Evolution of Global Slag Ash Trade Network Based on Social Network Analysis

Kexin Wang *

2774755209@qq.com

Xi'an International Studies University, Xi'an, China

Abstract: China is faced with many problems in the import and export trade of slag ash. This paper analyzes the network pattern of slag ash trade from multiple perspectives by using the trade data of UN trade database for five years from 2007 to 2022 and using social network analysis method. The conclusion shows that the slag ash trade network presents the characteristics of low aggregation and concentrated fluctuation, and the slag ash trade relationship between countries is not very close, but with the increase of years, the trade volume continues to rise. Therefore, this paper suggests that China should make full use of trade relations and hub advantages to realize the combination of "bringing in" and "going out" to promote the development of slag ash trade.

Keywords: Slag Ash, Social Network Analysis Method, Trade Network, Trade Relation

1. Introduction

Since the 21st century, the analysis of supply and demand of mineral resources and international trade has attracted more and more attention. Liang Ziyi (2014) [1] analyzed the evolution of the international trade pattern of zinc ore, and the study showed that the scale of international trade of zinc ore continued to expand, and the trade relations originally concentrated in a few countries gradually became more dispersed. Hao Xiaoqing (2017) [2] calculated the density, node degree, centrality and other indicators of the complex network of mineral products trade, and the results showed that the closeness of the mineral products trade relationship and the number of import and export countries increased year by year before the outbreak of the subprime crisis in the United States, among which the United States, China, Germany, South Africa, the United Kingdom and Canada were in an important position in the international mineral products trade network. It can be seen that the trend of globalization of mineral products trade is getting stronger and stronger [3].

Li Jing (2017) [4] used the method of network analysis to study the competitive and complementary relationship and dynamic changes of trade in goods of countries along the Belt and Road since 2005. Luo Shilon (2016) [5] studied the network structure and evolution of international trade based on the social network analysis method. Based on the commodity trade data of the United Nations from 2000 to 2010, he analyzed the main centrality measurement indicators such as network pair degree, intermedium number and strength, and came to the conclusion that the centrality of a country in the trade network has a relatively stable and clear hierarchy.

ICBBEM 2024, March 29-31, Wuhan, People's Republic of China

DOI 10.4108/eai.29-3-2024.2347325

The purpose of this study is to take the global trade of ore, slag and ash as the research object, including the introduction, the construction of trade network and research indicators, the analysis of trade status every five years from 2007 to 2022, and finally make further suggestions.

2. Methodology

2.1 Data Sources

The global slag ash trade data for 2007-2022 selected in this study are all from the United Nations Trade Database Category 26. (https://comtradeplus.un.org/)

2.2 Construction of Weighted Slag Ash Trade Network

In order to more clearly represent the relationship between the import and export of the global slag ash trade and the size

of the trade volume, the countries participating in the global slag ash trade every year are taken as the nodes of the trade network, the trade relations between countries are taken as the side, and the trade volume of slag ash is taken as the side weight, and the global slag ash trade network is constructed from 2007 to 2022. The complex network is represented by the adjacent square matrix as follows:

$$T_{(t)} = \begin{vmatrix} \omega_{1,1}(t) & \cdots & \omega_{1,j}(t) \\ \vdots & & \vdots \\ \omega_{i,1}(t) & \cdots & \omega_{i,j}(t) \end{vmatrix} \tag{1}$$

Figure 1 presents a directed weighted network graph of the year 2022, created using Gephi. Arrows denote trade directions, while the thickness of the lines represents the magnitude of trade.

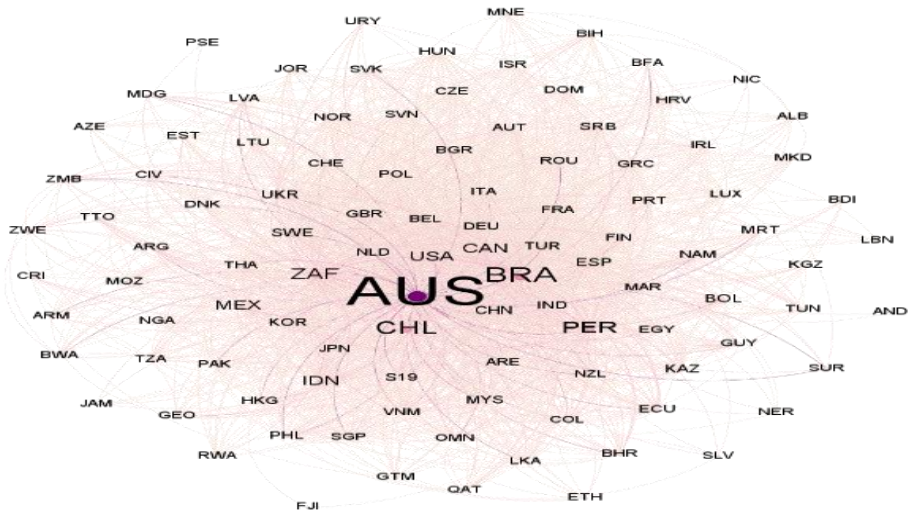

Figure 1. Directed weighted network graph of the year 2022

2.3 Related Measurement Index Description

2.3.1 Integral Network Density

Integral network density is an important concept in complex network analysis, which is used to measure the closeness of connections between nodes in the overall network. The formula for calculating network density is

$$D = \frac{2E}{N(N-1)} \tag{2}$$

D represents the network density, E represents the number of existing edges in the network, and N represents the number of nodes in the network.

2.3.2 Equilibrium Analysis

Reciprocity index is an important index in the complex network of international trade. Its mathematical expression is as follows:

$$\phi = \frac{m-d}{n} \tag{3}$$

Where, m is the total number of edges in the network and $m-d$ is the number of edges with inverse edges.

2.3.3 Centrality Index

The centrality of an individual in a group reflects its importance and influence in a network. The standardized index of relative degree centrality is

$$C_D' = \frac{d(n_i)}{g-1} \tag{4}$$

Where, d represents the sum of relationships in the network and $g-1$ is the maximum number of adjacent edges of a node.

And in a directed graph, the mathematical formula for the middle centrality is as follows:

$$C_B'(i) = \sum_{j}^{n}\sum_{k}^{n}\frac{b_{jk}(i)}{(g-1)(g-2)} \tag{5}$$

Where, b_{jk} represents the middle centrality of a point pair, $g-1$ represents the maximum number of adjacent edges of a node.

2.3.4 Centrality Index

If every node in a subgraph is adjacent to at least two other nodes in the subgraph, then such a subgraph can be considered a K-kernel.

2.3.5 Block Modeling

The block model analysis method is a method to study the network location model, which can intuitively reveal the association between various groups in the network. The classification

criteria of the block model adopted in this paper are as shown in Table 1.

Table 1. Block model classification standard table

Comparison of the actual internal relation ratio and the expected proportion of plate i	Plate i compares the number of relations it sends to other plates and the number of relations it receives from other plates	
	Sending relation number ≥Acceptance relation number	Sending relation number <Acceptance relation number
Actual proportion ≥ Expected proportion	Bidirectional overflow plate	Net beneficiary plate
Actual proportion<Expected proportion	Net overflow plate	Two-way beneficiary plate

3. Empirical Analysis

3.1 Integral Network Density

In this paper, Ucinet software is used to measure the trade network density in the following years, and the results are shown in Table 2.

Table 2. Global slag ash network density, 2007-2024

Year	**2007**	**2012**	**2017**	**2022**
Network Density	0.0441	0.0483	0.0474	0.0562
Standard Deviation	0.2052	0.2143	0.2125	0.2303

According to the data analysis from 2007 to 2022, the overall network density of the global trade network of slag ash has basically remained stable, about 0.04. This shows that the slag ash trade relationship between countries is not very close. Second, it can be observed that the network density fluctuates slightly every five years, with the highest density in 2022, indicating an increase in communication activity during this period.

3.2 Equilibrium Analysis

3.2.1 Reciprocity and Transitivity Analysis

In this paper, Ucinet software is used to analyze the 0-1 matrix formed by the national slag ash trade data from 2007 to 2022, and the results are shown in Table 3.

Table 3. Reciprocity coefficient of global slag ash network 2007-2022

Year	2007	2012	2017	2022
Reciprocity Coefficient	12.11%	12.64%	9.48%	4.7%
Clustering Coefficient	0.332	0.384	0.328	0.231

During 2007-2022, the reciprocity coefficient of the trade network is almost in the range of 5%-12%, indicating that the degree of mutual provision among countries in the trade network is low, that is, the trade between countries is not very balanced; The overall clustering coefficient is about 0.3, indicating that the interest transfer in the slag ash trade network is low, that is, the countries in the network lack of closely connected groups or clusters, and the trade relations between countries are relatively independent and dispersed.

3.3 Centrality analysis of global slag ash trade network

The analysis of eigenvector centrality helps to identify the key nodes and important participants in the slag ash trade network, and provides an important reference for further trade policy making and international economic cooperation. Ucinet software was used to analyze the 0-1 matrix of global slag ash trade data from 2007 to 2022, and the results were shown in Table 4.

Table 4. 2007-2022 Global slag ash network feature vector centrality

2007	2012	2017	2022
Brazil (36.20)	Brazil (37.27)	Brazil (36.70)	Chile (44.53)
Canada (34.75)	China (37.23)	China (34.48)	Brazil (30.29)
Belgium (32.16)	Canada (32.94)	Canada (34.40)	Turkey (28.93)
Australia (31.19)	Spain (31.02)	Chile (31.95)	Peru (28.28)
China (31.18)	Peru (30.87)	Germany (30.29)	Canada (27.44)
Germany (30.71)	Belgium (30.34)	Spain (29.94)	Czech Republic (25.91)
Netherlands (30.40)	Germany (29.12)	Peru (29.60)	Australia (25.76)
Chile (30.09)	Australia (28.30)	Australia (28.72)	Egypt (24.17)
Peru (30.03)	Mexico (27.48)	Netherlands (28.08)	Sweden (23.91)
Spain (29.92)	Chile (26.40)	Belgium (28.06)	Indonesia (23.75)

According to the annual eigenvector centrality, Brazil has always shown the highest eigenvector centrality from 2007 to 2017, and ranked second in 2022, which indicates that Brazil plays an important role in the slag ash trade network, and is closely related to other important nodes, and its influence and role in the trade network cannot be ignored.

3.4 Coacervation Subgroup Analysis

This paper uses Ucinet to conduct K-nuclear analysis of the global slag ash trade network.

Table 5. 2022 K-nuclear analysis

K-nuclear	Country
12	Mauritania, Brazil, Egypt, Kyrgyzstan, Australia and 25 other countries
11	Countries including the 12-nuclear group, as well as Burkina Faso, Belgium, etc
10	Countries including the 11-nuclear group, as well as Botswana, China, Ecuador, Fiji Islands, Madagascar, Mexico, Mozambique, Serbia, Ukraine
9	Countries including the 10-nuclear group as well as Germany and Guyana

Table 5 shows that from 2022, 25 countries, including Mauritania, Brazil, Egypt, Kyrgyzstan and Australia, have a higher audit number in the network, indicating that they have closer ties and higher importance in the trade network. The low scores of the other 14 countries mean that they have relatively weak links in the trade network and are at the edge of the network.

3.5 Tectonic Analysis of the Global Slag Ash Trade Relationship Network

In this paper, the block model analysis method is used to analyze the global slag ash trade network, and the Concor algorithm in Ucinet software is used to divide the import-export relationship of the global trade in 2007, 2012, 2017 and 2022 into blocks. (This paper takes 2022 as an example) those with similar economic structures are grouped into the same block. As shown in Table 6.

Table 6. Segmentation in 2022

	Reception Relation Number				Plate Membership	Expected Interior Relation ratio (%)	Actual Internal Relationship Ratio (%)	Receiving Block Relationship Numbers	Plate Function
	Plate 1	Plate 2	Plate 3	Plate 4					
Plate 1	61	236	0	1	35	36.1	20.5	28	Net overflow plate
Plate 2	25	129	0	0	36	37.2	83.8	242	Net beneficiary sector
Plate 3	0	0	0	0	19	19.1	0	0	Net overflow plate
Plate 4	3	6	0	1	5	4.25	10	1	Bidirectional overflow plate

It can be found that with the passage of time, the overall network density of slag ash basically shows a trend of gradual increase, indicating that the global slag ash trade network is more and more closely connected. There is a close relationship between textile trade in Block 2. China is in the middle of Block 2, indicating that China plays an important two-way influence in the global slag ash trade. This means that in 2022, China, as an important player in the slag ash trade, will not only have an impact on the countries that export slag ash, but also be affected by these countries.

This paper calculates the density matrix of the overall network in 2007, 2012, 2017 and 2022, and the image matrix of the trade network in each year can be obtained according to the density matrix. The image matrix is a simplification of the overall network structure, where the element of the image matrix is 1 when the block density is greater than the overall network density, otherwise it is 0,1 indicates that there is a strong trade connection between the two economies. 0 indicates weak trade links between the two economies.

Table 7. 2022 density matrix and image matrix

	Density Matrix				Image Matrix			
	Plate 1	Plate 2	Plate 3	Plate 4	Plate 1	Plate 2	Plate 3	Plate 4
Plate 1	0.048	0.01	0.227	0	0	0	1	0
Plate 2	0.011	0.005	0.077	0	0	0	1	0
Plate 2	0.01	0.004	0.064	0	0	0	1	0
Plate 2	0	0	0	0	0	0	0	0

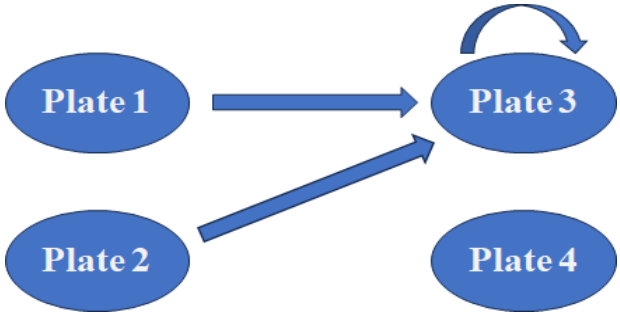

Figure 2. 2022 image matrix reduction map

As shown in Table 7 and Figure 2. According to the above results, plate 1, plate 2 and plate 3 are closely related to each other, because in the image matrix, their relation to other plates is represented as 1, while plate 4 is represented as 0, that is, no relation.

4. Conclusion and Suggestion

This paper analyzes the overall characteristics of the slag ash international trade network by constructing a complex network, studies the evolution characteristics of the network pattern nodes, including node distribution characteristics and node centrality characteristics, and identifies the core countries of the trade. The main conclusions are as follows:

1. The slag ash trade network presents the characteristics of low aggregation and concentrated fluctuation, and the slag ash trade relationship between countries is not very close. However, the scale of the slag ash international trade network has gradually expanded with the year, the number of participating countries has increased, and the trade volume has increased, and it will be more close in 2022. The reciprocity coefficient tends to be between 5%-12% and the value of clustering coefficient fluctuates around 0.3, so it can be concluded that the benefit transfer is low in the network and there is a lack of close groups in the network.

2. According to the degree centrality analysis, Brazil has always played a core role in this network as an export power, while China has always occupied a core position in terms of relative import centrality, but showed a significant downward trend in 2022, indicating that its import position is relatively weakened. Moreover, China has strong trade control in the network and is an important hub in the global trade network.

3. After the analysis of the relationship network, it is found that in 2022, China and France and South Africa, which are close to the center, are in the block 1, indicating that there is a complementary relationship between China and these two countries in terms of trade structure. Bolivia, which is close to China's centrality, is also in block 2, indicating that its trade structure is similar to China's and there is a competitive relationship.

Combined with the above conclusions, this paper puts forward relevant suggestions to promote the development of higher quality in China's slag ash trade network in the future. The suggestions are as follows:

1. The change trend of the overall network density and other indicators shows that the global slag ash trade network tends to be loose as a whole, and China has become a major importer of slag ash. It can make good use of its own trade relations and the advantages of the trade hub core, strengthen trade links with more countries, combine "bringing in" and "going out", give play to the advantages of the Chinese government's macro-control and avoid risks. Thus, the safety and stability of slag ash supply can be improved.

2. Diversified trading partnerships. Although China plays an important role in the slag ash trade network, in the face of China's relations with Brazil, Botswana and other countries, China should seek diversified trade partnerships to reduce trade dependence on a single country and reduce trade risks. At the same time, according to the analysis that the countries close to China's centrality are in different sectors, China should conduct in-depth analysis of the countries close to China's centrality, such as France, South Africa and Bolivia, to understand their trade structure and competition relations, so as to formulate more targeted trade development strategies.

3. Enhancing trade relations with Brazil. According to the sectionalized analysis of the relationship network, there is a solid trade relationship between China and Brazil, and China can further strengthen cooperation with Brazil and carry out more global and multilateral cooperation projects to expand trade scale and deepen cooperation relations.

References

[1] Liang Ziyi, Dong Zhiliang. Zinc ore pattern of international trade based on complex network evolution characteristics analysis [J]. Journal of resources and industry, 2021, 23 (4): 63-69.

[2] Hao Xiaoqing, An Haizhong, Liu Xiaojia et al. Main minerals analysis [J]. Journal of international trade resources and industry, 2013, (6): 3543.

[3] Dai, J., Hiung, E.Y.T., Destek, M.A. and Ahmed, Z., 2024. Green policymaking in top emitters: assessing the consequences of external conflicts, trade globalization, and mineral resources on sustainable development. International Journal of Sustainable Development & World Ecology, 1-15.

[4] Li Jing, Chen Shu, Wan Guanghua et al. Spatial Correlation of Regional Economic growth in China and its Explanation: Based on Network analysis method [J]. Economic Research, 2014, 49(11):4-16.

[5] Luo Shilong, Gong Kai, Xing Xin et al. Research on structure and evolution of international trade network based on social network analysis [J]. China Management Science,2016,24(S1):698-703. (in Chinese).