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A complex network perspective on interrelations and evolution features of international oil trade, 2002–2013 ☆

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HIGHLIGHTS

- The top 1 network model can well reflect countries' preference in choosing oil trade partners.
- The modified closed-system input-output method can reflect the direct and indirect influences among oil trading countries.
- The interrelation and evolution features of international oil trade network have been discussed.
- The result shows us how to make a rational decision for a country to develop oil trade relations.

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ABSTRACT

In this paper, a directed and weighted world crude oil trade network is constructed. Based on the built network, we apply top network method and modified closed-system input-output method to assess the relative importance of countries in the international oil trade. The top 1 network consisting of top trade relations, can well reflect countries' preference in choosing oil trade partners. As a simplified network model of international oil trade network, the top 1 network has been analyzed the structure and evolution. In order to identify important oil trading countries, the modified closed-system input-output analysis has yielded some promising results, which show countries who play key role in international oil trade, are trading large oil volumes. In addition, by describing the influences of countries on each other, we find major oil importers have a much effect on other countries, including major oil exporters. The evolution analysis obtained by these two methods coincide with each other. To conclude, some suggestions are given according to the results.

1. Introduction

Crude oil is still the principal fuel source in the world, it accounts for nearly 32.9% of global energy consumption in 2015. As a national strategic resource, crude oil plays a pivotal role in economic development and national security. Due to the unbalance distribution of oil production and consumption, international oil trade gives a big push for the cross-border oil flows, which bind the whole world into a global oil trade network. A detailed understanding of oil trading-based network is meaningful for governments because they are eager to understand the global oil trade in order to avoid oil supply risk.

Actually, oil trade flows reflect the relationships among countries, which form a network where the countries are taken as the nodes and the trade relationships as the edges. Thus, the development of "the new science of networks" [1,2] has offered an effective tool when analyzing the trading patterns. The complex network approach has been proved fruitful and shed new light on international oil trade [3–7]. A directed oil trading-based network model was established by An et al. to study the relationship between countries with common trade partners [3]. Wang et al. employed a complex network approach to research the interaction patterns among the crude oil import dependency countries in the global oil trade network [4]. Zhong et al. studied the evolution of communities of the world oil trade network by setting up un-weighted and weighted oil trade network models using data from 2002 to 2011, and analyzed their evolutionary features and

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stabilities over the time [5]. Zhang et al. studied the competition among oil importers using complex network theory, combined with several alternative measures of competition intensity, to analyze the evolution of the pattern and transmission of oil-trading competition [6]. Du et al. studied the overall topological structure properties of global oil trade network, and by applying random matrix theory, explored the complex spatiotemporal dynamic from the country level and fitness evolution of the global oil market from a demand-side analysis [7].

Existing network studies have greatly contributed to our understanding of international oil trade. However some shortages are still existed. First, in the above global oil trade network, a country's trade partners are treated equally. However, not all the trading partners are equally important to a country. A country is concentrated in its trade with a few partners. This concentration is especially notable for developing countries, as most peripheral countries' foreign trade is heavily dependent on particular core countries, according to world system and dependency theories [8–10]. Thus it is necessary to distinguish a country's top trade partners from nonessential ones and to study the specific trade network based on these top trade relations. By introducing the definition of 'export intensity', Ji et al. constructed a global oil trade core network, which is a simplified model of the whole international oil trade, and analyzed the overall features, regional characteristics and stability of the oil trade by using complex network theory [11].

Second, the question of the relative importance of oil trading countries and influences between them has rarely been studied. Even if there existed study of identifying the centrality of nodes, they were often limited to some traditional indicators, such as degree, strength, betweenness, etc. [12–14]. In fact, the actual international oil trade network is both directed and weighted system, and trade relationship between two countries are presented as direct or indirect connections. In the former study, the indirect relation of oil exporters and oil importers has been neglected. For example, if there is an oil importer C, which heavily relies on oil exporter B, which in turn imports oil from another country A, then it is clear that even if there are no direct connections from A to C, A is a major contributor to C. Therefore, it would be significant to have a means of reflecting trade direction, trade volume, direct as well as indirect trade relations.

In light of these gaps, we specifically construct a top 1 import network and a top 1 export network based on top trade relations. The simplified network model can describe countries' preference in choosing trade partners well, and also reflect the positions of oil trading countries and evolution features well. We further develop a modified closed-system input-output analysis method, which not only contains the direction and the intensity of oil trade relations, but also considers the direct and indirect influences among oil trading countries, to discuss the relative importance of these countries and how this evolves. The results of the above two methods are compared. In this paper, Section 2 introduces the model and methodology. Section 3 is empirical analysis for global oil trade network. Section 4 is conclusions and suggestions.

2. Model and methodology

2.1. The global oil trade network modeling

We construct a model of directed and weighted global oil trade network, whose nodes are the nations, and edges are the oil trade relationships between nations. The oil flow out of and into a country can be presented by an edge with direction. The weight of the edge is measured by the trading volumes.

Since the international oil trade includes import and export flows, the network can be divided into oil import network, in which the in-degree and in-strength of nodes are only considered, and oil export network, in which the out-degree and out-strength of nodes are only considered. The in-degree k_{in} of a node (country) measures the number of countries, which export oil to the country. The out-degree k_{out} measures the number of countries, which import oil from the country. The in-strength s_{in} of a country means its total imports, and the out-strength s_{out} is its total exports. Fig. 1 is an example of the directed and weighted network.

Fig. 1 is an example of the directed and weighted network. Suppose there are crude oil trade relationships among four countries named A, B, C and D. Take node B for example, if B imports 5 tons of crude oil from A, the weight of the directed edge, which represents the oil flow from A to B, is 5. Thus, for B, $k_{in} = 1,\ s_{in} = 5$. At the same time, B exports 2 tons of crude oil to D, and exports 1 ton crude oil to C. The weights of the two directed links connecting B to D, and B to C, are 2 and 1 separately. Thus, for B, we have $k_{out} = 2,\ s_{out} = 3$.

2.2. Top network analysis method

Based on the above international oil trade network, we further build a simplified network to capture most important relations in the oil trade by using the core idea of Ref. [10]. The specific simplified network is on the base of top oil trading relations, that is, if country j is country i's top trade partner, country i is linked to country j; otherwise, there is no tie between i and j. Particularly, we consider oil import network. If country i imports oil from j and other countries, we rank the import trade relations of i with other countries by importing volumes. Thus, the top 1 oil import network is constructed by including each country's topmost import trade relation only. In the same way, by ranking the export trade relations of each country with other countries by exporting volumes, the top 1 oil export network is built by including each country's topmost export trade relation only. If each country's top two importing or exporting trade relations are kept, the resultant network is called top 2 import or export network. Further, we can go down the ranking of trade relations and obtain the top networks of the selected standard. One key characteristic of the top import/export network is that all nodes have an in-degree/out-degree not exceeding the selected standard, but the out-degree/in-degree varies across nodes.

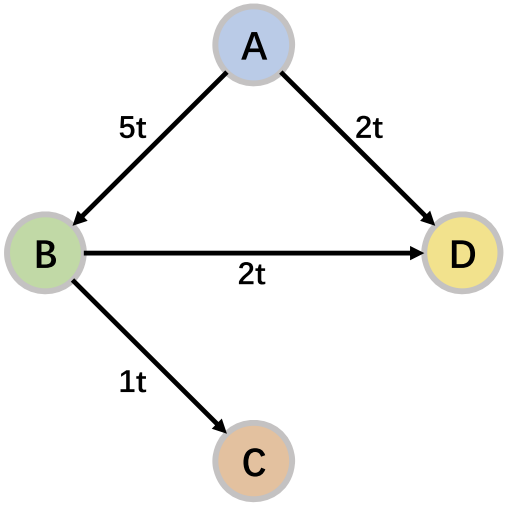

Fig. 1. An example of the directed and weighted network.

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