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The Network Structure Characteristics of Ventilator Trade under Covid-19

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***Abstract*—** *Based on the global trade data of ventilator products in 2020 and the social network analysis method, this paper depicts and reveals the features of the trade network structures of global ventilator products. The results shows that the trade network of global ventilator products has a high degree of collectivization and cohesion. What's more, it embodies high overall trade efficiency owing to its excellent accessibility and connectivity. It also presents the core edge structure with typical small world characteristics. Among the trade network of global ventilator products, we can see that the United States, Germany and France are in the absolute central position and act as a "bridge". On the whole, the trade of global ventilator products reflects a trade pattern which is dominated by developed countries and has uneven spatial layout.*

***Keywords*—** *Social network analysis: Trade network: Ventilators.*

I. INTRODUCTION

In December 2019, China broke out the novel coronavirus which produces unprecedented threats to Chinese citizens' health and safety. Through thorough thought, it is rarely hard to be found that all kinds of major epidemics human society has experienced in recent 30 years (influenza A H1N1, Middle East respiratory syndrome, Ebola, Zika, etc.) nurtures non-traditional characteristics like transnational proliferation, universal threat and multinational governance. Under the trend of economic globalization, no country can cope with these threats alone, and no country can stay out of it. Just as the WTO stated, no country (region) is capable to produce all the commodities needed to effectively fight the epidemic. However, with the expansion of the imbalance of world economic and social development, the trend of trade protectionism and anti-globalization has become increasingly conspicuous. In the recent two years, more than 80 countries and tariff areas have imposed export prohibitions or restrictions. The products mainly include masks, medicine, respirators, etc. The implementation of the export prohibitions on medical equipment products, to a large extent, will cut off the supply of medical products required by some import-dependent countries, which may trigger a supply shock. In this context, it shows great significance to study the trade evolution characteristics of these medical devices worldwide.

Social network analysis is often used to analyze relational data. Nowadays, the analysis of trade network structure based on social network analysis method has been widely used in the field of international trade. Some scholars apply it to ICT industry, while others use it to study carbon emissions (Huang and Tang 2021; Li, Chen, and Chen 2020. Wang, Wang, and Zameer 2021). In contrast, these studies are more applied to trade networks of resources and energy (Wu, Pu, and Shu 2021) such as oil (Zhang, Fu, and Pu 2019）, natural gas（Samadi and Zahedi 2019; Xiaoqing, Haizhong, and Hai 2014） and solar energy（Yang, Poon, and Dong 2017）. Few scholars have investigated the trade network characteristics of agricultural products（Vollrath, Hallahan, and Gehlhar 2006） and service trade（Xu and Cheng 2016）, and there are fewer studies on the trade network of medical equipment. In 2019, the sudden COVID-19 brought a health crisis to the whole world. In the case of the shortage of medical products, all countries are bound to strengthen trade links in this area to ensure the stability of the value chain, industrial chain and supply chain of medical products. In view of such special context, this paper selects ventilator products as the research object to study the inter-dependence of countries all over the world in ventilator product trade.

II. DATA AND METHODS

A. Data sources

The data of ventilator trade used in this paper comes from the United Nations Commodity Trade Statistics Database. By consulting the customs HS code, the HS code of the ventilator product is 901920. This paper selects the top 45 countries whose cumulative trade volume of ventilator products account for 99% of the world's total trade volume as the network node. (USA, Germany, Switzerland, Ireland, Belgium, China, Italy, France, United Kingdom, Netherlands, Japan, Rep.of Korea, Austria, Spain, Canada, Hungary, Singapore, Australia, India, Sweden, Brazil, Poland, Denmark, Turkey, Mexico, Czechia, Israel, Vietnam, Croatia, NewZealand, Slovenia, Argentina, Greece, Romania, Colombia, Portugal, Thailand, Indonesia, Norway, Finland, Ukraine, SouthAfrica, Lithuania, Slovakia, Malaysia) Considering that the customs data of China, Hong Kong, Macao and Taiwan is separate from the Chinese mainland's. Therefore, the "China" mentioned in this paper is referred to Chinese mainland.

B. The construction of ventilator product trade network

The global trade network is a network used to describe the trade relations between countries. The links between countries reveal the import and export trade relations between them. According to the composition method of the complex network, the countries engaged in ventilator trade are used as nodes and the transnational trade relations of countries are used as edges to construct the ventilator trade network model. In the trade network constructed in this paper, $Vi = [v_i]$ (i = 1, 2,..., 45) is the trade exporting country, and $V_j = [vj]$ (j = 1, 2,..., 45) is the trade importing country. The weight matrix $W = [w_{i,j}]$ (i = 1,

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2,..., 45; j = 1, 2,..., 45) represents the trade volume of ventilator products exported by exporting country Vi to importing country Vj. By standardizing the trade volume of ventilator products, a binary trade matrix is obtained, and an unauthorized trade network is formed on this basis. In an unauthorized trading network, if $w_{i,j}$ greater than 0, the element a_{ij} of adjacency matrix A equals 1, otherwise the element a_{ij} of adjacency matrix A equals 0. Considering that the network only reflects whether there is a trade relationship of ventilator products among countries, it cannot well reflect the degree of mutual influence among countries in the trade relationship of ventilator products. Therefore, we deal with the edges. The trade volume is modeled as the weight of the edge (where the direction of the edge represents the direction of import and export) to obtain a directed weighted trade network. In the directed weighted trade network, the weight of ventilator products from node i to node j is represented by elements w_{ij}. As shown in Figure 1, each node represents trading country, the connecting edge with arrow represents the import and export trade relationship of various countries on ventilator products, and the thickness of the connecting line represents the trade volume. Among them, Germany, the United States, France, Italy, Canada and other countries have a large trade flow of ventilator products and occupy a relatively central position. It means that they have powerful influence and control in the trade network.

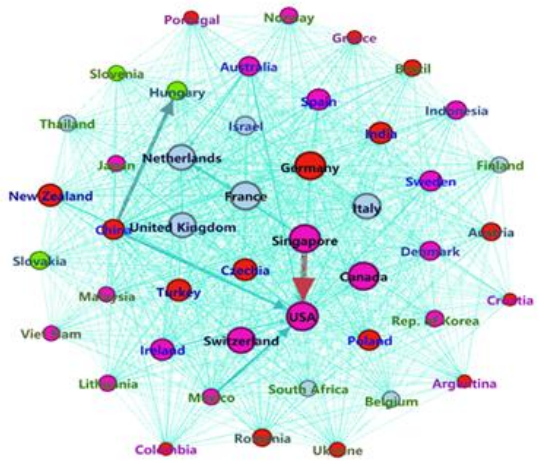

Fig. 1. Topology of global ventilator product trade network in 2020.

C. Indicators of network structural measurement

a. Network density

Network density is an indicator to show the characteristics of the overall network structure from the perspective of network connectivity and diffusion. Network density mainly examines the number of links established between different nodes in the network, which can objectively reflect the proportion of the number of nodes actually connected in the network in the links established by all trade network members. The higher the ratio, the greater the density of the network and the more connections between nodes. On the contrary, the smaller the network density, the less the connections between nodes. For directed networks, the expression of network density is d = m / (n (n-1)), where m represents the number of actually owned connections in the network and n represents the total number of nodes. The value range of network density is [0,1].

b. Centrality

Generally, the centrality of network analysis can be divided into three indicators: "degree centrality", "betweenness Centrality" and "closeness Centrality". Degree centrality represents the number of other nodes directly connected to a node. In a directed network, it is divided into in-degree centrality (IDC) and out-degree centrality (ODC). Betweenness centrality (BC) indicates the ability of a node to control the relationship between other point pairs, that is, the ability of the point to be on the shortest path of other point pairs. Closeness centrality, also known as overall centrality, represents the sum of the shortest paths between a node and other nodes. In a directed network, it is divided into out-closeness centrality (OCC) and in-closeness centrality (ICC). Through the analysis of the above three indicators, we can find the status and role of each node country in the whole trade network.

c. Core edge structure

The analysis of core edge structure mainly divides into the core, semi edge and edge areas, which makes the whole trade network structure be able to present the characteristics of close connection of the core and sparse and scattered edges. This paper separates the core edge structure in the ventilator product trade network through the core & periphery algorithm in UCINET. Countries with a core degree of less than 0.1 are defined as edge countries, while countries with a core degree of 0.1-0.2 are defined as half edge countries and countries with a core degree of more than 0.2 are defined as core countries.

III. Analysis of Trade Network Structure Characteristics

A. Overall network structure characteristics

The relevant characteristic indicators of the global ventilator product trade network in 2020 are calculated by Ucinet6 software (see Table 1). The network density (D)of the whole trade network is 0.81, indicating that the trade between countries on ventilator products is quite close. The average path length (APL) of the network is 1.19, which shows that the network has high transmission performance and efficiency. Each country can establish trade links through at most three countries, showing high cohesion. The average clustering coefficient (ACC) is 0.826, which reflects the high degree of collectivization of the network and the close relationship between countries. The shorter average path length and higher clustering coefficient show a typical small world feature of the whole network.

TABLE 1. Overall characteristics of ventilator product trade network

N	M	D	APL	ACC
45	1603	0.81	1.19	0.826

B. Partial structural features

a. Centrality analysis

Through the calculation of the three centrality of the global ventilator product trade network, the top 15 trade network centrality index countries are obtained (see Table 2 and Table 3). As a whole, Germany, the United States, France, Italy,

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Canada, the United Kingdom, Switzerland and the Netherlands all ranked among the top ten of the three centrality statistical indicators, which fully shows that these eight countries are in an important node position in the global ventilator product trade network and have high connectivity.

TABLE 2. Degree centrality in top 15 economic entities

ODC		IDC	
Countries	**Values**	**Countries**	**Values**
Germany	44	Germany	43
USA	44	USA	42
France	44	France	42
Italy	44	Singapore	41
Canada	44	Italy	41
Switzerland	44	South Africa	41
Netherlands	44	Canada	40
United Kingdom	44	Switzerland	40
Spain	44	Netherlands	40
China	44	United Kingdom	40
Ireland	44	India	40
Singapore	43	Turkey	39
Turkey	43	Czechia	39
Sweden	43	Norway	39
New Zealand	43	Spain	38

From the perspective of out-degree centrality (ODC), Germany, the United States, France, Italy, Canada, Switzerland, the Netherlands, the United Kingdom, Spain, China and Ireland are all connected with other countries in the network, indicating that these exporters are relatively popular among all economies. They take the most active performance in the whole network and show strong communicative competence. From the perspective of in-degree centrality (IDC), Germany, the United States and France still rank among the top three, indicating that the three countries take the core position in the trade of ventilator products and other countries are willing to have contact with them, which enjoy high reputation.

TABLE 3. Closeness centrality and betweenness centrality in top 15 economic entities

OCC		ICC		BC	
Countries	**Values**	**Countries**	**Values**	**Countries**	**Values**
Germany	1.000	Germany	0.978	USA	0.0101
USA	1.000	USA	0.957	France	0.0098
France	1.000	France	0.957	Singapore	0.0097
Italy	1.000	Italy	0.936	Germany	0.0096
Switzerland	1.000	Singapore	0.936	Canada	0.0096
United Kingdom	1.000	South Africa	0.936	Switzerland	0.0084
Netherlands	1.000	Switzerland	0.917	Netherlands	0.0083
Canada	1.000	United Kingdom	0.917	Italy	0.0082
Spain	1.000	Netherlands	0.917	United Kingdom	0.0079
China	1.000	Canada	0.917	New Zealand	0.0063
Ireland	1.000	India	0.917	Turkey	0.0061
Singapore	0.978	Turkey	0.898	Czechia	0.0060
Turkey	0.978	Czechia	0.898	India	0.0058
Sweden	0.978	Norway	0.898	Ireland	0.0057
New Zealand	0.978	Spain	0.880	Spain	0.0055

From the perspective of out-closeness centrality (OCC), the out-closeness centrality (OCC) indicators of Germany, the United States, France, Italy, Switzerland, the United Kingdom, the Netherlands, Canada, Spain, China and Ireland are all 1, indicating that these countries have the highest ease of reaching other countries and have strong radiation capacity. From the perspective of in-closeness centrality (ICC), Germany, the United States and France have more obvious advantages and relatively strong integration ability, and it is easier for other countries to contact them. From the perspective of betweenness centrality (BC), the United States, France, Singapore, Germany and Canada rank among the top five, indicating that these countries mainly act as "intermediaries" and "bridges" in the whole trade network of ventilator products.

b. Core edge analysis

The core degree of the global ventilator product trade network in 2020 is calculated through Ucinet6 software. The top 15 countries are shown in Table 4.

TABLE 4. Core degree in top 15 economic entities

Countries	**Values**	**Countries**	**Values**
USA	0.245	Ireland	0.224
Germany	0.245	Sweden	0.208
Switzerland	0.245	NewZealand	0.207
UnitedKingdom	0.245	Netherlands	0.206
China	0.245	Mexico	0.205
Italy	0.235	Australia	0.196
Canada	0.229	Singapore	0.194
France	0.227		

As shown in Figure 2, there are 13 core countries, accounting for 29%, mainly involving the North America represented by the United States and Canada, Europe represented by the United Kingdom, and East Asia represented by China. There is no doubt that the core countries play an important leading role in the trade connection and development of global ventilator products. There are 10 semi-marginal countries, accounting for 22%; It is mainly composed of Asian countries represented by Japan. There are 22 marginal countries, accounting for 49%. Obviously, compared with core and semi marginal countries, their trade participation needs to be improved.

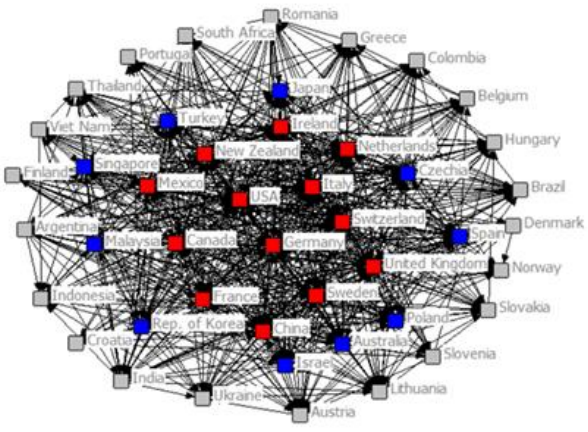

Fig. 2. Core edge structure of ventilator products trade in 2020

IV. CONCLUSION

This paper makes the use of the import and export trade data of ventilator product trading countries worldwide in 2020 provided by United Nations Commodity Trade Statistics

Database to build a ventilator product trade network. With the method of social network analysis, this paper explores structural characteristics of the global ventilator product trade network and the inter-dependence of countries in trade. The conclusions are as follows. First and foremost, the global trade network of ventilator products not only has high density, but also has excellent accessibility and connectivity. The overall trade efficiency is high and owns typical small world characteristics. Secondly, the United States, Germany and France are in the absolute central position in the global ventilator product trade network. Meanwhile, they also act as a "bridge" to closely connect other countries. Last but not the least, the global trade network of ventilator products presents a core edge structure, in which China, as a developing country, also ranks among the core countries. On the whole, although the global trade of ventilator products presents a trade pattern dominated by developed countries and uneven spatial layout. It is undeniable that the trade pattern of ventilator products is developing in the direction of "diversification".

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