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# Analysis of the Spatial Pattern and Structure of the Global Cross-Border Logistics Network

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**Abstract:** Under the background of fierce competition in global cross-border e-commerce, cross-border logistics has become the most important and weakest link in the whole industrial chain. Based on data mining and tracking of 357 cross-border logistics channels and 380 million waybills, this paper constructs a global cross-border logistics network with 213 countries and regions as nodes, and conducts network analysis and geographical interpretation. The results show that: (1) At present, the global cross-border logistics development has become more mature, and its overall spatial pattern presents a hub-and-spoke structure with China as the outflow core and the US as the inflow core. The connections between nodes are imbalanced, and for most countries and regions, inbound flows exceed outbound flows. (2) The global core hubs are China, the United States, the United Kingdom and Hong Kong, followed by Germany, France, Canada and India. (3) The entire network is highly connected, showing an obvious core-edge layer structure, without obvious small groups. (4) The core circle layer is China and the United States, while the half-edge circle layer and the edge circle layer contain 85 and 126 countries and regions, respectively. The overall flow direction between the circles presents a diffusion state from the inside to the outside. The long-tail effect is significant, and the regionalization degree of the edge circle is higher than that of globalization.

**Keywords:** Cross-border logistics; Network analysis; Global trade; Cross-border E-commerce

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## 1. Introduction

Recently, cross-border E-commerce has become one of the main battlegrounds of the global economy. It boasts a massive consumer base, accumulating substantial economic benefits, vast big data resources, and significant cultural influence. Recognizing its potential to reshape the international status quo, countries around the world are investing huge resources to promote the development of cross-border E-commerce and compete for large data resources and international discourse rights based on this. It develops rapidly and has strong driving ability, and possesses a "late-mover advantage" in global competition, despite its later start.

The study of global trade patterns has always been the focus of geography. Research in recent years mainly uses the data on trade flows and input-output relationships to understand the pattern of import and export trade in various industries [1–4], and its influencing factors [5,6], evolution of the world trade network [7], interregional interdependence [8], etc. Based on this, they analyze China's trade status [9], compare the pattern between China and the United States [10], and

interpret trade fairness [11], etc. On the whole, in the current global trade network, the traditional global center status of the United States and Europe is basically stable but slightly declining, while China's trade status rapidly rises to become a new global center. India, Brazil, South Africa and some others have become the new regional trade centers.

In this paper, the research on logistics spatial pattern based on OD line and network analysis is extended to the global scale based on the above research background. Through mining and utilizing big data from logistics networks the spatial difference and geographical connection of cross-border logistics are analyzed, and its spatial characteristics and its influence are understood, so as to provide support for related space management and decision-making, maintaining and expanding the advantage of cross-border E-commerce in China.

## 2. Data sources and research methods

The data in this study comes from the mining and tracking of cross-border logistics waybill data from a big data platform in the Beijing Key Laboratory of One Belt and One Road data analysis and decision support. By combining the waybill numbering rules of cross-border logistics around the world, the platform generates waybill numbers in batches and tracks them to obtain cross-border logistics OD data. Among them, there are a total of 357 logistics channels that have obtained data, mainly including postal parcels and express delivery, and including some special lines and LTL logistics. Therefore, the data do not include those for bulk international commodity trade logistics, letters, unregistered parcels, etc., and the senders and receivers are mainly from two sides of cross-border e-commerce transactions, and a small number of individual deliveries. This data source is highly integrated, has wide coverage, and contains a large volume of data, which can display the development status of logistics comprehensively and systematically under the background of cross-border E-commerce, and has a strong explanatory power for the study of its global spatial pattern and regional connections. This study obtained global cross-border logistics data from July 2013 to June 2024, totaling 383,103,198 pieces.

The core research method of this study is Social Network Analysis. Ucinet software is used to build a network model, and to identify Network features and structure. The spatial elements are abstractly expressed to establish a model for network analysis. In this study, 213 countries and regions of the study sample are taken as nodes, and the delivery location-destination relationship of cross-border logistics is taken as a connection. A global cross-border logistics network model is established, with node size representing centrality and connection weight representing parcel volume. The network model is an asymmetric directed weighted network, which can be divided into centripetal flow and centrifugal flow according to the direction of connection.

Centrality is mainly used to measure the importance and influence of the node in the whole network, and its evaluation index mainly includes Degree, Betweenness, and Closeness. The analysis of spatial structure mainly focuses on agglomeration, correlation, hierarchy, centralization, and dispersion trend, etc., corresponding to many analysis methods in network analysis, such as agglomeration subgroup, clustering, correlation, and block model. When analyzing the spatial structure of cross-border logistics, we should not only pay attention to the connotation of its network model, but also pay attention to its geographical explanation. In this paper, the exploration-synthesis approach is adopted, that is, a variety of network analysis methods are first applied to explore, and then comprehensively analyze the spatial structure of cross-border logistics based on the significance of the analysis results and the corresponding geographical interpretation.

## 3. Spatial pattern analysis

From the perspective of the overall spatial pattern, the current global cross-border logistics is closely linked, with the overall network density reaching 40.72%. On average, each country has established connections with at least 53 others. On a global scale, an obvious hub-and-spoke structure with China and the United States as the core has been formed. The significant direction of inter-regional connections is that a large number of connections flow from all over the world to

North America, South America to Europe, China to all over the world, and Africa to all over the world. Overall, the global logistics network is not evenly connected. The top 80% of packages in the world is concentrated in 18.8% (40) countries and regions, 79.6% of places of dispatch are concentrated in China, and 29.7% of places of receipt are concentrated in the US, forming a very obvious spatial pattern with China as the outflow core and the US as the inflow core.

In the cross-border logistics network, the importance and influence of different countries and regions are different, and the various centrality degrees of each node are calculated to measure them quantitatively, as shown in **Table 1**. Among them, the degree of centrality mainly represents the number of connections and volume of parcels, which is the embodiment of importance and dominance. The betweenness of centrality reflects the media, and the closeness of centrality reflects the accessibility. When it comes to the distribution of the top 10, all kinds of centrality of China, the United States, the United Kingdom, and Hong Kong are in the top 10, and that 4 countries are the core hubs of the global cross-border logistics network with many logistics links, large capacity, and high efficiency. The centripetal and centrifugal accessibility of the core hubs are both higher. The core hubs have strong control over resources, which makes them important transfer stations connected to other countries and regions. This is not only the path dependence of the core hub status of the United States and the United Kingdom in the traditional international trade pattern, but also verifies the rapid rise of China's status in world trade, particularly cross-border E-commerce.

**Table 1.** Top 10 node centrality in the global cross-border logistics network

| Centrality | | Country or region |
|---|---|---|
| Degree | Power | China, USA, UK, India, France, Hong Kong, Australia, Canada, Germany, Netherlands |
| | Weighted | China, United States, France, United Kingdom, Russian Federation, Germany, Brazil, Canada, Netherlands, Japan |
| Betweenness | | China, USA, France, UK, India, Australia, Hong Kong, Canada, Germany, Netherlands |
| Closeness | Centripetal flow | China, USA, France, UK, Canada, India, Germany, Australia, Italy, Hong Kong, China |
| | Centrifugal flow | China, Netherlands, Hong Kong, USA, India, Sweden, Taiwan, Poland, Singapore, UK |

## 4. Structural feature analysis

Firstly, through calculation and verification, the global cross-border logistics network has strong connectivity: (1) The calculation result of network connectedness is 1, reaching the maximum value of the connectedness, which means that any two nodes can establish a connection. (2) K-core module analysis shows that the K-core is as high as 85-core, that is, there are subgraphs in which any node is connected with at least 85 nodes, and the correlation is very close.

It can be found that there is no significant small group in the global cross-border logistics network by exploring the coherence of the network; each node has many connections, and it is difficult to form relatively independent cliques characterized by "small subgraph cliques and relatively weak external relations." By exploring the hierarchical nature of the network, it is found that the core-periphery feature of the cross-border E-Commerce network is obvious; nevertheless, the hierarchical structure is relatively fuzzy.

The core-edge discrete model was applied to analyze the global cross-border logistics network. The core layer is China and the United States, while the edge layer is other countries and regions. The core-edge continuous model was used to calculate the core degree of each node. It can be seen that the core degree of China and the United States is much higher than that of other countries and regions, and the global cross-border logistics network shows obvious "core-edge" circle structure characteristics. The core circle is closely connected, with higher volume and more connections. The core actors have greater power and are in a comparative advantage position in the exchange relationship with the edge of the circle.

By calculating the freight volume in and between circles, the flow direction of the whole interlayer diffuses from

inside to outside. In particular, the freight volume of the flow from the core circle to the half-edge circle is the largest, accounting for 53.24% of the world, and the long-tail effect is significant. The freight volume in the circles is lower than the flow between the circles, and the freight volume in the core and half-edge circles is relatively large, accounting for 26.63% and 14.79%, respectively, while the freight volume in the edge circle is very small. The centripetal flow is mainly reflected in the flow from the half edge to the core circle, with a volume ratio of 4.24%. The flow from the edge to the half edge circle is greater than that from the edge circle, which indicates that the degree of regionalization of the edge circle is higher than that of globalization.

## 5. Conclusion and prospect

In conclusion, the current development of global cross-border logistics has become mature, with a high degree of connectivity, numerous links, and high density. Its overall spatial pattern presents a core hub-and-spoke structure with China outflow and US inflow, with unbalanced connections between nodes. The inflow of most countries and regions is greater than the outflow. The primary centrifugal flows originate mainly from the United States, China, France, and Russia, while the first centripetal flow is mainly from China. 22.6% of logistics connections are one-way, the rest are two-way, with two-way connections concentrated in the United States, China, Germany, the United Kingdom, the Netherlands, and South Korea.

In the global cross-border logistics network, the most core hubs are China, the United States, the United Kingdom and Hong Kong, followed by Germany, France, Canada and India. They have many logistics connections, large freight volume, higher efficiency and centripetal and centrifugal accessibility, and strong control over resources. They are important transit stations connecting other countries and regions in the world. The centrality of Australia, the Netherlands, the Russian Federation, Brazil, Japan, and other centers is also relatively high, which assumes the function of a regional logistics hub to some extent.

The global cross-border logistics network has a strong overall correlation, showing a clear core-edge structure, no obvious clique, and a relatively fuzzy hierarchical structure. The global cross-border logistics is divided into a “core-half-edge-edge” three-layer structure based on the comprehensive freight volume, cohesion, connectedness, and other factors. Its core circle is China and the United States, which are absolutely dominant. The half-edge circle is made up of 85 countries and regions closely related to the core circle, which occupies an important position in the global cross-border logistics. The edge circle is composed of 126 other countries and regions with low density and relatively loose connections, which is an important potential region for the development of cross-border logistics. The flow direction of the whole circle is diffused from the inside to the outside, the long tail effect is obvious, and the regionalization degree of the edge circle is higher than the globalization.

There are also some deficiencies in this study, which can be further expanded and deepened in future studies. First of all, the data source of this study is based on the cross-border logistics waybill. Although it covers the vast majority of cross-border logistics channels, there are still some cross-border E-commerce self-established logistics, logistics with irregular waybill number and logistics not open for tracking, which are not included in the data source and need to be further deepened in the construction of the big data platform. Secondly, the data time range is only the most recent year, so the evolution rule of cross-border logistics cannot be observed due to the timeliness of the tracking of the waybill number. In future studies, the process rule and influence mechanism can be explored based on the time series. Finally, cross-border logistics data also contain information such as transit points and time efficiency, which warrants deeper mining of the big data. Based on this, the analysis method should be re-explored to further study hot issues such as “time cost” and “space compression.”

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