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Global energy investment structure from the energy stock market perspective based on a Heterogeneous Complex Network Model

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HIGHLIGHTS

- Proposed a novel derivative algorithm to construct global energy investment network.
- A novel empirical study based on heterogeneous network of energy stock market.
- Proposed some coefficients and formulas to analyze global energy investment structure.
- Some island countries and territories known as Tax heavens play important roles.
- Energy reserve is less important than financial environment for investment structure.

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ABSTRACT

Energy is not only an important international commodity but is also an important financial product. Many studies address the global energy structure by considering energy as commodity, but few study it based on energy's financial attributes. In this paper, we analyzed the global energy investment structure based on the shareholding relationships between listed energy companies and their shareholders by taking the frontier approach to complex network theory and treating these relationships as a heterogeneous complex network from a global angle. We constructed a primitive investment network of listed energy companies and their shareholders (two sets of actors). Then, based on the two-mode affiliation relationships between two sets of actors and countries, we constructed a derivative investment network of 112 countries (and regions). By calculating different topological features, we quantitatively analyzed the national diversity of outward and inward energy investment, the energy investment preference, the strength of the bilateral energy investment relationship between countries (and regions) and the most powerful group of energy investing countries based on the shareholding relationships of global listed energy companies. It is found that the vast majority of outward and inward investment relationships are still in the hands of a few countries: traditional developed countries, emerging countries, and a few particular island countries (and regions) that are tax havens. This study is helpful for analyzing the roles and investment relationships of nations as well as the global energy investment structure taking the perspective of the energy stock market.

1. Introduction

Energy has both commercial and financial attributes, and due to its rarity and nonrenewable nature, it represents a long-term strategic investment for many investors from different countries (and regions). Overseas energy investment is an effective hedging approach to accommodate volatile energy prices and thus attracts the attention of many countries. Because energy resources are not equally distributed across countries, both energy companies and countries seek greater international cooperation to obtain access to more resources. As countries develop, particularly emerging countries, energy investment is not only important for gaining

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increased commercial value but also for ensuring local energy security and balancing the energy structure [1]. 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, and it presents a growing trend toward diversification. Moreover, due to the diversity of energy regulations and policies [2], investment environments, and resource endowments as well as to geopolitics and the disturbance of relationships between states, the energy investment relationships between different countries reflects different characteristics. Reviewing the literature, we find that scholars focus on the domestic and global energy situation in terms of energy production [3] and supply [4], energy consumption [5] and use [6], energy trade [7], energy security [8], the energy market [9], and so on. There are dozens of traditional energy and new energy sources analyzed, such as oil and gas [9], shale gas [10], wind [11], nuclear [12], and bioenergy [3,13–15]. However, few papers analyze the global energy investment structure from a global perspective.

In addition to energy production [14] and consumption [16] as well as energy trade relationships [17,18], etc., the investment relationship between different countries can also show the global energy structure to some extent. As an important carrier of energy's commercial and financial attributes in the global energy market, listed energy companies play an important role in energy trade and energy investment. Holding the stock of listed energy companies is an important form of energy investment. Given the development and perfection of stock markets in different nations, the internationalization of investors (shareholders) has become common and unavoidable. Shareholders can control and gain returns from listed energy companies by holding their stock. Because global listed energy companies and shareholders come from many different nations, any country can act as either an investor (outward investment) or a target country for investment (inward investment), and the listed energy companies and their shareholders can belong to different nations. Therefore, we can obtain the shareholding relationships between different countries based on the shareholding relationships between the listed energy companies and their shareholders (economic agents) as well as the national affiliations of the listed energy companies and their shareholders. Then, we can analyze the investment features of different nations and the investment relationships between any two nations based on the shareholding relationships of the listed energy companies.

As an important theory and method for complexity science, complex networks are used to research relationships in economic systems and networks from a holistic perspective, especially the relationships between different agents and factors in the stock market and energy market. In the stock market, complex networks have been successfully used in empirical studies on topics such as the structure of the stock market [19], the relationships between oil price shocks and stock market returns [20], the stock trading network [21], the relationships between listed companies and shareholders as well the relationships between shareholders [22], and so on. In the energy market, complex networks have been used in simulating the global energy trade and security [23–25], energy price fluctuation [26], energy flow [27], and so on. Reviewing the literature, we find that one-mode homogeneous networks in both the stock market and the energy market are well documented. It is effective to analyze the structure of these markets by extracting features of the empirical system and simplifying them to a one-mode homogeneous network. However, all economic networks are heterogeneous, having different types of agents and different interactions between the agents that can strongly vary over time [28]. Based on the different interaction relationships between agents, we can construct heterogeneous networks, which can be more in accordance with the laws of an objective economic system. Scholars are primarily researching two-mode heterogeneous networks [29]; they construct two-mode heterogeneous networks through affiliation relationships [30], degrade the network to one-mode relationships [22], and then analyze the features of the derivative one-mode network [31]. As for the energy investment networks based on shareholding relationships, it is obvious that there are shareholders and listed companies (two actors) as well as countries (and regions) that the shareholders and listed companies belong to (two-mode affiliation networks), so it is more appropriate to use the heterogeneous network method to simulate the primitive shareholding relationships.

In this paper, we proposed a novel method and perspective to analyze the global energy structure based on the financial attributes of energy by taking the frontier to complex network theory and treating them as heterogeneous networks. First, we construct a primitive investment network with two different actors, the listed energy companies and their shareholders. Second, based on the two-mode affiliation relationships between the listed energy companies and the nations as well as between the shareholders and the nations, we construct a derivative investment network of nations. Then we analyze the national diversity of outward and inward energy investment, the national energy investment preference, the strength of the energy investment relationship between countries and the most powerful group of energy investment relationships using different indices that we proposed based on the topological features of the shareholding relationships of the global listed energy companies.

The rest of the paper is organized as follows. Section 2 focuses on the data and methodological issues. In Section 3, we report the calculation and the analysis of the empirical results. The discussion and conclusions are presented in Section 4.

2. Data and methods

2.1. Data

The data used in this paper include disclosed information about the listed energy companies and their main shareholders. The data attributes include the name of the listed energy companies, their code, the nations that they belong to, the name of the shareholders, the BVD ID of the shareholders, the nations that the shareholders belong to, and so on. The data used in this paper were primarily collected from one of the most famous worldwide listed company databases–ORISE PUBLICLY LISTED COMPANIES WORLDWIDE (https://osiris.bvdinfo.com), owned by BVD company, on December 31st, 2013 [31]. There are 2334 listed energy companies and 8302 non-duplicate disclosed shareholders, and these listed energy companies and shareholders come from 112 countries (and regions). The quantity of the disclosed shareholders is determined by the laws and regulations of the national stock markets, for example, according to China's company law, listed companies must disclose their top 10 main shareholders ranked by percentage of shareholdings, and in Malaysia, firms usually disclose the top 30 shareholders [32,33]. Usually, all the disclosed shareholders are very important and the primary owners of the listed companies, and each of the main shareholders can affect and be affected by the performance of the listed companies it owns. In addition, the market value of each listed company changes incessantly, so in order to map the global energy investment structure, we only take the number of shares held into account rather than the total shareholding value.

As required by data processing, we deleted duplicate items and used 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.

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