Characteristics of Networks in Financial Markets

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Abstract

We investigate the financial network of the Korea Stock Exchange (KSE) using numerical simulations and scaling arguments. The frequency of degree and the edge density for a real stock market graph are mainly discussed from a numerical point of view. In particular, our frequency of degree follows approximately the power law distribution.

Key words: Financial networks; Cross-correlation; Frequency of degree; Edge density

1. Introduction

The small-world and scale-free networks models [1] have recently been widely studied in various applications related to fields such as physics, biology, and economics, as well as in the social and technological sciences. These network models have played a crucial role in the theoretical and numerical investigation of complex phenomena. Of the many systems of current interest, the degree distribution for scale-free networks is particularly interesting because it follows the power law $p(k) \sim k^{-\gamma}$ for a large k while for random networks it decays faster than exponentially. Financial market networks are used extensively in various types of financial applications [2, 3]. Furthermore, the self-organization of individuals, companies, capitalists, and nations has focused on the formation of macroscopic patterns, such as commodity prices, stock prices, futures prices, and exchange rates. Several researchers have attempted to numerically estimate the correlation in price changes by examining how the random matrix theory influences the collective behavior in financial markets [4, 5].

In this paper, by investigating the cross-correlation of stock prices for all companies listed on the KSE in 2003, we mainly discuss the frequency of degree, edge density, and size of connected component.

2. Numerical calculation

Let $r_i(t)$ be the return of the stock price as defined by $r_i(t) = \ln p_i(t+\Delta t)/p_i(t)$, where $p_i(t)$ is the stock price of company i at time t. Then, since the cross-correlation between individual stocks is represented in terms of a matrix C, we calculate the matrix's correlation coefficient [6] as $C_{ij} = (\overline{r_i r_j} - \bar{r_i}\bar{r_j}) / \, [(\overline{r_i}^2 - \overline{r_i}^2)\ (\overline{r_j}^2 - \overline{r_j}^2)]^{1/2}$. Here the bars denote the time average over the transacted period, and the corresponding correlation coefficients have one value between $[-1, 1]$. Two companies are correlated (anti-correlated) if the coefficient $C_{ij} = 1(-1)$; however, they are uncorrelated if $C_{ij} = 0$. The largest eigenvalue is nondegenerate and real because matrix C is real and symmetrical. For the scaling argument of financial networks, the frequency of degree follows a

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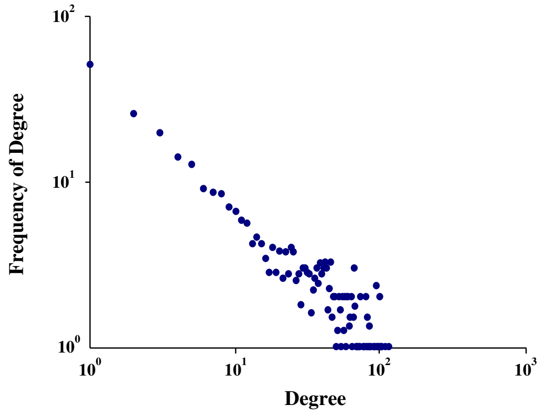

Fig. 1. Frequency of degree of KSE networks for $\theta = 0.5$, where $P(k) \sim k^{-\beta}$ with the scaling exponent $\beta = 0.91$.

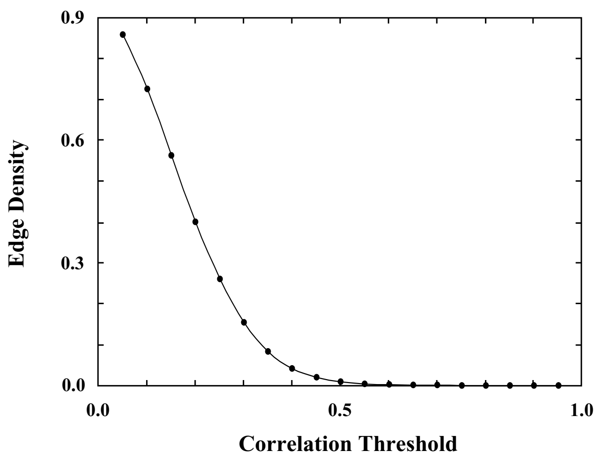

Fig. 2. Plot of the edge density as a function of the correlation threshold θ in KSE networks.

power law of $P(k) \sim k^{-\beta}$.

The market graph features a set of 554 companies that traded at the KSE. We analyzed the daily tick data for the period from January 2003 to December 2003. First of all, we examine the distribution of correlation coefficients and find that the average value of C_{ij} is 0.176. To discuss the frequency of degree and the edge density in the market graph, we regarded the set of companies as a set of the graph's vertices. For any pair of companies, i and j, a connected edge is given to the market graph if the corresponding correlation coefficient C_{ij} is greater than or equal to a correlation threshold θ. For the frequency of degree, our result is different from that of other models [2]. In that work, when the correlation threshold value exceeds $\theta = 0.4$, the degree distribution resembles a power law. In our network of the KSE, the frequencies of degree for $\theta = 0.4$, 0.5, and 0.6, particularly scale as a power law with scaling exponents $\beta = 0.76$, 0.91 (Fig. 1), and 1.15. In Fig. 2, we show the edge density as a function of different values of the correlation threshold, θ, for financial market networks in the range of $\theta > 0$. Moreover, it is found that percolation threshold at which all stocks are connected into one giant cluster is 0.148.

3. Summary

From a market graph of all companies listed on the KSE in 2003, we have discussed the cross-correlation, the frequency of degree, and the edge density of the stock prices. We found that the frequency of degree for $\theta = 0.4$, 0.5, 0.6 scales as a power law, and the power law is shown to break down in other regions. In the future, we expect the graph representation of the KSE and its scaling properties to give novel insight into the internal structure of other stock markets. We hope that the detailed description of the market graph proves to be useful for extending financial analysis to foreign financial markets.

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