Research on the Development of Industrial Internet from the Perspective of International Trade—Take Sensor Trade Network as an Example

Qing He [1] and Yang Hu [2]
[*] Corresponding author: heqing8673@163.com

[1]Capital University of Economics and Business, Beijing 100070, China
[2]China Industrial Internet Research Institute, Beijing 100102, China

Absrtact- Recently, the manufacturing industry has moved from the digital stage to the network stage, and the industrial Internet has developed rapidly. The sensor industry is changing rapidly, with a large number of sensor manufacturers, a wide variety of products, and a high level of technology. The global demand for the number of sensors is increasing. Starting from the sensor trade network, this paper analyzes the evolution trend of the sensor trade network by using complex network analysis method, computing centrality and network density, and further analyzes China's influence in the global sensor trade. The study found that the United States, Germany, France, the United Kingdom, Switzerland, Sweden, Japan, China and the Netherlands and other countries have a strong ability to control the sensor trade, and the trade between countries is more frequent. The increase in the volume of trade indicates that the global demand for the number of sensors is growing, and China's sensor import and export trade is expanding.

Keywords-Industrial Internet; Sensor trade network; Complex network analysis method

1. INTRODUCTION

Industrial Internet is the product of the deep integration of the new generation of information technology and manufacturing industry. It connects people and machines and establishes a system of comprehensive connection of industrial chain and elements. Accelerating the development of industrial Internet conforms to the general trend of industrial development and is the requirement of promoting innovation in manufacturing industry.

In China, the Industrial Internet plays an important role in economic development. Nowadays, with the rapid development of science and technology, the study of sensor trade network plays an important role in promoting the transformation of real economy, developing digital economy and establishing a strong country.

This paper starts from the sensor trade network, and uses the complex network analysis method to analyze the trade network, and comprehensively understands the evolution trend of the sensor trade network by analyzing the data.

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2. LITERATURE REVIEW

Industrial Internet is the product of the deep integration of the Internet and the new generation of information technology. Industrial Internet is a comprehensive network, which forms a complex network system through the connection of people, machines and data. Complex network is an abstract model to describe complex systems. It analyzes the evolution of the network by studying the statistical characteristics of the network.

A large number of existing complex systems can be studied by complex networks, such as grain trade network, airline economic trade network, oil trade network, etc. At present, the research on complex network mainly focuses on the characteristics of complex network structure, network structure and statistical parameters to study the properties of complex network. Chen Yurong[1] took the international oil trade volume from 2002 to 2010 as the sample data and based on the complex network theory, constructed the complex network and studied the evolution of the international oil trade network. The research results showed that the trade links between international oil trading countries were close. Based on the complexity theory, Liu Baoquan[2] regarded the international trade system as a complex economic system composed of several countries and studied the evolution law of the development of international trade through the analysis of global trade relations. Wang Wenxiao[3] selected 30 countries as the objects, established the trade network of the Arctic Air Route Economic Circle with countries as nodes, studied the trade evolution of the Arctic Air Route Economic Circle in the past 14 years, and concluded that the trade relationship between the countries in the Arctic Air Route Economic Circle was closer. Xia Rong[4] constructed the 2018 national LNG trade network, analyzed the international LNG trade network, and put forward optimization suggestions for the development of China's LNG industry.

The Industrial Internet brings opportunities to the development of sensors. The diversification of sensors promotes the development of the market, digitalization and intelligentization. Meng Xueqin[5] analyzed the application and development of photoelectric sensors and put forward relevant suggestions and prospects. Zhang Qiang, Guo Rong, Chen Rongze, Chen Jiaying [6] summarized the development of technology brought by the intellectualization and put forward suggestions for the development of sensors. Li Shao[7] believes that the biggest characteristic is diversification. Liao Yuanlai[8] proposed to realize data connection through communication network and wireless sensor network, thus establishing a comprehensive complex system. Xu Zhengzhong[9] proposed that countries in the world are interrelated and competing economically, and the global economy has formed multi-level integrated development in terms of resources and production.

To sum up, with the deepening of economic globalization, Industrial Internet research become a hot spot, the domestic scholars pay more attention to China and the related area of trade development, but now research focus on a single country or a particular area, so the need for international trade of industrial evolution of Internet research. From the perspective of research objects, the research objects of international trade are diverse. At present, studies have been carried out from different perspectives such as oil trade, network measurement, aerospace economy, and trade in goods, while few studies have taken sensor trade network as an example. From the perspective of research methods, complex network analysis is needed

to study the development status of industrial Internet from the perspective of international trade by taking sensor trade network as an example.

3. SENSOR TRADE NETWORK

3.1 Data sources

This paper takes the evolution of the sensor trade network as an example to study the development of the industrial Internet from the perspective of international trade. In order to ensure that the research data includes all the countries that have joined the sensor trade in the world, the United Nations Trade Database (UN-COMTRADE) is selected as the data source of the global sensor trade. This article selects 2006-2020 global sensor data of imports and exports, mainly is the commodity code for HS902690 all pressure sensors. Countries with large trade volume play a key role in the global sensor trade. Therefore, the data with trade volume less than $500,000 is deleted from the import and export data of sensor trade, and the original data with annual trade volume of more than $500,000 between countries is obtained from 2006 to 2020. Finally, 122 countries are selected as the nodes of the trade network. In the UCINET software, the initial Excel data is sorted out and transformed into the data format that UCINET can process.

3.2 Construction of sensor trade network

By sorting out the import and export volume of global sensor trade, 122 countries are selected as complex network nodes, and the direction of sensor trade flow between countries is the directed edge. According to the data, a complex network diagram is made. In the sensor trade network, the direction of the edge is the flow direction of the sensor trade, and then use UCINET software to draw the trade network diagram.

3.3 Building sensor trade networks in different periods

The data of 2006, 2010, 2015 and 2019 are used to make the trade network diagram. The trade volume of sensors is not representative, so the data of 2019 are used to make the network diagram.

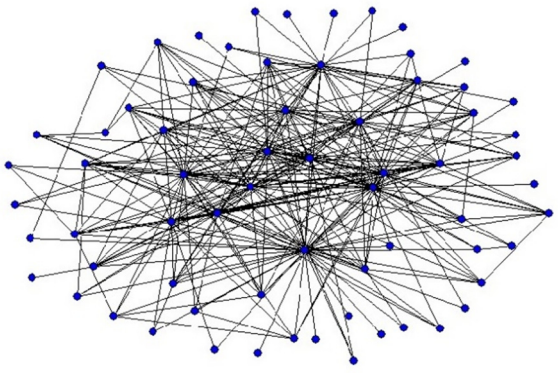

Fig.1 trade network in 2006

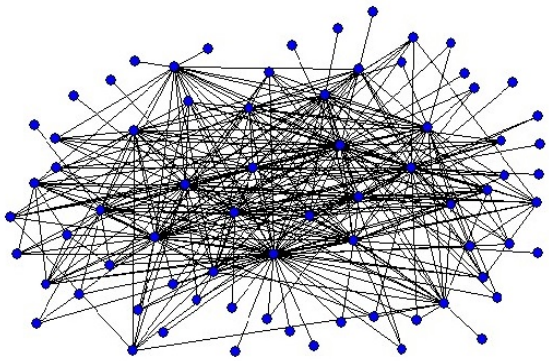

Fig.2 trade network in 2010

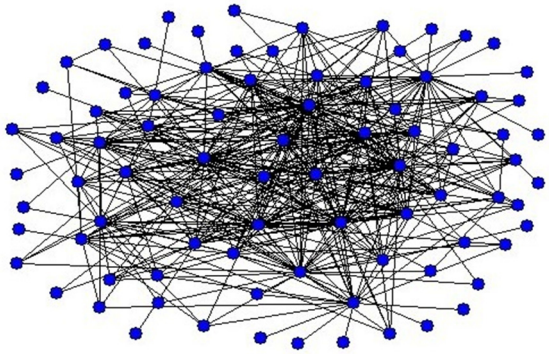

Fig.3 trade network in 2015

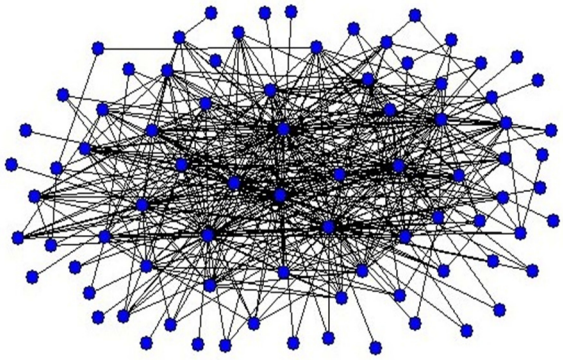

Fig.4 trade network in 2019

4. EVOLUTION ANALYSIS OF SENSOR TRADE NETWORK

Based on the complex network analysis method, the paper makes network diagrams of global sensor trade in 2006, 2010, 2015 and 2019, analyzes the evolution and characteristics of global sensor trade network and analyzes China's position in the sensor trade network and points out the disadvantages.

4.1 Stage analysis of sensor trade network

1) Import and export volume

There are many factors influencing the import and export trade. From 2006 to 2019, the total imports and exports of the global sensor trade increased on the whole, while the import and export volume decreased in 2015. On the whole, it can be seen that the global sensor trade import and export is on the rise year by year. Countries on the increasing demand for sensors, resulting in a gradual rise in the import of sensors, on the one hand, means the rapid development of the sensor industry, on the other hand, can also reflect the role of the industrial Internet, the evolution of the sensor trade reflects the development of the industrial Internet in various industries.

TABLE 1 TOTAL IMPORT AND EXPORT VOLUME FROM 2006 TO 2019

	Import (US $)	Export volume (USD)
2006year	2649088084	2491487020
2010year	3219468881	3158206537
2015year	1262012603	2697213222
2019year	4307040872	3741816166

2) Correlation analysis of network density

In the sensor trade network, the network density represents the closeness of trade between countries in the network. The more edges in the trade network diagram, the more trade relations between countries in the global sensor trade network. The value of network density is between 0 and 1. The closer the value is to 1, the closer the trade relations between countries. If the value is closer to 0, the fewer countries in the global sensor trade network.

By calculating the data, the density of the sensor trade network is gradually increasing, and the total number of edges is also gradually increasing. With the development of industrial Internet and manufacturing industry, the sensor trade between countries is more and more close, and the trade amount is also increasing year by year.

TABLE 2 NETWORK DENSITY FROM 2006 TO 2019

	Network density	Number of edges
2006	0.0276	408.00
2010	0.0309	456.00
2015	0.0321	474.00
2019	0.0400	591.00

4.2 Typical characteristics of sensor trade networks in different periods

In the sensor trade network, there are trade relations among countries, thus forming a trade network. However, different countries have different influences in the trade network. In the trade network, the influential countries play a strong role in the trade network and become the core of the sensor trade network. Centrality analysis is a key point of network analysis. Centrality analysis reflects the influence of nodes in network diagram. Centrality index is the quantitative analysis of each node in network diagram.

1) Degree centrality

The degree centrality of each country in the sensor trade network diagram is the number of other points connected with that point. If the degree centrality of a country is the highest degree in the network diagram, it means that the country itself is closely connected with other countries, then that country is likely to have the greatest impact. Table 3, Table 4, Table 5 and Table 6 are the national degree centrality data with degree centrality not less than 20.

It can be seen from the centrality of each country in the table that the countries with high centrality from 2006 to 2019 are the United States, Germany, France, China, Japan, the Netherlands, Italy and other countries, which shows that these countries are at the core of the sensor trade network, have close ties with other countries, have frequent trade exchanges, and have strong control over the sensor trade network.From 2006 to 2019, the network centrality grows gradually, which can represent that the international sensor trade is expanding year by year, and the trade between countries is close.

TABLE 3 DEGREE CENTRALITY IN 2006

country	Degree centrality	country	Degree centrality
U.S.A	47	Netherlands	27
Germany	39	Sweden	25
britain	30	Norway	25
Italy	29	China	25
Japan	28	Switzerland	24
France	28	Singapore	22

TABLE 4 DEGREE CENTRALITY IN 2010

country	Degree centrality	country	Degree centrality
U.S.A	50	Norway	26
Germany	42	Netherlands	26
France	34	Singapore	24
China	33	Switzerland	24
Japan	30	the republic of korea	22
Italy	28	Canada	20
britain	28	India	20
Sweden	20		

TABLE 5 DEGREE CENTRALITY IN 2015

country	Degree centrality	country	Degree centrality
Germany	50	Italy	28
France	37	Costa Rica	23
U.S.A	36	the republic of korea	23
Netherlands	34	Norway	22
China	31	Cotedia	22
britain	30	India	21
Japan	30	Singapore	21
Belgium	29	Sweden	20
Croatia	29		

TABLE 6 DEGREE CENTRALITY IN 2019

country	Degree centrality	country	Degree centrality
U.S.A	54	Japan	32
Germany	53	the republic of korea	29
britain	47	Singapore	28
China	40	Sweden	24
France	38	Switzerland	22
Italy	37	Australia	21
Netherlands	34	India	2

2) Closeness centrality

Closeness centrality shows the close relationship between nodes.Closeness centrality is to calculate the centrality of a node based on distance. If the distance between a node and all other nodes in the network is very short, the closer it is to other nodes, it indicates that the node has high Closeness centrality and is easier to contact in information. From the data analysis in Table 7, it can be seen that the sum of the average value of the outCloseness and inCloseness centrality of all nodes in the sensor trade network diagram is gradually increasing, which indicates that the trade between countries in the network diagram is becoming easier and easier, and also represents the gradual development of industrial Internet.

TABLE 7 CLOSENESS CENTRALITY FROM 2006 TO 2019

	The average of outCloseness	The sum of outCloseness	The average of inCloseness	The sum of inCloseness
2006	1.055	128.929	1.018	124.181
2010	1.095	133.565	1.056	128.806
2015	1.004	122.517	1.013	123.595
2019	1.218	148.605	1.096	133.736

3) Betweenness centrality

Betweenness centrality is a measure of how much a node is in the middle of the network. If a node is in the contact path of many other nodes, it indicates that the node is in an important

position.From 2006 to 2019, the Betweenness centrality of some countries has been zero, reflecting that they have little contact with other countries and have little influence in the sensor trade network. During the past 15 years, the Betweenness centrality of the whole trade network shows an upward trend. The Betweenness centrality of the United States, Germany, France and other countries is large. The Betweenness centrality of some countries is 0, which indicates that they have no control over other countries.

4.3 Analysis of sensor trade in China

With the development of China sensor industry, China sensor trade has experienced a complex process. On the whole, China's sensor trade plays a key role in the world. China has made great progress in sensor trade network. First, the degree of network increased from 25 to 40, leaping from the 10th to the fourth and occupying a more and more central position. Second, China's related import and export volume has grown rapidly and become an important part of the global sensor trade, accounting for 7.96% in 2006 and 26.37% in 2019.

Along with China's rapid economic development, China's overall trade growing, but some deficiencies in trade: one is that China's ability to cope with trade risk needs to be strengthened, and China should improve the ability to guarantee the stability of the economic and trade. Second, trade in sensors is unstable. As sophisticated electronic products, the dependence on imports has not improved. For example, from 2006 to 2020, the trade deficit in 2006 was USD166969463 and in 2019 was USD20670,326. We can find that the trade deficit has a further trend of expansion, which is worth our warning.

5. CONCLUSION

It can be found from the trade data that the global sensor trade is booming, not only the total trade volume increased from $5140575,104 to $80,48857,038, but also the global trade network is further complicated, for example, the network density increased from 0.0276 to 0.0400 and the number of edges increased from 408 to 591. This shows the growing capacity of the international sensor trade network. Through calculation, it is found that the United States, Germany, France, the United Kingdom, Switzerland, Sweden, Japan, China and the Netherlands and other countries have a strong ability to control the sensor trade, and the trade between countries becomes more frequent, more convenient and easy. Studies of network linkages show that the sensor trade links between countries are gradually strengthening, and the overall growth of the trade volume indicates that the global demand for sensors is growing. Based on the analysis of the development, evolution and change of import volume of China's sensor trade, the scale of China's sensor import and export trade is expanding continuously. Through the study of sensor trade, it is found that the integration of information technology and various industries and fields has prospects, and the industrial Internet has obvious development in all industies.

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