Physica A 443 (2016) 583–594

Contents lists available at ScienceDirect

Physica A

journal homepage: www.elsevier.com/locate/physa

Novel indexes based on network structure to indicate financial market

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HIGHLIGHTS

- Stock market modeled by dynamic financial network based on rank-based Spearman correlation coefficient.
- Novel indexes based on maximum and fully-connected subnet.
- Different indexes are compared and analyzed.
- Investigation on the ability of indexes to indicate the future trend of the market and turning point.
- Detailed test and analysis based on simulated investment.

ARTICLE INFO

Article history:
Received 25 July 2014
Received in revised form 21 June 2015
Available online 13 October 2015

Keywords:
Network analysis
Structure-based index
Maximum and fully-connected subnet

ABSTRACT

There have been various achievements to understand and to analyze the financial market by complex network model. However, current studies analyze the financial network model but seldom present quantified indexes to indicate or forecast the price action of market. In this paper, the stock market is modeled as a dynamic network, in which the vertices refer to listed companies and edges refer to their rank-based correlation based on price series. Characteristics of the network are analyzed and then novel indexes are introduced into market analysis, which are calculated from maximum and fully-connected subnets. The indexes are compared with existing ones and the results confirm that our indexes perform better to indicate the daily trend of market composite index in advance. Via investment simulation, the performance of our indexes is analyzed in detail. The results indicate that the dynamic complex network model could not only serve as a structural description of the financial market, but also work to predict the market and guide investment by indexes.

1. Introduction

In recent years, the complex network has been applied as a leading tool for understanding and managing the complex financial markets [1–3], which has always been appealing to researchers because of its complicated mechanism and potential benefits.

Current research of the complex network model in financial market has obtained remarkable achievements, including two main directions. One direction is to explore different ways to model the financial network, especially the coefficient for links [4]. For example, Creamer et al. built a corporate news network to evaluate the impact of news on asset return [5]; Gao et al. built a causal network based on risk and analyzed its performance in crisis and bull period [6]; Tumminello et al. used statistically validated networks to identify clusters of investors [7]. Recently, the mutual information [8] and

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http://dx.doi.org/10.1016/j.physa.2015.10.008
0378-4371/

cointegration coefficient [9,10] have also been used to model the network. The other direction focuses on characteristic analysis of financial networks, including (but not limited to) the topological structure [11–13], scale characteristic [14], community organization [15] and correlation [16–18], in order to assess the state of the market or its members.

Furthermore, researchers have begun to pay attention to quantitative analysis of the market with an observable network-based index. For instance, Emmert-Streib et al. tried to identify critical points of the financial market with network theory, and demonstrated that it is possible to establish a network-based index that can reflect the current state of the market in the context of crashes [19,20]; Battiston et al. introduced a new index called DebtRank to measure systemic impact inspired by feedback-centrality of financial network [21]. However, the index by Emmert-Streib et al. is to recognize crisis which occurs extremely infrequently, and the DebtRank index is used to assess the importance of institutions. As the dynamic network is changing all the time along with the market, its dynamic characteristics (such as the changing connectivity) should be able to reveal certain evolution features of the market, which suggests that network-based indexes can be used in daily investment to indicate the daily trends of the market instead of only warn of critical crashes or assess companies.

In the paper, we propose novel daily indexes that are based on dynamic network model of the financial market to show how network models can help investors in practice. Compared with existing network indexes, the novel indexes are analyzed in detail to demonstrate their ability to serve as a forecast of the market. Furthermore, not limited to only making empirical suggestions for investment, we simulated an investment guided by our indexes to show that the network-based index can be directly used to guide the investment. The paper is organized as follows. In the next section, the paper analyzes and models the stock market as a network based on the Spearman Correlation Coefficient. Then the characteristics of the network are analyzed by existing indexes and the results are compared in Section 3. The novel indexes to indicate the market are put forward and analyzed in Section 4. Next, in Section 5, an investment is simulated to validate the effect of our indexes. The final section concludes the paper.

2. Network model based on Spearman correlation coefficient

The market at time t is modeled as dynamic network G_t, consisting of vertex set and edge set which describe the nodes within the network and the links between the nodes respectively. For each stock s in the market of M_t stocks, the vertex set is:

$$V_t = \{s|s = 1, 2, \ldots, M_t\}. \tag{1}$$

The closing price of each stock s at time t within the latest N days (denoted as $p_{s,t}$) is used to model the links. There are several methods to model the relationships between nodes. Thereinto, the conventional cosine similarity is an index located in $[-1, 1]$ that measures the angle between two vertices. For stock $i, j \epsilon V_t$, the similarity relationship could be modeled as:

$$sim(i, j, t) = \frac{\sum_{n=t}^{t-N+1} p_{i,n} p_{j,n}}{\sqrt{\sum_{n=t}^{t-N+1} p_{i,n}^2}\sqrt{\sum_{n=t}^{t-N+1} p_{j,n}^2}}. \tag{2}$$

Generally speaking, the cosine similarity changes when vector (namely vertex in network) moves. For example, according to Eq. (2), series (2, 1, 2) is quite different from (12, 11, 12). However, as a stock price series, (2, 1, 2) and (12, 11, 12) should be very similar to each other as a V-shape fluctuation. Consequently, we perform a decentration process to Eq. (2) and use a Pearson correlation coefficient as:

$$P(i, j, t) = \frac{\sum_{n=t}^{t-N+1} (p_{i,n} - \overline{p_{i,n}})(p_{j,n} - \overline{p_{j,n}})}{\sqrt{\sum_{n=t}^{t-N+1} (p_{i,n} - \overline{p_{i,n}})^2}\sqrt{\sum_{n=t}^{t-N+1} (p_{j,n} - \overline{p_{j,n}})^2}}. \tag{3}$$

However, there exists baffle that Pearson correlation coefficient deals with linear dependencies but the stock market is confirmed to behave in a nonlinear manner [9]. Moreover, the Pearson correlation coefficient statistically requires that the variable $p_{s,t}$ in Eq. (3) obeys the normal distribution. But as shown in Fig. 1, stock price series does not always meet that.

Fig. 1 shows the statistical distribution of the price of SH600004 from February 1st to November 30th. The distribution appears to have multiple peaks, which may result from irregular mean shifts or some more complex nonlinear interactions in the market. More examples could be found in the market especially during periods where significant changes happen.

Furthermore, research has confirmed that the volatility MSTs (Minimum Spanning Tree, a typical structure in a network) obtained starting from a Spearman rank-order correlation coefficient are more stable than the ones obtained starting from the linear correlation coefficient [22]. Therefore, the Spearman rank-order correlation coefficient is utilized in order to find a relatively stable structure in the following sections.