusions regarding systemic risk. A price move appearing in the metal markets, situated at the heart of the price system will have more impact than a fluctuation affecting peripheral markets such as PVC and glass.

4.2 Dynamical analysis of commodity futures market network structure

In consideration of this paper is based on time series data of futures price from 2014 to 2019, our study of commodity futures market network structure is intrinsically time dependent. In order to examine the time evolution of our system, we investigated the mean correlations of the returns and their variances. The mean correlation for the correlation coefficient in a time window can be defined as follows:

the variance of the correlation coefficient is defined as follows:

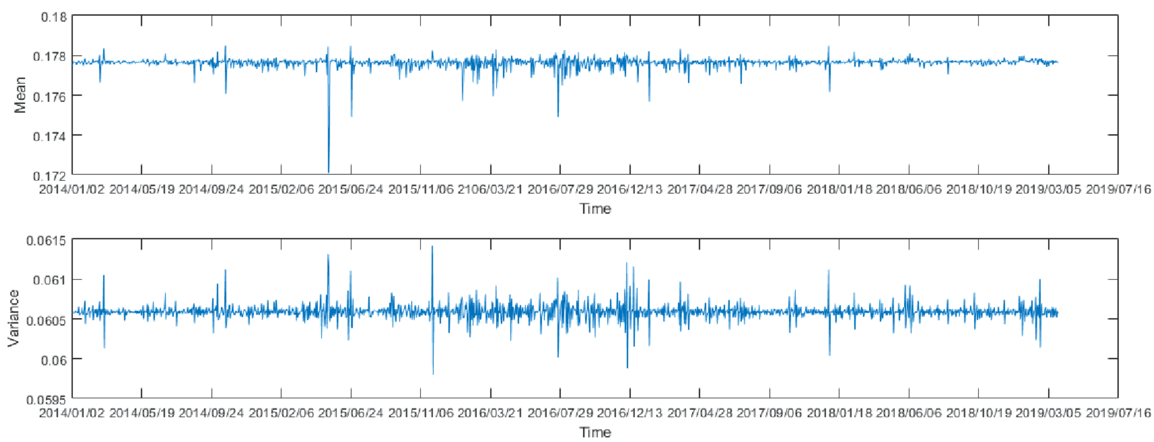

Figure 2. Mean and Variance of the correlation coefficients

Figure 2 represents the evolution of mean correlation and its variance, it shows that the mean correlation fluctuates around 0.177, and the variance fluctuate around 0.06052, we can also see some sudden change of them at some time, behind the huge fluctuations are hidden the occurrence of major events about futures market. From April 16, 2015, SSE 50 and CSE 500 stock index futures contracts were officially listed and traded; In November 2015, the Chinese government revised the hedging accounting system of commodity futures; From November to December 2016, affected by the US election, the price of gold and silver futures fluctuated sharply; In December 2017, Apple was listed as a new type of agricultural futures; In June 2018, PTA futures prices rose significantly. These major events caused common price fluctuations in the commodity futures market and have a significant impact on the whole futures market.

4.3 Dynamical analysis of MST normalized length

The normalized length is used to calculate the average length of the MST network, the calculation formula is as follows: where represents the average length of the minimum spanning tree at time , which reflects the size of the network, the larger the average length, the farther the distance between the points, and the smaller the average length, the closer distance between the points, that is to say when the becomes smaller, the MST structure is more aggregated.

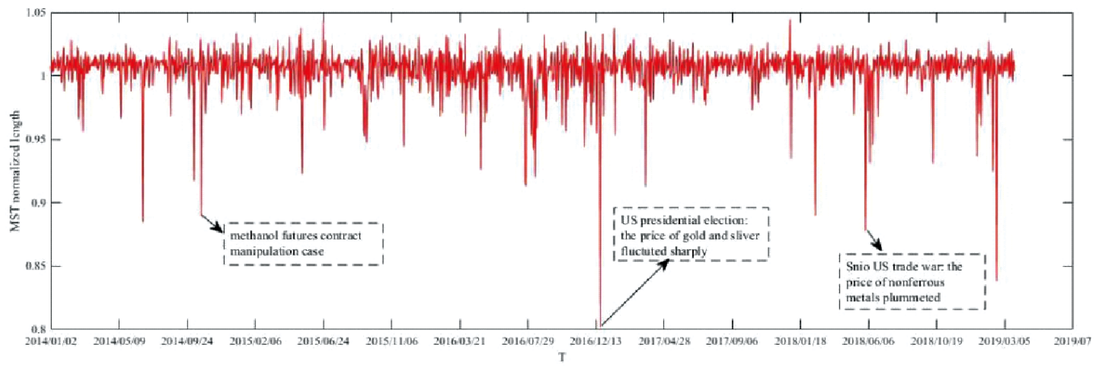

Figure 3. Normalized tree's length

Figure 3 shows the dynamic change of the normalized length of the MST, it is not difficult to find that when a vicious event occurs, the MST normalized length will drop suddenly, indicating that the emergence of crisis will make the connection between nodes closer, so that the most effective transmission path of risk becomes shorter.

5 Conclusion

In this article, we study systemic risk in Chinese commodity futures market based on minimum spanning trees. Firstly, based on the correlation coefficient of commodity futures price, we construct the correlation network of commodity futures market, further we use prim algorithm to get the minimum spanning tree of commodity futures market. Minimum Spanning Trees are particularly interesting in our context, because MST can be regarded as the most probable and the shortest path for the transmission of a prices shock. The visualization of the MST shows a star-like organization of the trees in Chinese commodity futures market, we find some key commodity futures: copper (at the center of the graph) rubber (linking metal futures and agricultural products futures), screw thread steel (linking metal futures and energy futures). These important commodity futures have the better candidate for the transmission of prices shocks. If such a shock appears at the periphery of the graph, it will necessarily pass through these key commodity futures before spreading to other sectors. Secondly, we discuss the dynamical analysis of MST, the results reveal how the MST structure changes when a vicious event occurs. When the risk occurs, the MST structure becomes smaller, leading to the most effective transmission path of risk becomes shorter.

These conclusions provide a valuable reference for maintaining the stability of the Chinese commodity futures market, preventing and controlling systemic risks, and formulating market rescue measures.

6 References

[1] A, Chi K. Tse; Jing Liu A B and Francis C. M. Lau A. 2010. "A Network Perspective of the Stock Market." Journal of Empirical Finance, 17(4), 659-67.

[2] Birch, Jenna; Athanasios A. Pantelous and Kimmo Soramaeki. 2016. "Analysis of Correlation Based Networks Representing Dax 30 Stock Price Returns." Computational Economics, 47(4), 501-25.

[3] Chan, K. C.; G. Andrew Karolyi and Renem. Stulz. 1992. "Global Financial Markets and the Risk Premium on U.S. Equity." Journal of Financial Economics, 32.

[4] Feng, Jichuang; Jianping Li; Lijun Gao and Zhongsheng Hua. 2012. "A Combination Model for Operational Risk Estimation in a Chinese Banking Industry Case." Journal of Operational Risk, 7(2), 17-39.

[5] He, Yongxiu; Tian Xia; Wei Xiong; Bing Wang and Yangyang Liu. 2013. "Risk Transmission Assessment of Electricity Price Chain in China Based on Ism and Ecm." International Journal of Electrical Power & Energy Systems, 46(MAR.), 274-82.

[6] Liangyu and Wang. 2014. "Study on the Extreme Risk Spillover between China and World Stock Market after China's Share Structure Reform." Journal of Financial Risk Management.

[7] Lin, Sharon Xiao Wen and Michael N. Tamvakis. 2004. "Effects of Nymex Trading on Ipe Brent Crude Futures Markets: A Duration Analysis." Energy Policy, 32(1), 77-82.

[8] Nikolaus, Hautsch; Schaumburg Julia and Schienle Melanie. 2013. "Financial Network Systemic Risk Contributions." Ssrn Electronic Journal, 19(2).

[9] Onnela, J. P.; K. Kaski and J. Kertész. 2004. "Clustering and Information in Correlation Based Financial Networks." European Physical Journal B, 38(2), 353-62.

[10] Wu, J. and D. J. Watts. 2002. "Small Worlds: The Dynamics of Networks between Order and Randomness." ACM SIGMOD Record, 31(3), 74-75.

[11] Xu, Xiaoqing Eleanor and Hung Gay Fung. 2005. "Cross-Market Linkages between U.S. And Japanese Precious Metals Futures Trading." Journal of International Financial Markets Institutions & Money, 15(2), 107-24.