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Deterministic factors of stock networks based on cross-correlation in financial market

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Abstract

The stock market has been known to form homogeneous stock groups with a higher correlation among different stocks according to common economic factors that influence individual stocks. We investigate the role of common economic factors in the market in the formation of stock networks, using the arbitrage pricing model reflecting essential properties of common economic factors. We find that the degree of consistency between real and model stock networks increases as additional common economic factors are incorporated into our model. Furthermore, we find that individual stocks with a large number of links to other stocks in a network are more highly correlated with common economic factors than those with a small number of links. This suggests that common economic factors in the stock market can be understood in terms of deterministic factors.

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1. Introduction

Stock markets have long been known to be extremely complex systems, evolving through interactions between heterogeneous units. Hence, the attempts to study and understand the nature of interactions between stocks have been important in understanding the pricing mechanism in the stock market. The cross-correlation matrix has been widely used to quantify interaction among stocks. If we can classify and use significant information included in the cross-correlation matrix between stocks, we will better understand the stock market. However, the extraction of significant information from the cross-correlation matrix has been quite difficult. In finance, researchers have usually used the methods of multivariate statistical analysis, such as principal component analysis, factor analysis, and cluster analysis. In econophysics, for instance, a stock network is proposed by Mantegna et al. for investigating the interaction between stocks using the minimal spanning tree (MST) method [1].

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The stock network visually constructs the relationship between stocks, which is extracted by the MST based on the cross-correlations between stock returns. Our work is based on the arbitrage pricing model (APM), widely acknowledged in financial literature [2]. That is, there are many common economic factors in the stock market, which influence all stocks traded [3]. Common economic factors include the industrial product, the risk premium, the term structure of interest, and inflation. The stocks with the same common economic factors are highly correlated with each other and tend to be grouped into a community. That is, individual stocks are divided into small homogeneous stock groups depending on the tendency of stock price changes in correlation with common economic factors [4–6]. Accordingly, the pricing mechanism of individual stocks might be explained by the common economic factors in the stock markets. These observations in the financial sector are similar to the results derived from the MST that in a stock network individual stocks belonging to the same industry from groups with linking relations [7–10].

In previous studies, much focus is made on the topological properties and the formation principles of stock networks, which revealed that the degree distribution of a stock network follows a power law [11,12]. This implies that most individual stocks in a network have a small number of links with other stocks, while a few stocks, so called hub stocks, have a large number of links. Eom et al. suggested that the larger the degree of a stock is in the stock network, the more it is correlated with the market index empirically [13]. Therefore, some stocks acting as a hub for each cluster in a network are affected much more by the market index.

In a recent work, Bonnano et al. investigated the degree of consistency between networks using estimated returns from the pricing model and networks from real stock returns [14]. The purpose of this study is to investigate whether stock returns from pricing models can explain interactions between stocks. This study may reveal the deterministic factors that significantly affect the formation process of a stock network. The widely accepted model in the previous study has been the capital asset pricing model (CAPM) [15,16]. In the CAPM, the prices of individual assets are determined by the market portfolio including all risk assets. In addition, the one-factor model (or the market model), which is a empirical model of the CAPM, uses a market index as a proxy for the market portfolio. However, stock networks from the estimated returns of the one-factor model show a very different structure from the original stock network [9,10,14]. That is, even if the market index as a representative factor is important for determining the stock price, the market index alone cannot completely explain interactions among stocks.

Therefore, the interactions between stocks may be explained better by the multi-factor model than the one-factor model. As the APM proposed by Ross suggests, stock prices are mostly determined by common economic factors observed in stock markets. These results show that the grouping process of stocks can be observed systematically by the cross-correlation matrix between stocks [17]. The previous study also found that an estimated stock network with returns generated by the stochastic dynamics model (with control parameters included in the market, group and individual stock properties) is very similar to the original stock network with real return data of the stock market [18].

In order to find deterministic factors of the stock network, we propose a model based on common economic factors and investigate whether these common economic factors in the stock market play an important role in determining the stock network. We used the APM, extensively acknowledged as the multi-factor model in financial literature, so that the estimated stock returns reflect the properties of common economic factors. In addition, we investigate the degree of consistency between the original stock networks with real return data and the estimated network with returns based on the multi-factor model. To quantify the strength of consistency between stock networks, we use the survivor ratios suggested in the previous studies [19]. This ratio measures whether stocks that are linked directly to specific stocks in the original stock network have the same links to those in the estimated stock network. We found that the estimated stock networks with more common economic factors in the stock market, give a higher consistency with the original stock network of real returns. In particular, in stock networks, stocks with a large number of links to other stocks in the original stock network have a higher consistency than those with a small number of links. Therefore, these results suggest that common economic factors in the stock market may help to explain the formation principles of stock networks.

In the next section, we describe the data and methods used in this paper. In Section 3, we present the results obtained from the APM. Finally, we end with a summary and conclusion.