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Analysis of linkage effects among industry sectors in China's stock market before and after the financial crisis

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HIGHLIGHTS

- We model China's stock market by using CITIC industry indices.
- Significant industry clusters and core nodes exist in the CITIC indices networks.
- The clustering degree strengthened within smaller ranges during the financial crisis.
- The network has great volatility during the financial crisis.

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ABSTRACT

This paper uses two physics-derived techniques, the minimum spanning tree and the hierarchical tree, to investigate the networks formed by CITIC (China International Trust and Investment Corporation) industry indices in three periods from 2006 to 2013. The study demonstrates that obvious industry clustering effects exist in the networks, and Durable Consumer Goods, Industrial Products, Information Technology, Frequently Consumption and Financial Industry are the core nodes in the networks. We also use the rolling window technique to investigate the dynamic evolution of the networks' stability, by calculating the mean correlations and mean distances, as well as the variance of correlations and the distances of these indices. China's stock market is still immature and subject to administrative interventions. Therefore, through this analysis, regulators can focus on monitoring the core nodes to ensure the overall stability of the entire market, while investors can enhance their portfolio allocations or investment decision-making.

1. Introduction

In recent years, many researchers have adopted the complex network theory in studying financial markets. For example, Eom et al. [1,2] investigated the topological properties of stock networks through analysis based on minimum spanning tree and random matrix theory in financial time series, concluding that the maximum eigenvalue has a significant influence on the formation of stock networks, and that the flow of information among stocks has an impact on market efficiency. Hughes [3] demonstrated that the minimum spanning tree and ultra-metric space based on time series are equivalent. Brida et al. [4] proposed an approach for constructing the minimum spanning tree and its corresponding hierarchical structure based on multivariable information, and demonstrated that the connection is not random by using Monte Carlo simulations. In addition to these examples, many studies used the minimum spanning tree technique to study the structure and topology

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of financial markets, for example, studies examining global stock market indices [5], global foreign exchange market [6], European banking market [7], European Union stock market indices [8], as well as studies on individual stocks in the UK's stock market [9,10], Germany's stock market [11], Turkey's stock market and foreign trade transactions [12–14], Brazil's stock market [15] and China's stock market [16].

The studies above mainly focus on global stock markets or individual stocks in one nation's stock market, while there have been few studies on one nation's stock market through industry classifications. In other words, the studies above either focus on global "macro" markets or on "micro" stocks in one country's market. Therefore, we conduct a "macro" structure study in a "micro" market in this paper, using CITIC (China International Trust and Investment Corporation) industry indices to obtain the classification of China's stock market and conduct network structure research. CITIC industry indices are published and maintained by CITIC Securities, aimed to accurately portray dynamic characteristics of stock groups in China's stock market, and to facilitate financial professionals in investment analysis, performance evaluation and asset allocation. The industry classification of CITIC indices not only refers to the globally famous index services company MSCI's (Morgan Stanley Capital International) and FTSE's (Financial Times and Stock Exchange) classification criteria, but also takes full account of China's industry characteristics and circumstances. The sampling of CITIC industry indices is comprehensive, which includes all Class-A stocks with complete data disclosure and normally traded in China's stock market. Based on the abovementioned conditions, CITIC industry indices have become representative of China's stock market index and have been widely used.

Compared with mature markets in the US and Europe, China's stock market is immature and subject to administrative intervention. Acting as the regulatory authority, CSRC (China Securities Regulatory Commission) takes responsibility for ensuring the stability of China's stock market; CSRC can also participate in the decision-making process of the central government, which can make stimulating policies for various industries. Obviously, efficient market supervision does not need to monitor all sectors in the stock market, but should rather focus on the most important and representative ones. Through complex network modelling of China's stock market before and after the financial crisis, this paper analyses the structural features of these networks and finds out the core nodes in the networks. The regulator thus can monitor the core nodes instead of monitoring every node or simply monitoring the nodes with large market capitalization. Besides, the regulator can also advise the central government to appropriately stimulate the industries which correspond to the core nodes when necessary, to effectively keep the stability of the stock market as well as the real economy. In addition, through this analysis, investors can avoid duplication of highly correlated assets when making portfolio allocations, while when making investment decisions, they can observe the performance of the indices highly correlated with their holding assets. As China has already become the second largest economy in the world and is gradually opening capital controls, this analysis is also useful for those foreign investors who may want to invest in China's stock market in the future.

2. Research methods

2.1. Minimum spanning tree

In this paper, we use Kruskal's algorithm, which was published by Joseph Kruskal in 1956, to construct a minimum spanning tree of CITIC industry indices. A brief description of the algorithm is as follows:

Step 1. View each node in a graph as an isolated branch, and sort the edges by their weights.

Step 2. Traverse the graph once, find an edge which has the minimum weight and make sure this edge does not form a loop with the ones already added to the minimum spanning tree collection. If all the conditions are met, this edge is added to the minimum spanning tree collection. Otherwise, continue to traverse the graph to find a next edge which has the minimum weight.

Step 3. Recursively repeat step 1, until $n-1$ edges have been found (if the graph has n nodes, the minimum spanning tree should have $n-1$ edges). Then, the algorithm terminates and the graph's minimum spanning tree is obtained.

2.2. Subdominant ultra-metric space method

In mathematics, metric space refers to a collection in which distances between any two elements can be defined. The metric space has several mathematical properties such as Hausdorff, normality and measurable. Let X be a collection, if all x_i, x_j, x_k in $d : X \times X \to R$ meet the following conditions,

$$\begin{cases} d(x_i, x_j) \geq 0, d(x_i, x_j) = 0 \Leftrightarrow i = j & \text{(positive definiteness)} \\ d(x_i, x_j) = d(x_j, x_i) & \text{(symmetry)} \\ d(x_i, x_j) \leq d(x_i, x_k) + d(x_k, x_j) & \text{(triangle inequality)} \end{cases} \tag{1}$$

we call d a metric of collection X, (X, d) a metric space, and X a metric space for metric d. A metric space which meets the following conditions is called an ultra-metric space:

$$\begin{cases} d(x_i, x_j) \geq 0, d(x_i, x_j) = 0 \Leftrightarrow i = j & \text{(positive definiteness)} \\ d(x_i, x_j) = d(x_j, x_i) & \text{(symmetry)} \\ d(x_i, x_j) \leq \max\{d(x_i, x_k), d(x_k, x_j)\} & \text{(ultra-metric inequality).} \end{cases} \tag{2}$$

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