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The shareholding similarity of the shareholders of the worldwide listed energy companies based on a two-mode primitive network and a one-mode derivative holding-based network

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HIGHLIGHTS

- Constructed holding-based network of the shareholders of listed energy companies.
- Based on two-mode network and the equivalence network of the decreasing-mode method.
- Defined the un-weighted shareholding similarity coefficient.
- Defined the weighted shareholding similarity coefficient.
- Comparative analysis of the distribution of the two above-mentioned coefficients.

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ABSTRACT

Two-mode and multi-mode networks represent new directions of simulating a complex network that can simulate the relationships among the entities more precisely. In this paper, we constructed two different levels of networks: one is the two-mode primitive networks of the energy listed companies and their shareholders on the basis of the two-mode method of complex theory, and the other is the derivative one-mode holding-based network based on the equivalence network theory. We calculated two different topological characteristics of the two networks, that is, the out-degree of the actor nodes of the two-mode network (9003 nodes) and the weights of the edges of the one-mode network (619,766 edges), and we analyzed the distribution features of both of the two topological characteristics. In this paper, we define both the weighted and un-weighted *Shareholding Similarity Coefficient*, and using the data of the worldwide listed energy companies and their shareholders as empirical study subjects, we calculated and compared both the weighted and un-weighted *shareholding similarity coefficient* of the worldwide listed energy companies. The result of the analysis indicates that (1) both the out-degree of the actor nodes of the two-mode network and the weights of the edges of the one-mode network follow a power-law distribution; (2) there are significant differences between the weighted and un-weighted *shareholding similarity coefficient* of the worldwide listed energy companies, and the weighted *shareholding similarity coefficient* is of greater

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regularity than the un-weighted one; (3) there are a vast majority of shareholders who hold stock in only one or a few of the listed energy companies; and (4) the shareholders hold stock in the same listed energy companies when the value of the un-weighted *shareholding similarity coefficient* is between 0.4 and 0.8. The study will be a helpful tool to analyze the relationships of the nodes of the one-mode network, which is constructed based on the two-mode network, and it provides a means to discover the similarity of the shareholding behavior among the shareholders; in addition, this study will be useful for further research studies regarding the stability of the structure of the energy institutes and the level of risk in the energy stock market.

1. Introduction

As complex network theory has developed, it has been used in a wide range of empirical research in various fields, such as biology [1–3], social sciences [4–6], economics [7–9], and so on. Complex network theory is becoming a very popular theory and method to analyze the phenomenon and problems of these various fields, and it is effectively used to present the topological features [10,11], relationship mining [12,13], evolution analysis [5,11], etc. However, most of the empirical research studies involving complex network theory were analyzed based on one-mode networks, which only took homogeneous nodes into account, and there are some limitations of one-mode networks in reflecting the complex relationships of the real world exactly [7]. Two-mode networks and multi-mode networks, which can simulate the real world and the relationships between different entities more properly, are new research directions and trends in the development of complex network theory. Many large real-world networks, which are composed of a number of actors and some events, exhibit a two-mode nature [14] because the events and actors are linked by the affiliations, relationships or interactions between them [15]. Two-mode network is a special form of complex network whose data involves two levels of analysis (also called two "modes"), actors and events, and it has bi-partite data structures [16]. Usually, we should transform the two-mode network into a one-mode network to solve the problems [16,17], and the matrix of one-mode relationships of actors or events can be constructed by using the co-attendance [18] relations or the co-membership relations [19].

The network of investment relationships of the shareholders and the listed companies has the key elements of a two-mode network. We can construct the two-mode affiliation network by considering the shareholders as the set of actors, the listed companies as the events, and the investment relationships as the links between the actors and events. By studying the literature about the relationships in the stock market, we found that some scholars researched the direct relations between the shareholders and the listed companies, such as the cross-shareholding relationships [20], the shareholders' holders [9], and the factors of influence of the institutional shareholders' investment behavior [21], to name a few. Meanwhile, some scholars constructed the holding-based networks on the basis of the shareholders' holding behavior and then analyzed the correlation of the holding behavior of different nodes in the holding-based network [9]. Shareholders are the owners of listed companies, and their relationships can directly affect the capital structure and stability of the stock market. The shareholding behaviors between different institutional shareholders were found to exhibit a significant correlation when they are in the same geographic locations or have the formal or informal information communications [22,23], but no study in the literature has analyzed the shareholding similarity of the shareholders.

Worldwide listed energy companies are the principal part of the energy market and play an important part in the energy trade and energy economy. Research on the shareholders' shareholding similarity of the listed energy companies is helpful to analyze and determine the relationships between the institutional shareholders, and it will also be helpful for further research studies about the stability of the shareholders' structure as well as the potential risk of the energy stock market. In this paper, we draw lessons from the concept of two-mode networks and the decreasing-mode method of the complex network theory to construct a primitive two-mode un-weighted directed network with the shareholders as the actor nodes, the worldwide listed energy companies as the event nodes, and the investment relationships between the shareholders and the listed energy companies as the edges. We construct the derivative one-mode weighted undirected network using the decreasing-mode method based on the equivalence holding-based relations [9]; in this network, we take the shareholders as nodes, whether holding the same listed energy companies' stock at the same time as the edges, and the number of the listed energy companies holding at the same time as the weights. We use H–L to represent the two-mode primitive network, and H–H to represent the derivative network. On the basis of the two networks, we define the un-weighted and weighted shareholding similarity coefficient of the shareholders as well as their computational formulas, and then we analyze the distributions of the un-weighted and weighted shareholding similarity coefficient on the basis of calculating the degrees of the nodes of the H–L and the weights of the edges of the H–H. We also perform a detailed comparative analysis regarding the distribution of the un-weighted and weighted shareholding similarity.