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Global Energy Investment Structure Based on the Shareholding Relations of Global Listed Energy Companies

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Abstract

This study proposed a novel visualization and quantitative method for analyzing the roles and investment relationships of nations as well as the global energy investment structure. We constructed a primitive investment network of two different actors—listed energy companies and their shareholders. Then, based on the two-mode national affiliation relationships, we constructed a derivative investment network of 112 nations. Then, we quantitatively analyzed the national diversity of outward and inward energy investment, the strength of the energy investment relationship between countries (the most powerful group of energy investment) based on the shareholding relationships of global listed energy companies.

Keywords: Global energy investment structure; Listed energy company; Shareholding relationship; Multi-mode networks; Visualization

1. Introduction

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In recent years, the global energy structure has adjusted to the aftermath of the global financial crisis and the boom in shale-gas production in North America as well as the increasing concerns about low-carbon issues, and it presents a growing trend toward diversification. Moreover, due to the diversity of energy regulations and policies [1], investment environments, and resource endowments as well as the disturbance of relationships between states and geopolitics, the energy investment between different countries reflects different characteristics.

As an important carrier of energy’s commercial and financial attributes in global energy market, listed energy companies play an important role in energy market and energy investment. Holding the listed energy companies’ stock is an important way of energy investment. As the development of stock markets, the internationalization of investors has become common and unavoidable. Since global listed energy companies and shareholders come from many different nations, any country can be either an investor (outward investment) or a target country for investment (inward investment), so we can obtain the shareholding relationships between different countries based on the shareholding relationships between the listed energy companies and their shareholders as well as the national affiliation relationships of the listed energy companies and their shareholders. Then, we can analyze the global energy investment features and relations.

As an important theory and method for complexity science and big data research, complex networks are well used to research relationships from a holistic and visualization perspective. In the energy market, complex networks have been well used in simulating the global energy trade and security [2], energy price fluctuation [3], and so on. Reviewing the literature, we find that one-mode homogeneous network is well documented. However, all economic networks are heterogeneous, having different types of agents and different interactions between the agents that can strongly vary over time [4]. As for the energy investment networks based on the shareholding relationships, it is obvious that, there are shareholders and listed companies (two actors), as well as the countries and regions which the shareholders and listed companies belong to (two-mode affiliation networks), so it is more appropriate to use multi-mode networks method to simulate the shareholding relationship.

In this paper, we mainly analyze the global energy investment structure based on shareholding relationships of the listed energy companies and their shareholders by frontier approach of complex networks theory for analyzing the potential relations of big data, multi-mode networks method, from a global point of view.

2. DATA AND METHODS

2.1. Data

The data used in this paper were collected on December 31st, 2013 from a famous worldwide listed company database owned by BVD company--ORISE (https://osiris.bvdinfo.com), which include the name of the listed energy companies, the code of the listed energy companies, the nations that the listed energy companies belong to, the name of the shareholders, the nations that the shareholders belong to, and so on. There are 2334 listed energy companies and 8302 non-duplicate disclosed shareholders from 112 countries and regions. Here, we use codes to represent economic agents. The codes are formed by one capital letter and four figures, and each code represents a unique economic agent, a listed energy company or a shareholder. Meanwhile, we also use a two character abbreviation to represent each of the nations.

2.2. Methods
First, according to the encoding data, we can construct three primitive investment relationship matrices: the investment relationship matrix between shareholders and listed companies (A), the affiliation relationship matrix between the listed energy companies and nations (B), and the affiliation relationship matrix between shareholders and nations (C). We use X to represent the set of listed energy companies, Y to represent the set of shareholders, P to represent the set of nations that the listed energy companies belong to, and Q to represent the set of nations that shareholders belong to. **\( a_{ij} \), \( b_{ij} \), and \( c_{ij} \)** represent the investment relationship between shareholders and listed companies, the affiliation relationship between the listed companies and nations, and the affiliation relationship between the shareholders and nations, respectively; Two-mode network theory contains two different sets of nodes, actors and events. In this paper, the two actors include the listed energy companies and the shareholders. We use Z to represent the set of two different actors, \( Z = X \cup Y \), and we use R to represent the set of events, \( R = P \cup Q \). \( d_{ij} \) represents the affiliation relationship between the economic agents and the nations, and its value is 0 or 1. On the basis of the relationship matrix A, B, C and D (\( D_1 \cup D_2 \)), we obtain the investment relationship matrix F according to Formula (1). \( f_{ij} \) represents the quantity of the investment relationship between any two nations.

\[
F = D_2^T \times A \times D_1
\]

where \( D_1 \) represents the relationships between B and R based on A, and \( D_2 \) represents the relationships between Y and R based on C.

Based on F, we can get the weighted direct investment relationship network of nations (HN-LN), which takes the nations as nodes, the investment relationship based on the shareholding relationships of the listed energy companies as edges, and the quantity of the investment relationship based on the shareholding relationships between any two nations \( (f_{ij}) \) as the weights. Then, we analyze the role of the different countries and their relations in the energy stock market quantitatively by calculating the topological features of the nodes, edges and the entire network. There are tens of topological features for complex network; here, we only chose degree and weighted degree of nodes and the K-core of the network to analyze the role of the countries, the investment relationships between counties and the powerful group of countries that have close energy investment relationships. Formula (2) to Formula (5) show the calculation approach for in-degree, out-degree, weighted in-degree and weighted out-degree [5, 6], while \( \Gamma_i \) is calculated by Formula (6).

\[
\begin{align*}
\Gamma_i^{\text{in}} & = \sum_{j=1}^t f_{ji} \\
\Gamma_i^{\text{out}} & = \sum_{j=1}^t f_{ij} \\
W\Gamma_i^{\text{in}} & = \sum_{j=1}^t f_{ji} \\
W\Gamma_i^{\text{out}} & = \sum_{j=1}^t f_{ij} \\
f_{ij}' & = \begin{cases} 1 & f_{ij} > 0 \\ 0 & f_{ij} \leq 0 \end{cases}
\end{align*}
\]

Meanwhile, K-core represents the connectivity of a sub-group of the network. The primary process is to cancel the nodes whose degree is lower than k and the edges that are linked on it repeatedly; we call the remaining sub-group the k-core sub-group. When the node belongs to the k-core sub-group but does not belong to the k+1-core sub-group, then the value of the node is k; the highest k value of the node is also the k value of the network, and all of the nodes that have the highest k value.

### 3. DATA AND METHODS

#### 3.1. The overall network
Fig. 1(a) is visualization of the primitive shareholding relationships of listed energy companies and shareholders [7], and Fig. 1(b) is visualization of the investment relationships between the nations (HN-LN) based on Fig. 1(a) and matrix D. We got 36849 pairs of relationships between the nations, which include 14282 pairs of relationships between different nations, and 22567 pairs of relationships between same nations. We removed the self-investment data. Then, there are 112 nodes and 1030 edges in HN-LN and the total weight of the edges is 14282.

3.2. The national diversity of inward and outward energy investment

The in-degree represents the national diversity of inward energy investment, and the out-degree represents the national diversity of outward energy investment. According to Formula (2) and Formula (3), countries such as Britain, America, Canada, Australia, Bermuda dominate the top of the table of national
diversity in inward energy investment, and countries such as America, Britain, Norway, Holland, France rank highly in the national diversity of outward energy investment.

Each country may have more than one shareholder and listed energy company, it is necessary to take weight into consideration when analyzing the nation’s real ability to invest outwardly or to absorb inward investment in the energy stock market. By Formula (4) and Formula (5), we get that some countries such as America, Canada, Britain, Australia, Bermuda, Norway have a strong ability to absorb inward investment from abroad, and some other countries such as American, Britain, Canada, Switzerland, France, Germany have a strong ability to invest outward in energy.

3.3. The powerful group of energy investment relationships

The set of the nodes that have the biggest k value is the countries that have strong investment ability or a strong ability to absorb investment from other countries in the energy stock market. In this paper, the highest k-core nations include America, Britain, Norway, France, Canada, Australia, Holland, France, Luxemburg, Italy, Switzerland, Sweden, Denmark, Germany, Japan, Singapore, China (and Hong Kong), India, Bermuda, the Cayman Islands, and the British Virgin Islands are in it. They are the most powerful well-connected countries in the energy stock market.

4. DATA AND METHODS

According to the analysis, we find that the vast majority of energy shareholding relationships are focused on a few nations, some being traditional energy investment countries such as America, Great Britain, Canada, while other territories such as Bermuda, The Virgin Islands (British), the Cayman Islands also see strong activity. Using the k-core method, we find the most powerful group of 22 countries and territories with strong linkages. These countries also can be divided into three difference categories: traditional developed countries, emerging countries, and some island regions. It indicates that other than the energy structure with the commercial attribute, global energy investment structure of shareholding depends on the degree of economic development as well as the investment and financial market environment of nations.

Next step, we will use time series data and analyze the evolution of global energy investment structure and we will also take the shareholding rate into consideration to analyze the flow of funds between different nations and thereby more effectively study the investment relationship.

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References


Biography

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