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LITERATURE REVIEW ON INTERNATIONAL TRADE NETWORK

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Abstract: *Using social network analysis method to study international trade can explain the complex network of international trade patterns, reveal its formation mechanism and evolution law, and the status of a country or region in it. This paper reviews the related research on international trade networks. Firstly, seven international trade network construction methods are introduced, including the classical network model, fitness model, hyperbolic model, trade flow network model, multi-layer trade coupling network model, international trade dichotomy network model, and international trade skeleton network model; Then the research objects of the international trade network are classified according to the goods and services of BEC; Finally, the main research contents of international trade network are sorted out from the importance of nodes, the characteristics and evolution of network structure and influencing factors. The main conclusions are as follows: 1) in addition to the classical network model, different network models are derived, which provide research paradigms for trade networks with different perspectives and characteristics; 2) The research object involves all walks of life. In the future, the heterogeneity of the same industry can be investigated and the research of trade network refined; 3) The current trade network mainly presents the characteristics of small world, "core-periphery" and community structure, but the research on the evolution law is not systematic; 4) Based on the CAGE framework, this paper sorts out the impact of cultural, administrative, geographic and economic factors on the international trade network. With the deepening of international bilateral and multilateral cooperation, the development of international trade networks will become more complex. A more systematic and scientific framework should be established for the study of influencing factors.*

Keywords: *International Trade Network, Network Model, Evolution, Influencing Factors*

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Introduction

The development of international trade is the wind vane of the world's political and economic pattern, and can directly reflect the development trend of countries and the world as a whole. With the in-depth development of economic globalization, the "wheel hub-spoke" phenomenon of World Trade and the "spaghetti bowl effect" overlap, showing a complex network and evolution. It is difficult for statistics such as WTO, OECD, or UN to stereoscopically reflect whether and how the international trade pattern has changed. It is also difficult to thoroughly explain the international status and influencing factors of a country's trade development from the perspective and method of unilateral or bilateral trade relations. New tools are needed to understand the trade system and trade network. Social network theory and social network analysis tools provide research paradigms. Using complex network tools and methods to study international trade can reveal the formation mechanism and evolution of international trade from a global perspective, and then explain the interaction mode of trade between countries (regions) and its impact on system structure and function.

Since the 21st century, breakthrough progress has been made in social network theory research, and exploring the characteristics of trade patterns has become a new trend (He, 2022; Li and Liu, 2023). Snyder and Kick (1979) were the first representatives to study trade patterns using social network analysis. They used the trade data of 118 countries in 1965 to construct the unweighted network and analyze its core-periphery structure. Smith and white (1992) further compared the changes in the core-periphery structure of unweighted networks in 1965, 1970, and 1980. Since then, with the development of social network theory and analysis technology, the social network analysis method has been rapidly applied in the field of international trade. Among them, the scale-free network model (BA model) (Barabasi and Albert, 1999; Albert and Barabasi, 2002) has laid an important foundation for a more comprehensive and systematic study of international trade issues. Subsequently, scholars studied the international trade network from the theory and practice perspective. However, there is little literature that provides a systematic review of research on international trade networks. This paper reviews the literature on international trade networks from network construction, research object, and content.

Methodology

This paper uses Web of Science (WoS) and China National Knowledge Infrastructure (CNKI) as search platforms, with international trade networks as keywords. A comprehensive search yielded a total of 161 articles from WoS and 175 articles from CNKI. The identified articles were then categorized and organized into eight groups based on the regulations outlined in the Broad Economic Categories (BEC). Representative literature from both domestic and international sources was selected to conduct a thorough literature review. The review encompassed various aspects, including network models, node importance, structural characteristics, pattern evolution, and influencing factors.

Construction of International Trade Network

The primary problem facing the study of international trade networks is the construction of the network, that is, to define the nodes and edges of the international trade network. In recent years, scholars have established network models from different angles, which has provided help for the study of international trade.

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Classic Network Model of International Trade

An international trade network is a complex system composed of node sets of countries (regions) and tie sets of trade relations. According to the different natures of the ties, the international trade network can be divided into the unweighted network determined according to the existence of trade relations between countries (regions) (Li, 2003; Serrano and Boguná, 2003), and the weighted network to quantify the trade intensity between different countries (regions) (Kali and Reyes, 2007; Fagiolo et.al., 2008; Fagiolo et.al., 2009; Fagiolo et.al., 2010; Chakraborty, 2010; Schiavo; 2010; Fan et.al., 2014). Defining tie weights mainly takes the following forms: the trade value between the two countries (Fan et.al., 2014), the ratio of import and export trade value to total trade volume (Kali and Reyes, 2007), and the ratio of import and export trade volume to GDP of exporting countries (Fagiolo et.al., 2008; Fagiolo et.al., 2010).

International Trade Fitness Model

The international trade fitness model is a mechanism model that reveals the relationship between the internal attributes of countries (regions) and the establishment of trade relations. The key is to define the inherent attribute of each country (region), that is, the fitness value. Relevant studies have found that GDP is not only closely related to the international trade network (Garlaschelli et.al, 2007) but also strongly related to the network node degree (Serrano and Bogun, 2003). Garlashelli and Loffredo (2004; 2005) took the normalized GDP as the fitness value of international trade network nodes and then determined the trade connection probability between countries (regions) through the fitness. Hoppe and Rodgers (2015) proposed a fitness model based on GDP standardized ranking. This method not only eliminates a degree of freedom and reduces the noise of the statistical process, but also finds that the fluctuations of international trade behavior mainly occur between countries with large differences in fitness and connection methods. To predict the trade volume of bilateral trading countries, Almog (2015) extended the fitness model to the weighted network based on the enhanced configuration model (ECM) (Mastrandrea, 2014), and determined the dual status of GDP in the international trade network.

Hyperbolic Model of International Trade

The hyperbolic model of a complex network studies the geometric characteristics of the international trade network and reveals the geometric significance behind the trade relationship through the relationship between the hidden attributes of the trade network nodes and the geometric space coordinates of the nodes. The key is to determine the hidden attributes and hyperbolic coordinates of nodes. Based on the topology information of the trade network, Garc (2016) defined the hidden variables, polar coordinates, and node connection probability of the trade network under the hidden metric model (Serrano et al., 2008). The biggest advantage of this model is that it only uses the network topology information to measure the economic scale and distance of countries (regions).

International Trade Flow Network Model

Abstracting the input-output model into an open equilibrium flow network can reveal the laws of dissipation, allometric growth, and allometric scaling in economic systems (Leontief, 1951). Trade networks can also be abstracted into open-flow networks for modeling and analysis (Shi et al., 2013; Shi, 2014; Wu, 2014). The essence of the international trade flow network model is a special directed weighted network. Compared with the classical network model, the model has two special nodes, namely "source" and "sink". The source point only has energy outflow, which represents the production of countries, and the sink point only has energy inflow. It represents the consumption of various countries. To ensure that the trade flows between

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countries (regions) are strictly equal, the trade network is usually balanced by the edging method (Shi et al., 2013).

Multilayer Trade Coupling Network Model

A multi-layer network is a network set composed of multiple single vertex networks. Each single vertex network corresponds to a network layer. The network edges include not only the inner edge of the network layer but also the edge between different layers (Kivelä, 2014; Boccaletti, 2014). The current research mainly focuses on the interdependent coupling network (Buldyrev, 2010), that is, each layer of the network takes the country (region) as the node and the number of nodes in the double-layer network is certain, in which the single vertex network takes the trade relationship as the edge, and each network determines the edge between layers based on whether the node corresponds to the same country (region). Liu (2016) analyzed the robustness of international trade multilayer network based on percolation theory; Lee (2016) used the trade data of different industries to build a two-tier coupling network to analyze the cascading failure of interdependent networks; Mahutga (2013) added information such as time and product classification when building the international trade coupling network.

International Trade Bipartite Network Model

The dichotomy network model of international trade is a network model composed of countries (regions) and import and export products as network nodes, and the import and export relationship between countries (regions) and products as edges. The classic method is to use RCA index to identify the significant edge connectivity in the dichotomy network (Hidalgo et al., 2007; Vidmer et al., 2015), that is, to set the RCA index threshold. When the RCA index is greater than 1, the country (region) and the product will have edge connectivity. The bipartite network model of international trade can also be projected into a single vertex network through the bipartite network (Wu et al., 2010), and then analyze the relationship between products. Hidalgo et al. (2007) believed that the ability of a country (region) to produce products depends on the ability to produce other products, that is, when the production factors of products A and B are similar, a country (region) being able to produce product A means that it is also able to produce product B.

Skeleton Network Model of International Trade

The international trade skeleton network uses the differences in edge weights to extract effective information, reduce the proportion of edges and nodes in the international trade network, and then simplify the complexity of the international trade network and the trade system. Duan (2011) made a detailed analysis on the research on the international trade skeleton network, and also applied the spanning tree theory in graph theory to the construction of the international trade skeleton network, and analyzed the structural characteristics and evolution law of the skeleton network. Serrano (2007) used the phase transition phenomenon of the proportion of edges and nodes as the basis of network extraction, that is, to study the changes in the proportion of skeleton network nodes and edges in the original network. In this way, the number of edges is minimized and the proportion of nodes maintained, keeping the number of countries in the economic and trade system and making network extraction more reasonable and scientific.

Research Object

To present the research results of international trade networks more clearly, this review sorts out the representative literature according to the eight categories made by the fifth revision standard of Classification by Broad Economic Categories (BEC) formulated by the United

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Nations Statistics Bureau, reviewed and approved by the United Nations Statistical Commission, and published by the United Nations Secretariat in 2018, as shown in Table 1.

Table 1: List of Research Objects of International Trade Network Classified by BEC

Research objects	Author(s)	Research countries	Time nodes
Total trade	Snyder and kick (1979)	118 countries	1965
	Smith and white (1992)	Global	1965, 1970, 1980
	Duan et al. (2008)	192	1950-2000
	Fagiolo (2010)	159 countries	1981-2000
	Chen (2011)	Global	2000-2009
	Dai (2012)	China-ASEAN Free Trade Area	2004-2010
	Zhao and Wan (2016)	124 countries	1995-2013
	Zou and Liu(2016)	Belt and Road countries	2001-2013
	Chong and Qin (2017)	Belt and Road countries	2012, 2014
	Chen (2018)	BRICs countries	2005-2015
	Basile et al. (2018)	E.U. regional trade	2010
1)Agriculture, forestry, fishery, food, beverage and tobacco			
agricultural products	Ma et al. (2016)	Global	1996-2013
grain	Han and Li (2020)	Belt and Road countries	2012-2017
soybean	He (2022)	Global	1996-2019
forest products	Lovrić (2018)	E.U. 27 countries	1988-2006
wine	Cassi and Morrison (2009)	Global	1970-2004
2)Mining, quarrying, oil refining, fuels, chemicals, electricity, water resources, waste disposal			
crude oil	Cheng and Wang (2011)	Global	2001-2009
crude oil	Sun (2012)	Global	2002-2010
gas	Liu (2016)	Global	2007-2014
gas	Ma and Xu (2017)	Belt and Road countries	2006-2015
3)Building, wood, glass, stone, basic metals, residential, electrical appliances, furniture			
copper ore	Dong (2016)	Global	2007-2014
4)Textiles, clothing, shoes, jewelry, leather			
textiles and textile articles	Cingolani et al. (2015)	Global	2006
clothing	Yao et al. (2018)	Global	1995-2015
5)Transportation and services, travel, postal services			
automotive	Blazquez and Gonzalez (2016)	172 countries	1996, 2009

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automotive	Qi and Li (2023)	Global	2017-2020
marine transportation	Kaluza et al. (2010)	Global	2007
container transportation	Fan et al. (2015)	Global	2000-2010
tourism	Lozano and Guitierrez (2018)	214 countries	2013
6)ICT, media, computers, business, and financial services			
technology transfer	Shih and Chang (2009)	48 countries	1997-1999
aerospace field	Sun and Liu (2014)	20 countries	2006, 2007
electronic information industry	Gao and Li (2017)	Global	1993-2012
financial network	Chinazzi and Fagiolo (2013)	70 countries	2001-2010
productive services	Chen and Shen (2018)	60 countries	1995, 2000, 2005, 2008-2011
7)Health, pharmacy, education, culture, sports			
health industry	Zhu and Zhuang (2018)	195 countries	2001-2015
cultural trade volume	Chen et al. (2018)	Belt and Road countries	1990-2016
core cultural products	Ji (2020)	18 countries (regions) in the Asia Pacific Region	2018
core cultural hardware and software products	Han et al. (2021)	195 countries	2000-2017

It can be concluded that except the eighth category of government and military fields, the research on trade network involves various industries and fields under various scales, and also includes some comprehensive research, such as high-end manufacturing (Sun et al., 2014; Xu et al., 2015; Yuan and Xin., 2019; Li and Liu, 2023) and intellectual property trade network (Feng, 2022). Because the statistical data of service trade is far more difficult to obtain than that of trade in goods, the research on trade in goods is far more than that of trade in services, and the depth and breadth of research are beyond the reach of trade in services. In addition, the research on the overall network of a certain industry is usually insufficient for the heterogeneity of different products.

Research Content

The research on the international trade network has formed a series of achievements focusing on the **importance of nodes**, **structural characteristics**, **pattern evolution**, and **influencing factors**.

Importance of Nodes

The importance of international trade network nodes is an important indicator of the network micro-level research, which measures the influence and trade status of a country (region) in the trade network. The initial research mainly focused on the analysis of node centrality index, that is, network node degree (Schiavo, 2010; Squartini,2011a; Squartini, 2011b), betweenness

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centrality (De Benedictis, 2011), eigenvector centrality (Ren et al., 2013), etc. However, this sort of ranking is only a preliminary result, which can not well reflect the real situation. Therefore, the K-means clustering method is used to classify the nodes of the trade network by integrating various central indicators, to have a deeper understanding of the trade level of countries (regions) (Ren et al., 2014). Other scholars start from the idea of percolation and use the random walk method to analyze the importance of nodes in the international trade network (Fagiolo, 2008; Fagiolo, 2009; Fagiolo, 2010; Blöchl, 2011). Ren et al. (2015) and Baxter (2015) introduced a modified bootstrap percolation model to measure the importance of countries (regions) in international trade weighted and unweighted networks with node influence. In addition, Hidalgo (2009) started from the dichotomy network model of international trade, coupled product quality and national (regional) export capacity, and then quantitatively described national (regional) competitiveness. Tacchella (2012) also did similar work by making changes in the quantification of commodity quality. The research shows that commodity quality depends on the quality of the weakest competitive country (region) among the countries (regions) exporting the commodity, that is, it uses the idea of "Barrel Effect" to measure commodity quality.

Structural Characteristics and Evolution

The international trade network displays “the typical properties of complex networks, namely, scale-free degree distribution, the small-world property, a high clustering coefficient, and, in addition, degree-degree correlation between different vertices” (Serrano and Boguná, 2003). The **"core-periphery" structure** is an important feature of the international trading system. At first, Snyder and Kick (1979) used trade data to divide countries (regions) into core, semi-core, and periphery ones. Through empirical data research, Fagiolo (2009) found that the network not only has a "core-periphery" structure but also has been stable. This structural feature has been verified in many trade networks. For example, in the trade network of the ASEAN Free Trade Area, the core countries include China, Singapore, and Vietnam, and the rest are peripheral countries (Dai, 2012). European and American countries are at the core of the global health industry trade network (Zhu and Zhuang, 2018); China is at the center of the trade network of the "Belt and Road" economies (Yang et al., 2018); The United States, Brazil, and Canada are the key nodes of the soybean trade network (He, 2022). However, with the development of economic integration, the position of countries (regions) in this structure is constantly changing. For example, Chen (2011) found that the centrality of the United States was declining, while the centrality of Japan, Germany, Britain, France, and the BRICs was rising; In the trade network of the world's high-end manufacturing industry, the advantages of developed countries are more obvious, while the status of emerging economies is improving (Sun et al., 2014); The spatial pattern of the global cultural trade network has gradually changed from a dual-core structure dominated by Europe and the United States to a tripartite structure dominated by Europe, the United States, and Asia (Han et al., 2021).

International trade activities have been affected by economic, policy, and cultural factors for a long time, so there are regions with close trade relations and relatively sparse regions in the trade system, forming an international trade **network community structure**. The strength of national trade relations is in direct proportion to income. High-income countries have strong trade ties and gather together, while low-income countries have the opposite (Fagiolo et al., 2008), with a more obvious phenomenon of "Rich Club" (Chen, 2011). Piccadi (2012) found that in the early stage of international trade, four community structures were formed, of which only four countries were small groups, while large communities covered most countries in Europe, Asia, Africa, the Americas, and Oceania. By 2008, Asia played an important role in

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international trade. However, there is no key community affecting the international economy, which shows that the links between communities are constantly strengthening, thus supporting the view of the globalized trading system. Blöchl et.al (2011) used the weighted extreme value optimization (WEO) algorithm of coarse-grained processing to divide the weighted network into communities and found that the topological information of international trade can reflect the geographical aggregation and division of labor of international trade. However, the network community structure and the trade preference agreement area are not perfectly coincident (Garc, 2016), and the geographical division has a greater impact on the trade community structure than the trade division. Compared with the overall trade network, the network structure of a specific industry is heterogeneous, and its agglomeration quantity, degree, and other characteristics are significantly different from the overall trade network (Barigozzi, 2011). For example, in the world crude oil trade network, the former Soviet Union, West Africa, North Africa, and North America (Canada and Mexico) are regionalized (Chen and Wang, 2011); From 1995 to 2015, the global clothing trade network experienced a transfer path of diffusion first and then agglomeration, forming three relatively stable agglomeration areas: China, South Asia and Southeast Asia, the Americas and Europe (Yao et al., 2018).

With the development of economic globalization, trade networks have emerged with different network characteristics. The most obvious feature is the emergence and evolution of **network levels**. He and Deem (2010) analyzed the reasons for the formation of the hierarchical structure of the trade network by using the cophenetic correlation coefficient (CCC), and explained the phenomenon of "survival of the fittest" from the perspective of system development, that is, the international trade network is constantly evolving under the impact of the international economic situation. Shi et.al (2013) found the phenomenon of allometric scaling in the international trade flow network, that is, there is a power-law relationship between the total flow through the node and the influence of the node. When the allometric scaling index is greater than 1, the network is centralized, that is, a few countries (regions) control the whole international trade network, such as industrial products. On the contrary, the network is decentralized, that is, countries (regions) can conduct trade exchanges equally. Ren et al. (2014) conducted cluster analysis on the centrality structure of the weighted trade network and obtained the distribution of countries (regions) at different levels. Ma et al. (2016) found that the global trade network of agricultural products showed a skewed distribution; Chen et al. (2018) believed that the BRICs' trade network follows a power-law distribution and has a hierarchical structure.

Influencing Factors

The traditional gravity model believes that the bilateral trade volume is positively correlated with the GDP of the two countries, but negatively correlated with the distance. Through the expansion of the gravity model and the innovation of research methods, scholars began to investigate other factors affecting the trade network. This paper mainly combs the literature according to the **CAGE** framework proposed by Pankaj Ghemawat in 2001, that is, cultural, administrative, geographic, and economic factors.

Language is often used as a variable to measure the **cultural** differences between countries. Language homology is a manifestation of cultural homology, so two countries (regions) with the same language will also have similar cultures. Different languages often indicate large cultural or institutional differences, which means the existence of transaction costs, so countries tend to carry out trade activities in countries with the same language. From a global perspective, countries with the same official language have closer trade ties (Chong et al., 2017), such as the

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gas trade network (Ma et al., 2017), the global high-end manufacturing trade network (Yuan and Xin, 2019), the grain trade network (Han, 2020) and the cultural products trade network (Ji, 2020). However, in the soybean trade network, the trade volume between countries with different languages is relatively large. The possible reason is that the soybean trade is mainly determined by supply and demand (He, 2022). In the regional "Belt and Road" high-end manufacturing trade network, religious and linguistic ties among countries are not the dominant factors (Xu, 2015).

Among the **administrative** factors, the degree of freedom of trade, finance and currency, and government efficiency have a significant positive role in promoting high-end manufacturing trade (Xu, 2015). The trade system can significantly affect the trade network (Chong et al., 2017). The smaller the difference in government governance between the two sides of the trade, the more conducive it is to the formation of trade network relations (He, 2022).

Geographic proximity has a significant positive impact on various trade networks, such as high-end manufacturing trade network (Xu, 2015; Yuan and Xin, 2019), gas trade network (Maet al., 2017), international service trade network (Yang et al., 2017), agricultural products trade network of countries along the "Belt and Road" (Wei, 2018), manufacturing trade network (Wang et al., 2019; Cheng et al., 2022), cultural products trade network (Ji, 2020), etc. However, it has little effect on the formation and development of the soybean trade network (He, 2022).

The volume of bilateral trade is positively correlated with the GDP of the two countries (Dai, 2012). Economies with similar **economic** development scales are easier to form and maintain trade cooperation relations (He, 2022). The difference in total economic scale is an important factor affecting the agricultural trade network of countries along the "Belt and Road" (Wei, 2018). It has a positive impact on the manufacturing trade network (Wang et al., 2019), and also contributes to the establishment of new energy vehicle trade relations but play a weaker role (Qi and Li, 2023). Economic distance has a significant negative impact on the international service trade network in the Asia Pacific region (Yang et al., 2017); The difference in economic aggregate between countries has a significant role in promoting their grain trade relations, and economic powers play a leading role in the grain trade network (Han, 2020).

In addition to the CAGE factor, foreign direct investment (FDI) and trade agreements are also important factors. Zhao and Wan (2016) believed that the difference in FDI has a great impact on the world trade network. Geographic connections, differences in FDI, and cooperation between economic and trade organizations can explain 30.3% of the world trade network (Zhao and Wan, 2016). The trade agreement relationship has a very significant impact on the pattern of the world trade network (Chong et al., 2017), and is an important factor affecting the "Belt and Road" high-end manufacturing trade network (Xu, 2015), the "Belt and Road" agricultural trade network (Wei, 2018), and the manufacturing trade network (Wang et al., 2019). Other influencing factors include industrial added value (Yuan and Xin, 2019), the impact of the financial crisis (Dai, 2012), the difference in per capita carbon dioxide emissions (Ma et al., 2017), logistics performance (Ma et al., 2017;Ji, 2020), the difference in Urbanization level (Ma et al., 2017; Ji, 2020) and technological distance (Yang et al., 2017)

Conclusion

With the continuous development of science and technology and the advancement of globalization, the research of international trade networks has become more complex and diverse. In addition to the classic network model, scholars have successively derived a variety of new research paradigms when exploring trade networks with different perspectives and characteristics, including seven international trade network construction methods, which are the classic network model, fitness model, hyperbolic model, trade flow network model, multi-layer trade coupling network model, international trade dichotomy network model, and international trade skeleton network model. These paradigms can help us better understand the formation and evolution of trade networks.

The research object of trade networks involves all walks of life. Future research can further investigate the heterogeneity of trade networks within the same industry to more carefully analyze the impact of different characteristics on trade relations. This will provide us with more accurate and practical trade policy suggestions and promote the sustainable development of international trade.

The current research shows that the trade network presents the characteristics of small world, core-periphery, and community structure. However, there are still some deficiencies in the study of evolution law. Future research can further explore the evolution process of trade networks, reveal the internal mechanism, and better predict and explain the future development trend of trade networks.

Based on the CAGE framework, this paper systematically reviews the impact of cultural, administrative, geographic, and economic factors on the international trade network. This framework provides us with a comprehensive perspective and helps us understand the mechanism of different factors in the trade network. However, with the deepening of international bilateral and multilateral cooperation, the development of trade networks is bound to become more complex. Therefore, we need to establish a more systematic and scientific framework to study the influencing factors of trade networks more comprehensively and deeply and provide more powerful theoretical support for future international trade cooperation.

In general, the study of international trade networks is deepening and expanding. Through different research paradigms, more specific industry research, in-depth excavation of the evolution law, and the establishment of a more systematic and scientific framework, we will be able to more comprehensively and deeply understand and respond to the challenges and opportunities of the international trade network. This will help promote the sustainable development of the global economy and the stable growth of international trade.

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