Characteristics of the Korean stock market
correlations

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Abstract

In this study, we establish a network structure of the Korean stock market, one of the emerging markets, with its minimum spanning tree through the correlation matrix. Based on this analysis, it is found that the Korean stock market doesn’t form the clusters of the business sectors or of the industry categories. When the MSCI (Morgan Stanley Capital International Inc.) index is exploited, we found that the clusters of the Korean stock market is formed. This finding implicates that the Korean market, in this context, is characteristically different form the mature markets.

Key words: Correlation-based clustering, Emerging market, Minimum spanning tree, Econophysics

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1 Introduction

The stock price of a given company is a mutual inference of various information, such as company revenue, competition performance, currency policy, business barometers, political situation, and so on. In other words, when the company price is estimated, there are numerous complicated factors that must be confronted. In the stock market, all companies are interconnected and consequently their stock prices are correlated. This correlation, known as the potential of deep inner impact, forms the stock market network.

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Network theory, a fruitful approach to analyzing complex systems, has been extended into a wide range of subjects, including the Internet, WWW, biology, and economy[1,2,3] since Erdős and Rényi (ER) introduced their model, which generates a random network with the number of nodes and connection probability, known as the ER model[4]. A stock market is one of inhomogeneous network systems; every company has a different revenue, performance, stock price, market capitalization and name.

Recently, Barabási and Albert (BA) introduced the scale-free network[5]. They constructed the network by the preferential attachment rule, the essential point to understanding the stock market network. We consider the preferential attachment rule as the connectivity of an influential company in stock market - a more influential company has more connections with other companies. The interaction strengths in the network system are important, many models are binary networks, whose links have 0 (not connected) or 1 (connected). Non-binary network, recently introduced by Yook, Jeong and Barabási (YJB), takes a continuous weight between 0 and 1[6]. We regard companies as nodes (vertices) of the network, their interactions between stock price changes as links (edges) and correlation coefficients as weights.

The minimum spanning tree (MST) is widely used to identify clusters of companies and stocks[7,8], after Mantegna first constructed the network based on the correlations[9]. There have been several attempts to obtain clustering of the stock market[10,11,12]. We choose the MST because simply observe the topology of the stork market network by the MST.

While there has been an abundance of literature concerning mature markets - especially, the US market - relatively little work has been published in connection with emerging markets such as those of Korea, BRICs and Eastern Europe. Mature markets have a long history, abundant liquidity and financial data, and also are characterized by market stability. These factors simplify research on the mature market relative to that of emerging markets. The model of the mature market cannot be applied to an emerging market[13] and thus it seems likely that it will be necessary to determine the model that is appropriate to each market.

We aim to explore the topological characteristics of the Korean market, a representative emerging market. Kim et al. introduced a non-binary network system showing scale-free behavior in the S&P500[14]. And we study the taxonomy and network topology of the Korean market. The S&P500 forms clusters with the business sectors and the portfolio optimization with these clusters is successful[8].
2 Financial Properties of the Korean Stock Market

The Korean stock market is much smaller than the US stock market. There are two stock markets in Korea - the Korea Stock Exchange (KSE) and the KOSDAQ. About 700 companies are listed on the KSE and the total market capitalization is approximately $400 billion. In the case of the KOSDAQ, there are 900 listed companies with $30 billion in market capitalization. In the NYSE and NASDAQ, there are thousands of listed companies and the total market capitalization is approximately $11 trillion. From above, we can calculate a company’s average market capitalization of Korea and the US very roughly. The US companies’ average market capitalization is ten times greater than that of Korea, which is about $2 million.

The most important Korean stock index is the KOSPI200 with 200 companies chosen by the KSE. Whereas the S&P500 contains companies listed on the NYSE and NASDAQ, the KOSPI200 has only 200 KSE companies, and no KOSDAQ companies. There are two well-known methods to obtain a stock price index; one is a price-equally-weighted index and the other a value-weighted index. The DJIA index is calculated by the former while the S&P index is by the latter. In the former, every company has the same influencing power on the index despite differences in market capitalization. In contrast, value-weighted indexes are suitable to measure the influencing power of companies. The KOSPI200 is a value-weighted index and is appropriate the purposes of this study.

Table 1 shows the market capitalization of some largest companies listed on the S&P500 and KOSPI200. This quantity refers to the economic scale of a given company and the fraction of total market capitalization in a stock market such as a commodity market. (·) denotes their symbols. The total portions of top 10 S&P500 companies are 22.82%, that of KOSPI200 are 49.13%. In the KOSPI200, SEC, only one company, occupies 21.94%, but GE is only 3.39%. It means that KOSPI200 index is more sensitive to the influence of a few top companies.

Table 2 shows the KSE’s shareholdings by investor group. We can notice few foreign investors having large companies’ stocks. Thus, the foreigner’s trading pattern is important to the Korean stock market. A large part of liquidity is supplied by the foreigner. Thus, in spite of Korean prosperity, a recession in the US can cause a slump in the Korean stock market.
3 Methodology

We create a network of KOSPI 200 companies; every node (company) has a different number of links (connections) and weights (correlations). In general, we consider a large firm from the viewpoint of size, market capitalization and share stock price to be dominant on the stock market. Hence, such a company forms a hub in the network system. We call this company powerful.

We use the cross-correlations in stock price changes between KOSPI200 companies from Jan. 2001 to Jun. 2004. Let $Y_i(t)$ be the stock price of company $i$. Then, the log-return of the stock price is defined as

$$S_i(t) = \ln Y_i(t + \Delta t) - \ln Y_i(t),$$

(1)

where $\Delta t$ means time interval. In this paper $\Delta t$ is one day. The cross-correlations between stock i and j can be written as

$$\rho_{ij} = \frac{< S_i S_j > - < S_i > < S_j >}{\sqrt{( < S_i^2 > - < S_i >^2)( < S_j^2 > - < S_j >^2)}}$$

(2)

where $< \ldots >$ means a time average over the period. These correlation coefficients form a correlation matrix $C$. This matrix is a symmetric $N \times N$ matrix. Then $\rho_{ij}$ varies between -1 and 1. If stock i and j are completely correlated (anti-correlated), $\rho_{ij} = +1(-1)$. The case of $\rho_{ij} = 0$ means they are uncorrelated.

Companies correspond to nodes, which are fully connected to one another through $N(N-1)/2$ links. Each link is assigned a weight $w_{ij}(= w_{ji})$, simply defined from the cross-correlation coefficient; $w_{ij} = \rho_{ij}$.

The influence strength (IS) is a physical quantity to measure how strongly a node influences other nodes. This quantity is defined as the sum of the weights on the links incident upon a given node $i$,

$$q_i = \sum_{j \neq i} w_{ij},$$

(3)

where $j$ denotes the links connected to the node $i$. Since the weight is distributed in the range [-1,1], the IS can be negative. Merely, we hope to determine how strongly a given company affects other companies, whether positively or negatively. Thus, we deal with the absolute magnitude of the IS; $|q_i|$.
4 Characteristics of the Korean Stock Market

In Fig. 1, we plot the IS distribution $P_K(|q|)$ of KOSPI200. Kim et al. found the IS distribution of S&P500 follows a power law distribution, $P_{SP}(|q|) \sim |q|^{-\eta}[14]$. The exponent $\eta$ is estimated to be $\eta_{SP} \sim 1.8$. It is known that as the degree exponent is smaller in SF networks, the connectivity of a node with a large degree becomes higher, and hence the network tends to be more centralized to a few nodes. In other words, a powerful company is more powerful. The IS component of the S&P500 is smaller than the degree exponent values for SF networks in the real world such as the Internet and the World-Wide Web[1,2]. However, we can’t find power-law distribution in Fig. 1.

By Table 1, the largest company from the viewpoint of a market capitalization in the S&P500 is General Electric (GE); its fraction of the total is 3.39%. In the case of the KOSPI200, Samsung Electronics Corporations (SEC) occupies this position; its fraction is 21.94%. As such, we consider the KOSPI200’s hub to be more powerful, and the network is more centralized to this company compared to the S&P500. However, Fig. 1 shows this assumption is not valid.

We obtain the asset tree through the minimum spanning tree (MST) to find the difference between the S&P500 and KOSPI200. GE can be considered the hub of the S&P500’s MST[9,8]. However, we cannot find any hub in the KOSPI200. In general, investors of the Korean stock market consider SEC as the center of the market and the KOSPI Index increases with an increase in SEC value. However, the SEC is located far away from the center (Fig. 2). This means the fraction of SEC’s market capitalization is large, and as such the KOSPI Index moves with SEC while most companies’ stocks do not follow this trend. Neither SEC nor the others in Table 1 is the center of KOSPI’s MST. GE influences its neighbors. Hence, they move with its movement, and the index follows the trend of GE. Even though SEC has a weak influence on its neighbors, its market capitalization’s power is very strong (Table 1), and as a result the index follows it. The weak influence of SEC means weak weights of links and no preferential attachment. Hence, we cannot find WSF behaviors in the Korean market in comparison with the American market.

The American stock market is a mature market. There are numerous powerful companies such as GE, Microsoft and Citigroup. These companies have similar market capitalization and influence power on the market. In the Korean stock market, an emerging market, there is a great gap between the SEC and the others - even though, 9 companies of Table 1 - with a viewpoint of the market capitalization.

We hope to make groups of stocks in the market. If we can make reasonable groups of stocks, they can then be applied to the portfolio optimization
method. Before making these groups, we introduce some terminology. The term *branch* is defined as a subset of a tree, to all nodes that share a specified common parent and *cluster* as a subset of a branch. There are two kinds of clusters. One is a *complete* cluster and the other is *incomplete*. A complete cluster contains all the companies of the studied set belonging to the corresponding branch, so that none are left outside the cluster. Onnela *et al.* found that clusters of S&P500 with business sector or industry categories are mostly incomplete, but come very close to being complete clusters, only missing one or two companies of the cluster[8]. We consider this situation as a complete cluster from the viewpoint of practical portfolio optimization. As a result, portfolio optimization with this concept is successful. However, we cannot make clusters of KOSPI200 with business sectors or industry categories. In addition, they made the portfolio using the central node (GE), but the KOSPI200 has no single central hub, and thus this method cannot be applied to the Korean situation.

We attempted to make groups of KOSPI200 with other rules except business sectors or industry category. Most Korean major companies are members of conglomerate forms of enterprise. For example, Samsung Electronics Co. is a member of Samsung Conglomerate; in Korea this is known as the Samsung Group. This conglomerate is comprised of many companies, i.e., Samsung Electronics Co., Samsung Life Insurance, Samsung Heavy Industries Co., Samsung Petrochemical Co., Samsung Corporation, and so on. They have deep relationships and co-operation of finance, services, development, and so on. As such, their stocks can be considered a group. However, we cannot find any group with Korean major conglomerates - Samsung, LG, SK, Hyundai, and so on.

We consider patterns of Korean domestic investor dealings in stocks. Foreign investment patterns are important signals and information for the Korean stock market. Domestic investors think foreigners deal with standards and developed trading rules. Thus, they refer to foreign investor trading. We apply the MSCI index to make groups of Korean stocks. Morgan Stanley Capital International Inc. (MSCI) is one of the leading providers of equity indices and offers the most widely used international equity benchmarks by international investors. MSCI Equity Indices are designed to fulfill the investment needs of a wide variety of global institutional market participants. These include many categories of indices, i.e. Sector, Industry Group and Industry Indices, Global, Regional and Country Equity indices, and so on. We focus on the MSCI Korean Index - one of the MSCI Country Equity Indices. Fig. 3 shows that we can make groups with MSCI Index. While all of them are incomplete clusters, they can be considered complete clusters from the viewpoint of practical portfolio optimization. This is the most acceptable grouping method for the Korean market.
5 Conclusions

We have studied the characteristics of the Korean stock market and obtained some characteristics that differ from the US market. The pertinent question is why does the Korean stock market have different properties? One possible reason is the composition of firms. The history of mature markets is longer than that of emerging markets. Thus, the mature markets have many companies including several large firms. In the case of the Korean market, there are only a few large firms, e.g. SEC; these corporations are very large in comparison to others. As such, these large firms are separated from the other companies of the market. This accounts for why there is no hub in the Korean stock market. We don’t know yet whether this is the characteristics of emerging markets or only Korean characteristics.

The other is the trading culture and globalization. Foreigner trading patterns are much important in the Korean market. Globalization has progressed very rapidly and the influencing power of a few developed countries has become stronger and stronger. At present, many stock markets’ synchronization to the US market is observed. In other words, the whole markets in the world are synchronized. Thus, we can find clusters in terms of the MSCI index. If a specified company’s stock is included in the MSCI index, it is more synchronized to the foreign market and regarded as a good company’s stock to the Korean market.

All markets throughout the world have characteristics of their own. We need to study each market with its own properties and make groups of markets.

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References


Fig. 1. Plot of the KOSPI 200's influence strength (IS) distribution versus the absolute magnitude of the influence strength. The slope of the guide line is 6.5.

Fig. 2. Positive correlations between market capitalization and $|q|$ are appeared in the S&P500. But the KOSPI200 has no correlations.
Fig. 3. A Minimum Spanning Tree of the KOSPI 200. The upper left side is the cluster of white spots (○). White spots mean the stocks included in MSCI index, black spots (●) mean the stocks which are not included. The lower left and right side are the clusters of black spots. All of these 3 clusters are not perfect complete, but practical complete. The upper right is the shuffled.
Table 1
50 top listed companies by market capitalization in S&P500 (except MER and MWD) and KOSPI200. (Jun. 2004)

<table>
<thead>
<tr>
<th>Rank</th>
<th>S&amp;P 500</th>
<th>KOSPI 200</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Company (Symbol)</td>
<td>%</td>
</tr>
<tr>
<td>1</td>
<td>General Electric (GE)</td>
<td>3.39</td>
</tr>
<tr>
<td>2</td>
<td>Exxon Mobil (XOM)</td>
<td>2.96</td>
</tr>
<tr>
<td>3</td>
<td>Microsoft (MSFT)</td>
<td>2.91</td>
</tr>
<tr>
<td>4</td>
<td>Pfizer INC. (PFE)</td>
<td>2.39</td>
</tr>
<tr>
<td>5</td>
<td>CitiGroup (C)</td>
<td>2.36</td>
</tr>
<tr>
<td>6</td>
<td>Wal-Mart (WMT)</td>
<td>2.19</td>
</tr>
<tr>
<td>7</td>
<td>Amer.Intl.Group (AIG)</td>
<td>1.82</td>
</tr>
<tr>
<td>8</td>
<td>Bank of America (BAC)</td>
<td>1.73</td>
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<tr>
<td>9</td>
<td>Johnson&amp;Johnson (JNJ)</td>
<td>1.66</td>
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<tr>
<td>10</td>
<td>P&amp;G (PG)</td>
<td>1.41</td>
</tr>
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Table 2
Shareholding by investor group (2003)

<table>
<thead>
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<th></th>
<th>Individual</th>
<th>Foreigners</th>
<th>Institution and Others</th>
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</thead>
<tbody>
<tr>
<td># of shareholder(A)</td>
<td>99.33%</td>
<td>0.39%</td>
<td>0.22%</td>
</tr>
<tr>
<td># of shares(B)</td>
<td>48.50%</td>
<td>13.99%</td>
<td>37.51%</td>
</tr>
<tr>
<td>Market capitalization(C)</td>
<td>23.44%</td>
<td>37.67%</td>
<td>38.89%</td>
</tr>
<tr>
<td>B/A</td>
<td>0.488</td>
<td>35.8</td>
<td>170.5</td>
</tr>
<tr>
<td>C/A</td>
<td>0.236</td>
<td>96.6</td>
<td>176.8</td>
</tr>
<tr>
<td>C/B</td>
<td>0.483</td>
<td>2.70</td>
<td>1.04</td>
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