Effects of common factors on stock correlation networks and portfolio diversification

Cheoljun Eom [a,*], Jong Won Park [b]

[a] School of Business, Pusan National University, Republic of Korea
[b] College of Business Administration, University of Seoul, Republic of Korea

ABSTRACT

This study empirically investigates the effects of common factors on the connectivity of the network among stocks and on the distribution of the investment weights for stocks. The network is defined as a stock correlation network from the minimal spanning tree (MST), and portfolio is defined as an efficient portfolio from the Markowitz mean-variance (MV) optimization function (MVOF). For these research goals, we devise a method using the comparative correlation matrix (C-CM), which does not have the property of a single common factor included in the sample correlation matrix (S-CM). The results reveal that common factors clearly affect the changes of connectivity among stocks in the networks, and that their influence is much greater on stocks with many links to other stocks in the network. Further, common factors significantly affect the determination of the investment weight's distribution for stocks from the MVOF. In particular, among the common factors, a market factor plays a dominant role in both structuring the network among stocks and in constructing the well-diversified portfolio. In addition, the devised method of the C-CM without the property of the market factor in the S-CM plays a crucial role in constructing a more diversified portfolio with better out-of-sample performance in the future period. These results are robust in both the Korean and the U.S. stocks markets.

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1. Introduction

The global financial crises of the 2007-2009 U.S. sub-prime mortgage collapse and the 2011–2012 European sovereign debt crash have stimulated research from the new perspective of a financial system based on connectivity among various market components, with systemic risk being a particular focus of study. Systemic risk in the previous studies is difficult to define as a single concept, but is commonly referred to as an environment prone to interconnected contagion and a financial system with its stability threatened by negative shocks across the overall market. Hence, the connectivity among the components in the financial market is an important characteristic of the systemic risk. Schweitzer et al. (2009) emphasized the need for a new approach capable of understanding the complexity of an economic network, and in particular, the network approach is mentioned as an alternative that can limit the risk of global financial market crises. Billio, Getmansky, Lo, and Pelizzon (2012) investigated the impact of negative shocks on the commonality extracted by principal components analysis and the connectivity of the network constructed by Granger causality test using return data of hedge fund, banks, broker/dealer and insurance included

in the U.S. financial sector. They presented evidence that U.S. financial institutions have closer connectivity depending on commonality, and that with an increasing degree of commonality in a market crash, the interconnected contagion effect from negative shocks becomes much higher. Eom, Park, Kim, and Kaizoji (2015) also empirically verified that the degree of commonality among stocks clearly increases in the case of the 1997 Korea currency crisis and the 1990–2000 Japan long-term recession. Diebold and Yilmaz (2014) examined the connectivity among stocks and the contagion effect from negative shocks by devising a method of volatility decomposition using realized volatility from high frequency intraday returns of stocks in the U.S. financial sector. Acemoglu, Ozdaglar, and Tahbaz-Salehi (2015) mentioned that closer interconnectivity of a financial system may lead to the collapse of the financial system when the negative shocks across the overall market unexpectedly exceed a certain level.

In the traditional financial theory, the common movement on the return changes of stocks is quantified through a correlation matrix among stocks, the common factors classified for each of the typical properties of commonality among stocks are extracted from the correlation matrix among stocks, and the portfolio risk management and pricing model utilize the common factors as important influential variables. Sharpe (1964), Ross (1976) and Fama and French (1993) suggested pricing models to explain the return changes of stocks using common factors

* Corresponding author.
E-mail addresses: shunter@pusan.ac.kr (C. Eom), parkjw@uos.ac.kr (J.W. Park).

as independent variables, and the variation part of stock returns due to common factors in the pricing model is defined as a systematic risk. The Markowitz (1952) mean-variance (MV) optimization function (MVOF), a scientific tool for effective asset allocation, utilizes the correlation matrix among stocks as a key input for constructing an efficient portfolio, along with expected returns and standard deviations of returns. Therefore, based on previous studies, the systemic risk that is associated with the changes of a financial system caused by negative shocks across the overall market is very relevant for the commonality and connectivity of the network among stocks. Furthermore, the traditional portfolio theory and pricing models are highly dependent on common factors and the correlation matrix among stocks. On the basis of the relevance between new and traditional key words, we empirically investigate the impact of common factors, which may be defined as typical properties of commonality among stocks, on the correlation matrix among stocks, the connectivity of the network among stocks, and portfolio diversification of the MVOF.

Interdisciplinary studies with the field of finance have recognized the stock market as a typical case of a complex system and considered the perspective of connected relationship between stocks to understand the underlying characteristics of the complex system. Mantegna (1999) visualized a connected relation between stocks from the minimal spanning tree (MST) using a correlation matrix among stocks as a key input, that is, a stock correlation network. Eom, Kwon, Jung, and Kim (2010) investigated the significant information flow based on all links of $N(N-1)$ among N stocks in the Korean stock market, using the Granger causality test similar to Billio et al. (2012), and found that using only $(N-1)$ links from the MST gives the same result as using all links of $N(N-1)$, which demonstrated the usefulness of the MST. The structure of the network among stocks usually is examined through the frequency distribution of the number of links to other stocks for each stock. A well-known characteristic is that many stocks have few links to other stocks, whereas only a few stocks have many links. This is defined as the power law distribution, unlike a normal distribution with a high peak at its center. Onnela, Chakraborti, and Kaski (2003) topologically showed that stocks having many links to other stocks tend to be located in the center of the network and stocks having few links to other stocks tend to be located in the outer of the network. Eom, Oh, Jung, Jeong, and Kim (2009) provided evidence that the number of links to other stocks in the network has a significant positive relationship with common factors. On the other hand, many researchers have recently discussed the need to change the traditional views on portfolio risk management. Campbell, Lettau, Malkiel, and Xu (2001) and Ang, Hodrick, Xing, and Zhang (2006) showed that idiosyncratic volatility known as a diversifiable risk in traditional portfolio theory is not removed and, furthermore, exerts an information effect to induce meaningful changes of stock returns in the future period even when constructing an efficient portfolio. This means that it may be exposed to a high level of risk caused by the idiosyncratic volatility even in a well-diversified portfolio, as well as to more serious risks if the portfolio is not well diversified. As a result, the question of how to construct a well-diversified portfolio for effective risk management is an important topic in practice and in academia. Onnela et al. (2003) verified that stocks in a low-risk portfolio tend to be located in the outer of the network, whereas stocks in a high-risk portfolio tend to be located in the center of the network. That is, the location of stocks in the network is related to the level of portfolio risk. Tola, Lillo, Gallegati, and Mantegna (2008) proposed a method of a correlation matrix estimated using $N-1$ links between stocks from a single-linkage method of cluster analysis, which uses the same algorithm as MST, and presented evidence that an efficient portfolio from the proposed method in the past is closer to an efficient portfolio realized in the future investment period. Eom et al. (2015) provided evidence that a method using the random matrix

theory (Mehta, 1995) to remove the property of a market factor included in a correlation matrix among stocks seemed to overcome the limitation of the MVOF which does not effectively achieve the effect of portfolio diversification in market crashes of Korea and Japan.

On the basis of previous studies, we empirically examine the evidence supporting the crucial role played by common factors in constructing the structure of the stock correlation network, in determining the investment weight's distribution for stocks in the portfolio, and in changing the magnitude of the correlation matrix among stocks. That is, the common factor with a typical property of commonality among stocks definitely affects the correlation matrix, which in turn affects the structure of the network among stocks and the determination of investment weight for stocks, because the correlation matrix is a common input in the MST and the MVOF. The rationale for the research goal is as follows. The MVOF based on Markowitz (1952) prefers to allocate investment weights to stocks having a low correlation to other stocks in the portfolio, because the objective function is to minimize the risk quantified by the covariance matrix among stocks. These stocks may have preferentially non-zero investment weights under a budget condition of no short-sale. The MST based on Kruskal (1956) with a condition of the shortest distance prefers to select stocks with a high correlation to other stocks, because these stocks are close to other stocks. These stocks may be preferentially located in the center of the network because they have many links to other stocks. Therefore, when using the sample correlation matrix (S-CM) as in previous studies, stocks having a lower correlation to other stocks tend to have non-zero investment weight from the MVOF and to be located in the outer of the network from the MST. We empirically present evidence of this characteristic from the MVOF and the MST. This observation from the S-CM is also utilized as a criterion of comparison to assess the impact of a common factor. Meanwhile, we devise a method of the comparative correlation matrix (C-CM) in order to substantially examine the influence of common factors. The C-CM is a correlation matrix that does not have the property of a single common factor included in the S-CM. This is calculated using residual data estimated from a single-factor model using a common factor as an independent variable. The C-CM is definitely smaller than the S-CM on average, because the common factor is a common part of stock returns' co-movement. Hence, we anticipate that when using the C-CM, the investment weight's distribution from the MVOF and the connectivity of the network among stocks from the MST must be changed, compared to when using the S-CM. As a result, by comparing the results using each of the C-CM and the S-CM, we may investigate the impact of a common factor on the stock correlation network and portfolio diversification. In addition, in modern portfolio theory, the general consensus is that the lower the correlation matrix among stocks in a portfolio, the more efficient portfolio will be constructed. That is why we can also assess the improvement in practical applicability of Markowitz optimum theory by comparing the S-CM and the C-CM.

The results can be summarized as follows. First, the structure of the stock correlation network from the MST using the C-CM, which does not have the property of a single common factor, is significantly different from that using the S-CM; that is, common factors significantly affect the connectivity of the network among stocks, and in particular, the market factor exerts the greatest influence. In addition, common factors have much higher impacts on stocks having many links to other stocks at the center of the network than on stocks having few links to other stocks in the outer of the network. Second, the distribution of investment weight from the MVOF using the C-CM is used to construct a much more diversified portfolio, compared to using the S-CM; that is, the number of stocks having non-zero investment weights from the C-CM is much higher than in the case of using the S-CM. Therefore, from the perspective of constructing a well-diversified portfolio, common factors significantly affect the distribution of investment weight into stocks in a portfolio. The C-CM without the property of the market factor generates the most diversified portfolio compared to the other common