



Modeling the interdependent network based on two-mode networks



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HIGHLIGHTS

- We construct two-layer interdependent network based on two-mode network.
- We proposed interdependent indexes of important nodes and edges.
- In China, loan-capacity is focus on a few industries and institutions.
- After the loss of 70% interdependent edges, the structure is destroyed.

ARTICLE INFO

Article history:

Received 26 July 2016

Received in revised form 2 February 2017

Available online 6 May 2017

Keywords:

Interdependent network

Two-mode network

Complex network

Financial network

ABSTRACT

Among heterogeneous networks, there exist obviously and closely interdependent linkages. Unlike existing research primarily focus on the theoretical research of physical interdependent network model. We propose a two-layer interdependent network model based on two-mode networks to explore the interdependent features in the reality. Specifically, we construct a two-layer interdependent loan network and develop several dependent features indices. The model is verified to enable us to capture the loan dependent features of listed companies based on loan behaviors and shared shareholders. Taking Chinese debit and credit market as case study, the main conclusions are: (1) only few listed companies shoulder the main capital transmission (20% listed companies occupy almost 70% dependent degree). (2) The control of these key listed companies will be more effective of avoiding the spreading of financial risks. (3) Identifying the companies with high betweenness centrality and controlling them could be helpful to monitor the financial risk spreading. (4) The capital transmission channel among Chinese financial listed companies and Chinese non-financial listed companies are relatively strong. However, under greater pressure of demand of capital transmission (70% edges failed), the transmission channel, which constructed by debit and credit behavior, will eventually collapse.

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1. Introduction

The internal topological structure and relations of homogeneous systems have been widely examined through complex network theory, namely internet, neural, transportation, power-supply, communication systems, time series and subsurface

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<http://dx.doi.org/10.1016/j.physa.2017.04.081>

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fluid detection [1–16]. However, the strong interactions among different systems undeniably exist, for instance power-supply system and internet, water conservancy control system and electronic instrumentation communication system. So exploring each complex system as an isolate network only offers a partial picture and ignores the integrated linkages and interdependence among different networks. For examples, On May 25, 2005 the power-supply network of Moscow was paralyzed. Within one day, traffic networks, water-supply networks, food-supply networks, financial networks and telecommunication networks all crashed since their dependence on power-supply networks. This accident caused the loss of over 17 billion Rubles. On August 16, 2007 American Countrywide Financial Corporation announced of using 11.5 billion bank credits. This action caused a great panic of the American stock market and real-estate market, because the Countrywide Financial Corporation provided 17% of the home mortgage loans in America. Eventually, such market panic evolved into the subprime mortgage crisis of America. All these examples fully illustrate that the interdependent relations among systems could spread the information and risk among originally independent networks and form a more systematical group of interdependent network. Not only resource but also failure will transmitted by some important nodes and edges to the entire network, such as the Countrywide Financial Corporation mentioned in the examples.

The construction of interdependent networks and the interdependent features' analysis of important nodes and edges could reach a better understanding of the empirical systems. However, and recent researches of interdependent networks mainly focus on the model construction of physical multiplayer networks and physical interdependent networks [17,18], discussion of new interdependent index [19], the control of extreme events in interdependent network [20], cascading failures of interdependent network [21–25], the percolation theory in interdependent network [26] and the researches of empirical networks [27–30]. Among all aforementioned studies, there lacks the exploration of the interdependent loan network and the loan interdependent features' analysis about important nodes. The operation of nonfinancial listed companies require financial support and capital promotion from financial listed companies, financial listed companies also need to ensure that its assets is safe and could increase by providing loans to nonfinancial listed companies. This kind of debtor–creditor relationships between financial network layer and non-financial network layer is one of the most basic and common relationships in the economy, which could be considered as typical interdependent relationships.

The construction of two-layer interdependent loan network model could reveal the important interdependent financial system, which could help us to study the empirical loan market from a more systematic perspective. In the event of American subprime mortgage crisis, apparently the Countrywide Financial Corporation owned huge dependent degree to creditor and great dependent transmission capacity between financial corporation and creditor. So when the Countrywide Financial Corporations collapse, the whole debit and credit market network crashed. Thus, it is even more important to monitor and control the important nodes and edges to avoid large-scale paralysis of financial systems. In interdependent loan networks, assets transfer from financial layer network flow to non-financial layer network through debit and credit behaviors. So the financial listed companies debit and credit loans and the non-financial listed companies borrowing the loans are both the important nodes in the interdependent networks. Thus, establishing and calculation the interdependent indexes of nodes and edges in the two layer networks of interdependent loan networks will be more helpful in monitoring the financial system to avoid large scale economic crisis.

In this paper we proposed a method to construct two-layer interdependent loan network. Besides, we propose two dependent feature indices of two-layer interdependent loan network based on traditional network feature indices: dependent degree and dependent betweenness centrality. This model transforms the status of the shareholders and listed companies into loan dependent features of listed companies. Through the case study of Chinese loan market, the dependent features of Chinese financial listed companies and non-financial industries are calculated. The results of this research provide several meaningful suggestions to avoid risks in Chinese stock market. This method not only can be used to analyze the loan market around the world, but also can be used to explore other kind of interdependent networks.

2. Methods

2.1. Model construction

The debit and credit behavior is a typical relationship between financial companies and non-financial companies, and the mutual benefit of both sides makes the debtor–creditor relationship a typical interdependent relationship. In order to study this kind of interdependent relationships, we build a two-layer interdependent network, contain a network of financial companies, non-financial networks and the debtor–creditor relationships between them, the conception figure is shown in Fig. 1.

In Fig. 1, the nodes of financial network and non-financial network are financial companies and non-financial companies respectively. The edges within financial network and non-financial network are both co-shareholder relationships, and the edges between financial network and non-financial network are debtor–creditor relationships.

Base-layer networks (financial network and non-financial network)

The principle base-layer networks within the interdependent loan network are non-financial network and financial network. In order to study the interdependent loan network model from the aspect of the inner capital flows, the base-layer network is constructed by listed companies and the co-attendance behavior of shareholders between listed companies. Shareholders are the owner of listed companies and occupy most of the assets. When one shareholder is affiliated with

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