Physica A xx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Physica A

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

Q1 Network trending; leadership, followership and neutrality among companies: A random matrix approach

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HIGHLIGHTS

- A method to reveal the collective behavior of stocks in a financial market is proposed.
- The markets were ranked based on their stocks' collective behavior.
- The stocks were categorized based on their participation in market's trend.
- The results of categorization could be used for portfolio selection.

ARTICLE INFO

Article history:
Received 23 December 2015
Received in revised form 6 May 2016
Available online xxxx

Keywords:
Correlation matrix
Complex systems
Collective behavior
Market trend
Leadership
Followership

ABSTRACT

In this article, we analyze the cross-correlation between returns of different stocks to answer the following important questions. The first one is: If there exists collective behavior in a financial market, how could we detect it? And the second question is: Is there a particular company among the companies of a market as the leader of the collective behavior? Or is there no specified leadership governing the system similar to some complex systems? We use the method of random matrix theory to answer the mentioned questions. Cross-correlation matrix of index returns of four different markets is analyzed. The participation ratio quantity related to each matrices' eigenvectors and the eigenvalue spectrum is calculated. We introduce shuffled-matrix created of cross correlation matrix in such a way that the elements of the later one are displaced randomly. Comparing the participation ratio quantities obtained from a correlation matrix of a market and its related shuffled-one, on the bulk distribution region of the eigenvalues, we detect a meaningful deviation between the mentioned quantities indicating the collective behavior of the companies forming the market. By calculating the relative deviation of participation ratios, we obtain a measure to compare the markets according to their collective behavior. Answering the second question, we show there are three groups of companies: The first group having higher impact on the market trend called leaders, the second group is followers and the third one is the companies who have not a considerable role in the trend. The results can be utilized in portfolio construction.

Q3

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http://dx.doi.org/10.1016/j.physa.2016.06.067
0378-4371/

1. Introduction

At the present time it seems that our financial situation is tied up to the companies in which their financial positions are interweaving together. It causes a complex situation for the ones who tend to investigate and forecast the market. In other words to understand the situation of a company in a market, it is not enough to study the company independently, but to consider the information of the whole financial society creating a market atmosphere. This feature of financial markets reflects the concept of collective behavior. As a significant complex system, financial markets are highly noteworthy to be studied [1–4]. One of the main features of a complex system which makes it very interesting for researcher is its collective behavior. Now the first significant question arises here is: How to detect collective behavior existing in a market? The second considerable question relates to the existence of a leadership among the companies of the market. In other words the question is about categorizing the companies based on their share in market's trends.

In this study we proceed to answer these questions. The method of random matrix theory is used. In this study we consider four different markets which are selected from some efficient and also emergent markets. The cross-correlation matrix of index returns of each market is computed. Searching for and detecting the collective behavior of system, one should precisely notice that the interaction between companies of each market is latent inside the correlation matrix and it should be found just there, this is the place to be carefully looked at Refs. [5,6].

Some previous studies [7–10] applying RMT methods to analyze financial markets showed two noticeable results: the first one says there exists a large eigenvalue among the eigenvalue spectrum which is an indication of market's trend and the second one corresponds to the bulk of the eigenvalue spectrum of the matrix which shares universal properties with the Gaussian orthogonal ensemble of random matrices [11–14]. Another study investigated different markets including emerging one and compared it with a mature market in terms of perturbed correlation matrices [15]. They analyzed the markets through RMT theory and the correlation coefficient distribution. They found the mature market was more sensitive to global perturbation than the emerging one. Ref. [16] provides the comparison of the results extracted from the empirical series in a larger domain which are fractional Gaussian noises (fGns) instead of comparing with RMT. The fGns family due to their well known correlation provides understanding the type of correlation. This method could reveal if the correlation shows a power law behavior or not. The other studies resulted in a collective behavior of the financial markets and a power-law decaying time correlation for the price fluctuations [17,8,18].

Considering that the region of the bulk had been unregarded, there might be some useful information about the collective behavior of the system in the region. It just needed a precise look at there. To show that the neglected bulk region was highly valuable for detecting and measuring the collective behavior of the system, we introduced a *shuffled-matrix* built from cross-correlation matrix by shuffling the elements of the later one. In this way, if there existed a non-random pattern in a cross-correlation matrix, shuffling the elements might cause the pattern to be washed out. We calculated the eigenvalue spectrum and eigenvectors of each of the cross-correlation matrices and their related shuffled-matrices. Using the eigenvectors, the participation ratio quantities were calculated for each pair of the matrices. The results remarkably showed a difference between the values of participation ratios of the shuffled and correlation matrices. The differences signified the collective behavior of the system. To obtain a measure for the behavior we calculated the relative deviation of participation ratios' average which resulted in the ranking of the markets based on their collective behavior.

The aforementioned method helped us to detect the collective behavior among the companies of each market. It is obvious that the shares of companies in the behavior are not the same. To understand the share of each company in the behavior we used the eigenvector corresponding to the largest eigenvalue of the cross-correlation matrix of each market. Based on the remarkable result reported in Refs. [9,10], the largest eigenvalue relates to an influence common to all companies that means the largest eigenvalue represents the market's trend. In this way the eigenvector related to the largest eigenvalue carries the information about the market's trend and the eigenvector has nothing but components, which means the components are the information carriers. As a matter of fact each component of the eigenvector is proportional to the share of a company in the influence or trend. Our results showed the companies could be categorized as leaders, followers and sleepers from this point of view. Finally, the categorization could be used for construction of an optimal portfolio.

In this study we analyzed daily stock prices of four financial markets of the world including: Dow Jones and S&P500 from USA; DAX, Germany; SSE180, China; from 2000 January to 2015 October. The data were collected from Ref. [19].

2. Cross-correlation and shuffled-matrices

As the interactions between the stocks are not known exactly, the cross correlation between them is analyzed utilizing the concept and method of random matrix theory. The theory was brought up and developed in the context of nuclear physics [20–22], where the precise nature of the interactions between the systems elements were not known in order to explain the statistic of energy levels of the complex quantum system. The standard method to evaluate the cross correlation matrix for the stocks has already been developed [4,23–25]. First, we measure the price fluctuations in such a way that the result is independent of the scale of measurement to observe correlation between the price movements of different stocks. Let $S_i(t)$ denote the price of the stock $i = 1, \ldots, N$ at time Δt then the price return of the i th stock, over a time interval is

$$G_i(t) = \ln S_i(t) - \ln S_i(t - \Delta t). \quad (1)$$

Please cite this article in press as: N.S.S. Mobarhan, et al., Network trending; leadership, followership and neutrality among companies: A random matrix approach, Physica A (2016), http://dx.doi.org/10.1016/j.physa.2016.06.067