Evolution of National Status in the International Oil Trade: A Complex Network Analysis

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Abstract: As one kind of non-renewable energy, the distribution of oil in the world is extremely uneven. International oil trade has become an important way due to the spatial separation of oil producing and consuming countries. Recently, changes of the international oil trade pattern have become focused issues, and complex network theory provides a new perspective for its study. Based on complex network theory, the international oil trade network model is built and the role and status of major exporters and importers is measured using node and strength centrality indexes. The results show that: First, The United States occupies an important position in the international oil trade, especially in 2014, the status of the United States more prominent.Second,China was always more important during 2002-2014 in the international oil trade network, which Russia has strengthened through the evolution of Russian central index.

Keywords: international oil trade network model; centrality index; national status; evolutionary features

1 Introduction

Since the 20th Century, the world oil trade has increased rapidly due to the uneven distribution of oil resources and the rapid growth of oil demand. Many researchers have implemented a great deal of qualitative research on the international oil trade pattern. For example, the analysis of Christy [1] obtained that the increase in Russian oil exports has changed the pattern of world oil trade and improved Russia's position in the world crude oil trade market, reducing the dependence of oil-importing countries in the Middle East. Balat [2] studied the oil potential and status of the Middle East in the international oil market from the perspective of petroleum production and foreign trade structure. Shan [3] analyzed the changes in the world oil trade pattern over the past ten years, and predicted that the Asia Pacific region will become an important part of the new world trade pattern with the further evolution of the global trade structure. In fact, the oil trade flows reflect the relationship between countries, so we can construct a network regarding countries as nodes and trade relations as edges. Therefore, the development of complex network theory provides an effective tool for identifying the evolutionary characteristics of trade network and analyzing quantitatively world oil trade model. So far, complex network theory has been widely applied to the research of global trade.

As an important quantitative method, complex network theory provides a new perspective for researching international oil trade. Zhang et al. [4-5] established a competitive international oil trade network model based on complex network theory, and found that the Asia Pacific region is becoming more and more important in the international oil trade, and gained that technical progress and energy efficiency have prompted the formation of the international oil trade patterns. Ji et al. [6] established the global oil trade core network using the complex network theory, and analyzed its overall characteristics, regional characteristics and network stability. Zhong [7-8] established the unweighted and weighted international oil trade network model to analyze the changes of international oil trade relations and community evolution characteristics, in addition, it also studied the status and role of China, a net oil importer, in the international oil trade network.

In this paper, we study the evolution characteristics of node centrality index from 2002 to 2013, and analyze the reasons for the changes. The main contributions of this paper are as follows: First, we establish an international oil trade

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network model according to the relationship of world oil trade using complex network theory; Second, we investigate the countrys status, contribution and evolution characteristics of the international oil trade network by the centrality index.

The paper is organized as below. Section 2 introduces the construction of the international oil trade network mode and the used network indicators. Section 3 presents the empirical analysis. Section 4 draws some conclusions and put forward policy recommendations.

2 Method

2.1 The construction of international oil trade network model

In the international oil trade, we regard the countries as nodes $V = v_1, v_2 \cdots v_N$ and trade relations between countries as edges E. Then, we get a bilateral undirected network $G = V, E)$. Network structure can be represented by an adjacency matrix A. If there is trade between states v_i and v_j, then $a_{ij} = 1$, otherwise $a_{ij} = 0$. Edge weight $w_{ij}1$ is the sum of the trade volume between the two countries, namely $w_{ij}1$ is trade value between states v_i and v_j.

2.2 Indicators system of network

Indicators in the theory of complex network can reflect the architectural features of the international trade. In this section, we will introduce the indicators used in this paper, including node centrality (NC) and strength centrality (SC), which are always used to measure countries position in the international trade network [9, 10]. Degree centrality, which is a measure of binary connectivity, is the simplest way to measure the importance of any given node. Although we mainly focus here on a weighted network approach, we study it because of its natural interpretation in terms of the proportion of trade partners. The degree centrality of node i is defined as

$$k_i = \frac{\sum_j A_{ij}}{N - 1}. \tag{1}$$

where N is the total number of nodes in the network. A_{ij} is the adjacent matrix of the network and can be defined as follows:

$$A_{ij} = \begin{cases} 1, & \text{if i and j have an edge} \\ 0, & \text{else} \end{cases}$$

In a weighted network, the natural extension of DC is strength centrality, and it is defined as

$$S_i = \sum_j w_{ij}. \tag{2}$$

where w_{ij} is the weight of edge between nodes i and j. Strength centrality indicates the share of bilateral trade of any given country with regard to total world trade. It is a measure of weighted connectivity and gives us an idea of countries' trading shares in the world market.

3 Empirical analysis

3.1 Data sources

In this paper, the 2002-2014s oil import and export data is used to build an undirected weighted network of international oil trade which aims to analyze the overall characteristics of the international oil trade network. The data are derived from the United Nations Commodity Trade [11], in US dollars.

3.2 Evolution of centrality indexes

Since the central index of oil importing and exporting countries may differ, we give the evolution characteristics of the top ten countries in imports and exports of centrality indexes. (1) Evolution of the DC
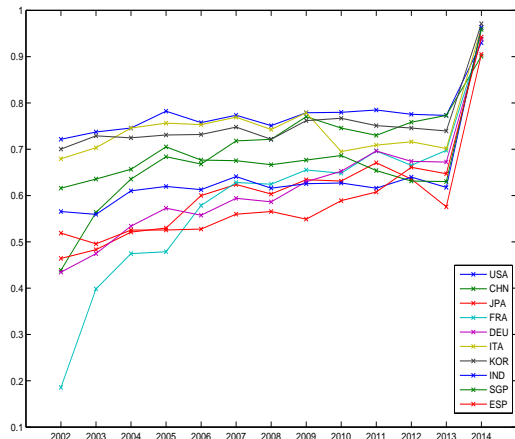
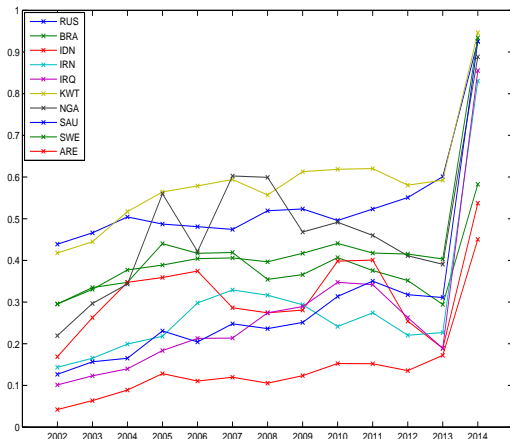Figure 1: Evolution of DC of importers.

Figure 2: Evolution of DC of exporters.

Figs. 1 and 2 illustrate that: First, the DC of the US is very stable, and the value is also the largest. It shows that the US has the most oil trade partners. Second, China's oil imports have been concentrated on the Middle East and West Africa, due to the political instability in these areas, China has been actively seeking trade partners to reduce the risk of external supply. In 2013, relative to 2002, Chinas trading partners was increased by 79, including Iraq, Argentina, Bulgaria, Myanmar and other countries. The proportion of imports from the Middle East and West Africa has gradually decreased, which has dropped to 62 percent in 2012. Therefore, the value of DC is gradually increasing, which ranked second only to the US in 2013. Third, Although Japan is a major importer of oil because of the low level of the diversification of its oil imports, the ranking of its degree centrality is relatively stable. Fourth, for India, with the economic growth, its oil imports are rising steadily, which has been far more than Japan in the past few years. India's oil import dependence is rapidly increasing and it will become a country that has one of the greatest growth in demand for oil in the future, while 80% of India's oil are from imports, in which Saudi Arabia occupies 18 percent, Iran 16 percent, 10 percent in Kuwait, Iraq 9%, UAE 8%, Niger 8%. In order to avoid risks, India has been increasing the sources of imports, which has reached 64 countries in 2013. As the exporting places of the exporting countries are concentrated, and there is almost no imported oil, the value of DC of oil-exporting countries is significantly smaller than the importing countries, such as Russia, the exports of Russia is precedent in the world, but mainly focus on the United Kingdom and Ireland (Russia accounted for exports to regions outside the CIS 1/4); central and Eastern Europe (Czech Republic, Slovakia, Hungary and East Germany, accounting for a quarter of exports); therefore, the value of DC is not high. With the cooperation of Russia and Asian countries, the value is increasing. Iraq is a major exporter, but due to his export areas are mainly concentrated on China, the US , Japan and some other countries, the exporting countries are few, so the value of the degree centrality is small. But whether the oil importer or exporter, the DC index are greatly improved in 2014, mainly because the world's major oil producing countries continued to increase production and exports, which causes the decline of the world oil price. Therefore, the importing countries are constantly seeking partners, expand the export sources actively. In the case of China, newly added Algeria, Brunei, Belarus and other 130 countries, Not only did not the exporting countries reduce production, but also their output is increased. they are also active in export, which cause the world oil price continues to fall, such as Russia, whose new partners include Albania, Africa ,Comoros and other 83 countries. (2)Evolution of SC

As can be seen from Figs. 3-4, the value of SC for the US is very front, because of its large amount of oil import and export. Due to the impact of the Iraq War, and Iraq is a major source of oil for the US, the strength centrality of the US decreased significantly in 2003. Due to the development and use of shale gas in the United States, from 2000 to 2010, the output of shale gas that accounts for the US natural gas had risen from the initial figure of 1.6% to 23.1% rapidly, and the ways to use oil in the US has continued to improve. From a macro perspective, facts have proved that high oil output along with a quiet revolution of the ways of using oil, the vehicles consumed 72% of gasoline and other liquid fuels, so oil imports continued to decline. China's oil exports is very small, but its imports continues to increase, so the ranking of SC also continues to increase. With the development of economy in Japan, Japan's oil consumption is increasing, Import strength continues to strengthen. Affected by the Iraq war in 2003, the exports of Saudi Arabia decreased significantly, the Middle East oil exports were also in decline, but in order to avoid the disruption of oil supply, many countries reduced the oil imports from the Middle East, While the number and strength of Russia's export countries did not decrease. After
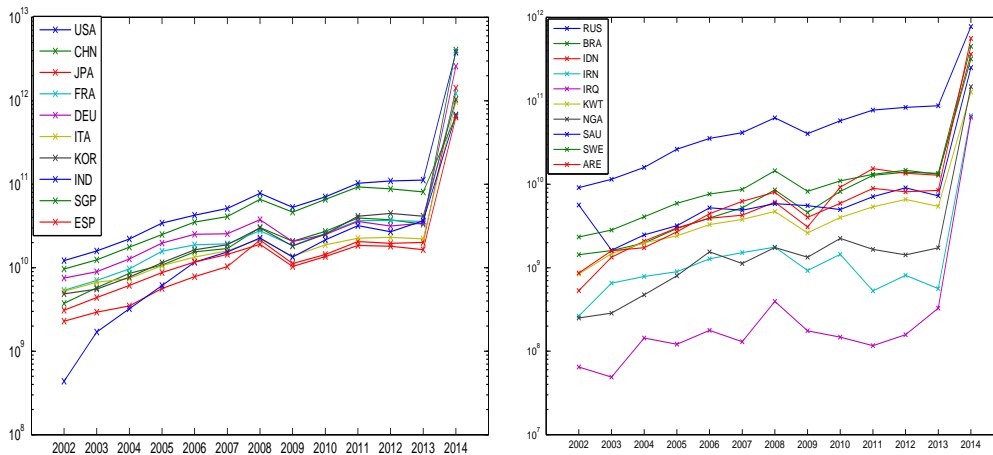
Figure 3: Evolution of the strength centrality of the import country.

Figure 4: Evolution of the strength centrality of the export country.

that, the oil trade strength of Russia continued to increase, which surpassed the US in 2007. Later, it also exceeded the US in 2012 and 2013. It can be seen from the figure that the trade volume of import and export countries increased greatly in 2014, which was mainly because the main export countries increased their production instead of reducing under the circumstances of the dropping of the oil price. From the research over the evolution of the two indexes, we found that: 1) The position of the US in the international oil trade is more important, But with the development of shale gas, its energy self-sufficiency ability has greatly improved, and the oil imports strength from other countries has decreased significantly. However, in 2014, the position of the US in the international oil trade went back to the dominant position, the dropping of oil price greatly affected some countries such as Russia, While the crude oil production of the US increased substantially in 2014, which had an average daily production of 9.13 million barrels, almost equal to Saudi Arabia's crude oil output. This production hit a record, which was 1 million barrels higher than the same period last year. The commercial crude oil inventories of the US increased from 7.3 million barrels to 387.2 million barrels, which was 19.6 million barrels higher than last year. The crude oil inventories of the US increased, and the OPEC said it would not cut the production, which made the market worried about the global crude oil market oversupply, pushing the dropping of oil prices; 2) During 2002-2014, We can see that in order to cope with the increasing demand for oil and to prevent oil supply disruptions, China continued to develop oil trading partners, and therefore the level of China's oil imports diversification has constantly improved, The value of center index has also been improved . It shows that the status and role of China in the international oil trade is increasing, and China has become an important member in the international oil trade; 3) Japan, as a net importer of oil, its oil imports are mostly from West Asia, which is a relatively stable source of imports. With the increase of oil consumption in Japan, its position in the international oil trade has improved; 4) Russia is a major exporter of oil, but because of the geographical conditions and political constraints, it doesnt have many trading partners, so the value of degree centrality index is not very high. Russia should continue to seek trade partners, and coupled with strong exports, Russia will play an important role in the international oil trade; (5) As the world's major oil producing country, Saudi Arabia has a daily crude oil production of more than 9 million barrels;.(6) In the year of 2014, Iraq increased production, as OPEC's second oil producing country, its sales volume also increased. In May, its crude oil exports amounted to 3.17 million barrels per day.

3.3 The international oil trade network chart in 2014

From the evolution characteristics of the central index, we can see that 2014 is a special year. In order to understand the trade situation in 2014 more clearly, and according to the international oil import and export trade relations in 2014, in the state as nodes, trade relations as edges, we can get the network model of international oil trade (See Fig. 5).

From Fig. 5 we can know that, the connection between the nodes is more closely in 2014. It is mainly because under the background of the falling of oil prices, the major exporting countries, represented by Saudi Arabia, increased the production rather than reduce it, which caused the oil market oversupply, and oil price continues to fall, The importing countries also increase oil imports in the case of low oil prices.
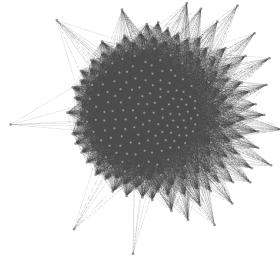
Figure 5: The international oil trade network chart in 2014.

4   Conclusions and policy recommendations

With the development of economic globalization and oil trade globalization, the relations between countries has become more closely. Since different countries play different roles in the oil trade network, their oil imports also suffer different external supply risks. In this paper, we have established a global oil trade network. And, with the node centrality to analyze statehood in the international oil trade, the results are as follows: The United States occupies an important position in the international oil trade, especially in 2014, the status of the United States more prominent. The status and role of China in the international oil trade continue to highlight, Japan's position in the international oil trade network is relatively stable, but it is not very high. Russia is a major exporter of oil, the level of export diversification is low, and in 2003, the impact of the Iraq war, the center index of Russia are greatly improved.

In recent years, the rapid development of Chinese economy, driven by China's oil import dependency rising, so, in recent years, Chinese government has been actively exploring the international energy cooperation to increase in the international oil trade status. Based on these findings, we put forward the following suggestions for Chinese future energy development: First, from Chinas importing countries we can see that China is too dependent on Middle East countries, so we should change the pattern over-reliance on the Middle East, strengthen energy cooperation with neighboring countries, especially in some countries, Russia and Central Asia, in order to increase the value of the center index, thereby increasing China's position in the international oil trade.

Second, The international oil market uncertainty and the huge pressure of environment and climate is problems of China's future for a long period of time must be faced and solved, which requires China to accelerate the adjustment of energy structure, efforts to promote the development of natural gas, and actively developing alternative energy, Such as wind energy, solar energy, and shale gas, resolve China's oil supply security from the fundamental.

Acknowledgments

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