Connectedness Study on the Main Financial Institutions by Metal Mining Listed Companies from Perspective of Complex Networks

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Abstract: This paper studies the network model of the relationship between metal mining listed companies by co-holding financial institutions as the node, and adopts the complex network theory analysis method to carry out the centrality calculation of the network model. The aim is to analyze the impact of main financial institutions in equity financing of China's metal mining listed companies on the relationship between listed companies in the metal mining industry. According to the research, it is found that the overall network relationship characteristics of metal mining listed companies, the status of each company in the network and the interrelationship of each company. Meanwhile it can help metal mining listed companies to make correct decision-makings, effectively promote enterprises improvement and development.

1. Introduction

China's mining industry plays an invaluable role in China's economic development. Especially the development of metal mineral resources takes an important role in China's industrialization and industrial diversity. Mining is a capital-intensive industry with high risk, long-term, and large investment[1], and it is urgently needed to support by the capital market. Therefore, in recent years, the number of metal mining listed companies has continued to grow. They actively seek cooperation with banks and other major financial institutions to integrate more capital, thereby expanding their market share. However, due to the complexity of financing behavior, a financial institution can finance another listed company while financing a metal mining listed company, so that metal mining companies can share the expected benefits and possible risks from financing. More importantly, because the mutual financing brings the interaction between enterprises, the business behavior and experience of a company will be transmitted to another company through the financial institution as a medium, making the mining metal listed companies with a certain close relationship between them[2]. Through the joint venture financial institutions' investment in two metal mining listed companies, the complex network among listed companies in metal mining can be established.

This paper uses the co-holding relationship to build a topological structure model of complex networks between metal mining listed companies with the co-holding financial institutions as the medium. By means of the "centrality" theory and method of complex networks, this paper analyzes and forecasts of the industry's core companies and the overall development of the mineral industry.
2. Methodology and data

2.1 Data Source
The statistical data comes from the wind database, which records the relevant information of Chinese listed companies in more detail. In the precious metals and non-ferrous metals sectors, a total of 81 mining listed companies were selected to screen and analyze the financial institutions among the top ten shareholders of each company, such as China Bank, China Construction Bank, Agricultural Bank, Industrial and Commercial Bank. Further statistical analysis of the financing behaviors and financing situations of these financial institutions, the relevant data selected as of December 31, 2018.

2.2 Network model construction
The preliminary statistics of 81 metal mining listed companies are based on the 2-module data of the financial institution shareholders held by each metal mining company, as shown in Table 1.

Table 1. Two-Mode relationship between the company and financial institutions

|                  | Industrial and Commercial Bank | Merchants Bank | China Bank | Bank of Communications | Agricul-tural Bank | Construc-tion Bank | Social Security Fund |
|------------------|-------------------------------|----------------|------------|------------------------|--------------------|--------------------|---------------------|
| Hunan Gold       | 1                             | 1              | 0          | 1                      | 0                  | 0                  | 0                   |
| West Gold        | 1                             | 1              | 1          | 1                      | 0                  | 0                  | 0                   |
| Shandong Gold    | 1                             | 0              | 0          | 1                      | 1                  | 0                  | 1                   |
| Zhongjin Gold    | 1                             | 0              | 0          | 1                      | 0                  | 0                  | 1                   |
| Chifeng Gold     | 1                             | 0              | 0          | 0                      | 0                  | 0                  | 0                   |
| Zijin Mining     | 0                             | 0              | 0          | 1                      | 1                  | 1                  | 1                   |

Then, using MATLAB, the 2-module data (Table 1) reflecting the financial institutions held by each metal mining company is converted into 1-module data of the relationship between the company and the company. See Table 2 for specific examples.

Table 2. List of financial institutions held by metal mining listed companies

|                  | Hunan Gold | West Gold | Shandong Gold | Zhongjin Gold | Chifeng Gold | Zijin Mining |
|------------------|------------|-----------|---------------|---------------|--------------|--------------|
| Hunan Gold       | 3          | 3         | 2             | 2             | 1            | 1            |
| West Gold        | 3          | 4         | 2             | 2             | 1            | 1            |
| Shandong Gold    | 2          | 2         | 4             | 3             | 1            | 2            |
| Zhongjin Gold    | 2          | 2         | 3             | 3             | 1            | 2            |
| Chifeng Gold     | 1          | 1         | 1             | 1             | 1            | 0            |
| Zijin Mining     | 1          | 1         | 2             | 2             | 0            | 3            |

The data in Table 1 indicates the number of holding financial institutions of metal mining listed companies. The financial institutions with no financing of the two companies are shown as 0. The number of financial institution shareholders included in each company is the data displayed on the diagonal. For example, Hunan Gold Company has three financial institutions among the top ten shareholders, and Hunan Gold Company and Western Gold Company hold two financial institutions in common.

After obtaining the matrix of mutual financial institutions based on the listed companies in the metal mining industry, GEPIH Software was used to build 81 metal mining listed companies as nodes, and the relationship between the financial institutions of any two metal mining listed companies as conjunctural edges. Therefore, the complex network model is established by the holding financial institutions of metal mining listed companies.

2.3 “Centrality” Analysis
In order to better study the characteristics of the holding financial institution relationship network of China Metal Mining Listed Companies, from the statistical characteristics of the network structure, we study and analyze the centrality of the network. And then it reveals the centrality of each metal mining
listed company in the overall network and the degree of interaction between them.

In complex networks, the measure of the nodes in the network or the center of the entire network is "centrality" [3-5]. The core position of a node can be measured by the centrality of its location in a complex network. Nodes with high centrality can help to understand the route of information transmitting in the network, the way of transmissions and even the effect of transmissions. Furthermore, they take the vital roles in the stability of the entire network. The main indicators for measuring centrality include: degree centrality, betweenness centrality, and closeness centrality.

**Definition 1. Degree Centrality**

Degree centrality is defined as the number of links incident upon a node. Accordingly, degree centrality is a count of the number of ties directed to the node. In complex network, the more ties one node is connected with, the more influential one it will be, and the higher this node’s centrality is. The degree centrality \( k_i \) is calculated as follow:

\[
k_i = \sum_{i,j \in N} d_{ij}
\]  

(1)

Where \( d_{ij} \) is a binary data whose value is 1 and 0. When there is a tie between node \( i \) and node \( j \), the value is 1. On the contrary, value 0 represents no ties between node \( i \) and node \( j \). \( N \) represents the vertex of all nodes.

**Definition 2. Closeness Centrality**

Closeness centrality (or closeness) of a node is the average length of the shortest path between the node and all other nodes in the graph. Thus the more central a node is, the closer it is to all other nodes. Closeness can be regarded as a measure of how long it will take to spread information from the node to all other nodes sequentially. Closeness \( C_{API} \) is defined as the reciprocal of the shortest path, that is:

\[
C_{API} = \left[ \sum_{j=1}^{n} D_{ij} \right]^{-1}
\]  

(2)

Where \( D_{ij} \) is the shortest path between node \( i \) and node \( j \).

**Definition 3. Betweenness Centrality**

Betweenness centrality is an indicator of a node's centrality in a network. It is equal to the number of shortest paths from all vertices to all others that pass through that node. A node with high betweenness centrality has a large influence on the transfer of items through the network, under the assumption that item transfer follows the shortest paths. Betweenness centrality is calculated as follow:

\[
BC_i = \frac{2 \sum_{j=1}^{n} \sum_{i}^{n} g_{jk}(i) / g_{jk} \cdot j \neq k, j < k}{n^2 - 3n + 2}
\]  

(3)

Where \( g_{jk} \) is the total number of shortest paths from node \( j \) to node \( k \), and \( g_{jk}(i) \) is the number of those paths that pass through node \( i \).

### 3. Results and discussion

Based on the above data and the "centrality" theory, UCINET6.0 software is used to calculate the degree centrality, betweenness centrality and closeness centrality of each Chinese metal mining listed company in the complex network.

**3.1 Degree Centrality**

From the Equation (1), it can be known that the degree of the node represents the ability of a metal mining listed company to develop a relationship with other metal mining listed companies, in the complex network model of a metal mining listed company based on the relationship of co-holding financial institutions.
Table 3. Degree of nodes (top 10)

| Company Name         | Degree | Company Name        | Degree |
|----------------------|--------|---------------------|--------|
| Ningbo Yunsheng      | 62     | Yunlv Share         | 57     |
| Hunan Gold           | 60     | Zhongfu Industry    | 57     |
| Tibet Mount          | 60     | Xingye Mining       | 55     |
| Tongling Metal       | 58     | Jiaozuo Wanfang     | 55     |
| Jiangxi Copper Industry | 58   | Shengdun Mining     | 55     |

Table 3 shows the top 10 company degrees from high to low. Ningbo Yunsheng company has the highest degree which is 62, indicating that the company has the largest association with other companies, and it is at the core situation of the entire network. The statistical results show that there are 3 companies with a degree of 60 or higher, and 3 companies with a degree of 0 (isolated point, that is, no association with other companies). The degree of 30 or more account for 73.70% of the total. It can be seen that most companies have higher degree, indicating that the correlation between companies is relatively close, and the density of the network is relatively large.

Figure 1 shows the probability of node degrees appearing within a certain range, and displays degree distribution of co-holding financial institutions overall metal mining listed companies. For example, if the degree is between 40 and 49, the probability of occurrence of the node is the largest, which is 26.58%. From the distribution results, it can be shown that the relationship of co-holding financial institutions of the listed companies in China's metal mining industry is concentrated.

![Probability distributions of different degree of nodes](image)

Fig.1. Probability distributions of different degree of nodes

3.2 Closeness Centrality

From the Equation 2, the closeness centrality of the nodes reflects the degree of proximity by the actors to all other actors in the network, in the complex network model of metal mining listed companies based on the relationship of co-holding financial institutions. Table 4 shows the closeness centrality of the top 10 metal mining listed companies. Among them, Hunan Gold Company has the highest degree of closeness centrality is approximately 0.79, indicating the company has the least dependence on other companies in the network, that is, the company is least controlled by other companies, and has an important position in the network.

Table 4. Closeness centrality of nodes (top 10)

| Company Name               | Closeness Centrality | Company Name           | Closeness Centrality |
|----------------------------|----------------------|------------------------|----------------------|
| Hunan Gold                 | 0.788333333          | Tongling Metal         | 0.777868688          |
| Tibet Mount                | 0.786944444          | Yunan Copper Industry  | 0.777868688          |
| Luoyang Molybdenum Mining  | 0.786944444          | Sitong New Material    | 0.777868688          |
3.3 Betweenness Centrality

From the Equation 3, the betweenness centrality of the node is used to measure the control with interaction between others to what extent, and the point is reflected the power of control and influence with strong practical significance, in the complex network model of metal mining listed companies based on the relationship of co-holding financial institutions. Table 5 lists the betweenness centrality of the top 10 listed companies. Among them, Ningbo Yunsheng has the highest degree of betweenness centrality is approximately 5.50%, and indicates that the company has the strongest control and influence in the network.

| Company Name     | Betweenness Centrality |
|------------------|------------------------|
| Ningbo Yunsheng  | 0.055064423            |
| Shenghe Resource | 0.054625269            |
| Hunan Gold       | 0.044064423            |
| Luoyang Molybdenum Mining | 0.043159906 |
| Zhongfu Industry | 0.043157854            |
| Tongling Metal   | 0.032118068            |
| Yintai Resource  | 0.028333333            |
| Shandong Gold    | 0.026944444            |
| Jiaozuo Wanfang  | 0.026944444            |
| Yunan Copper Industry | 0.025538462 |

4. Conclusions

This paper studies the relationship among the metal mining listed companies by using co-holding financial institutions as a medium, and analyzes the centrality by using complex network methods. Through the analysis of the centrality indicators related to the network, most companies have higher degree, indicating that the correlation between companies is relatively close. As can be seen from the complex network, Ningbo Yunsheng is at the center of the network, with the highest degree centrality and the highest betweenness centrality, in line with the attributes of industry leaders, indicating that Ningbo Yunsheng has the strongest influence, control and resources occupation in the industry. The indicators calculated and analyzed in this paper are useful for understanding the individual situation of each metal mining listed company from different aspects, as well as the overall situation of the industry, and providing important relevant empirical information.

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