Grouping in the stock markets of Japan and Korea

Woo-Sung Jung\textsuperscript{a,*} Okyu Kwon\textsuperscript{a} Taisei Kaizoji\textsuperscript{b} Seungbyung Chae\textsuperscript{a} Hie-Tae Moon\textsuperscript{a}

\textsuperscript{a}Department of Physics, Korea Advanced Institute of Science and Technology, Daejeon 305-701, Republic of Korea
\textsuperscript{b}Division of Social Sciences, International Christian University, Tokyo 181-8585, Japan

Abstract

We investigated the temporally evolving network structures of the Japanese and Korean stock markets through the minimum spanning trees composed of listed stocks. We tested the validity of conventional grouping by industrial categories, and found a common trend of decrease for Japan and Korea. This phenomenon supports the increasing external effects on the markets due to the globalization of both countries. At last the Korean market are grouped with the MSCI Korea Index, a good reference for foreigners' trading, in the early 2000s [12]. In the Japanese market, this tendency is strengthened more and more by burst of the bubble in 1990's.

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

PACS: 89.65.Gh, 89.75.-k, 89.75.Hc

1 Introduction

The study of financial market has received attention from physicists [1,2]. Nowadays, the network theory is used to investigate complex systems with many interacting agents, and also many physicists have analyzed the financial market through the network theory. The financial market, where all listed companies are correlated with each other, is a typical complex systems.

\textsuperscript{*} Corresponding author. Fax: +82-42-869-2510.
\textit{Email address: wsjung@kaist.ac.kr} (Woo-Sung Jung).
The minimum spanning tree (MST) is useful to construct the asset tree, and it provides the study to find the market’s characteristics simply \([3,4,5,6,7,8]\). In the MST of \(N\) nodes, each node represents a company, and \(N - 1\) links with the most important correlations are selected. The MST is a loop-less network, and all of nodes have at least one link. This tree is obtained from a fully connected network of the correlation matrix. Also, the grouping of companies can be identified and extended to portfolio optimization. The companies of the US market are clearly grouped with the industry category or business sector [9].

Several papers that the characteristics of the mature market cannot be simply extended to emerging markets for every case in the recent days [10,11]. The Korean market is an emerging market and shows many particular properties including the grouping method [12,13,14,15]. Also, the Japanese market is an attractive market for econophysicists to study [16,17,18], and there are high correlations between two East Asian markets, the Japanese and the Korean market.

Korea and Japan have developed close interdependence of their economic systems for a long time, which leads to many common features of their economic systems including financial markets. Two countries experienced very high rate of economic growth, so Japan is ranked as the world’s second largest economy, and the economy of Korea as the tenth now. Their economies were commonly driven by the government-directed investment model and the protective trade policy at first. The success stories of two countries made East Asian economic model popular, and attracted much attention until 1990s. However, the long-term depression happened in Japan in early 1990s [17], and the severe recession happened in Korea due to the Asian Financial Crisis in late 1990s changed the economic environment very much [19]. The integration into the global economy has much developed in two countries in the recent days. Such violent changes make the studies of the East Asian financial markets very interesting, and we investigate characteristics of the Japanese and Korean stock market with the history of the markets.

2 Data analysis

We investigated grouping in the Japanese and Korean stock markets. There are several stock exchange markets in Japan and Korea, and we selected the Tokyo Stock Exchange (TSE) and the Korea Stock Exchange (KSE), the largest markets in Japan and Korea, respectively. In 2004, 2306 companies were listed on the TSE, which in its present form was founded in 1949. The KSE opened in 1956, and 695 companies are listed in 2005. We used the daily closure stock price from 1980 to 2001, in other words, the time interval (\(\Delta t\)) used was 1
day. A total of 228 companies in the Korean market and 624 companies in
the Japanese market were selected for our analysis. All of these companies
remained in the markets over this period 21 years. Fig. 1 shows the index for
the companies selected. The representative TSE and KSE indexes, NIKKEI
and KOSPI, are indexes of the value-weighted average of stock prices. However,
the indexes in Fig. 1 are price-equally-weighted indexes, such as that used for
the Dow Jones Industrial Average (DJIA).

The cross-correlation coefficient between stock \(i\) and \(j\) is defined as:

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

(1)

where \(S_i\) is the logarithmic return of a given stock \(i\). The correlation coefficient
\(\rho_{ij}\) has values from \(-1\) to 1. The logarithmic return is written as \(S_i(t) = \ln Y_i(t + \Delta t) - \ln Y_i(t)\), where \(Y_i(t)\) is the price of a given company \(i\).

We construct the minimum spanning trees (MSTs) with time windows of width
\(T\) corresponding to daily data for 3 years, with \(\delta t\) of approximately 1 month.
The MST is a simple graph with the most important connection selected
[3]. The MST of \(N\) nodes has \(N - 1\) links, and every node has at least one
link. Each node of the network corresponds to a company, and each link has a
weight \(w_{ij}(= w_{ji})\), which is simply the value of the cross-correlation coefficient,
\(w_{ij} = \rho_{ij}\).

Tables 1 and 2 show 17 and 33 categories of the Korean and Japanese markets,
respectively. There are actually more categories in the market, but we selected
only categories that contain the companies used for our data analysis. Fig. 2
shows global grouping coefficient \(G\) for the Korean and Japanese markets as
a function of time. This coefficient, \(G\), was defined with all of the nodes, and
the ratio of connections between companies in the same category to the total
number of links. Before the mid-1980s, the Korean market was unstable with
poor liquidity, and this is one possible explanation for the lower value in the
early 1980s in Fig. 2a. As the market prospered, groups of industry categories
also extensively formed. We found that the MST of the late-1980s can be
correlated to groups of industry categories [20]. However, globalization of the
Korean market has progressed, which was hastened by the 1988 Seoul Olympic
Games and the 1997 Asian financial crisis [19]. In particular, globalization of
the Korean market progressed to synchronization with external markets. In
the early 2000s, the companies of the Korean market were grouped as the
MSCI Korea Index [12]. In the Korean market, the influence of foreign traders
is strong, and the MSCI Korea index is a good reference for their trading. This
explains the decreasing coefficient in Fig. 2a after the mid-1980s.

We also observed the similar trend in the Japanese market (Fig. 2b). Before
the mid-1980s, the coefficient $G$ of the Japanese market showed no special movement. However, the coefficient tends to decrease after the mid-1980s. The influence of foreign markets is increasingly strong in the Asian market, including the Japanese and Korean markets. In the Japanese market this tendency was strengthened more and more by burst of the bubble in 1990’s. It is natural to form groups of industry categories, because companies included in the same category are highly related to each other in comparison to companies in other categories. However, the recent globalization of Asian markets has progressed to synchronization with foreign markets, especially the US market, and then the groups of industry categories are breaking down.

For example, the largest company in the Korean market is Samsung Electronic Co. (SEC), which is included in the Electrical & electronic equipment category. The Korean IT industry is well developed and there are many companies in the Electrical & electronic equipment category. SEC is well known throughout the world, and many foreigners trade in SEC stock. However, other companies in the same category are not as well known, and their stock price is easily influenced by the economic situation in Korea. On the other hand, SEC is synchronized to foreign markets or factors, and is thus separated from the category. This leads to a decrease in the grouping coefficient.

We define the quantity grouping coefficient to investigate the dynamics of the grouping method in the market. The coefficient of a given industry category $C$ is defined as:

$$g_C = \frac{\sum_{i \in C} n^C(i)}{\sum_{i \in C} n(i)}$$

where $i \in C$ are the nodes in category $C$, $n(i)$ is the number of links connected to node $i$ and $n^C$ is the number of links from the node included in category $C$.

Fig. 3a shows the grouping coefficient for each category of the Korean market over the whole period. We can observe that categories 12, 15, 16 and 17 form a well-defined group. Category 12 is the Construction industry, and reflects domestic demand. We think that categories 15 (Banks), 16 (Insurance), and 17 (Securities) can be regarded as one category, the Financial industry. Fig. 3b shows the grouping coefficients for the Japanese market. Categories 27, 30, 31 and 32 are well-defined categories. In addition, categories 30 (Banks), 31 (Securities & commodity futures) and 32 (Insurance) are regarded as a financial industry category. In Japan, there are several electric distribution companies, and they have a monopoly for a given area, e.g. Tokyo Electrical Co. and Osaka Electrical Co. Category 27, Electric power & gas, consists of such companies, which are highly related to each other. The category represents an domestic industry that is not strongly influenced by foreign factors. Another domestic industry is category 20, (Construction), which also forms a rather well-defined group. Domestic industry is relatively independent of
foreign factors, and companies included in the financial category are highly correlated to each other, regardless of foreign factors. This explains why the coefficients for these categories are higher over the whole period.

We now focus on the maximum grouping coefficient for each industry category. We take the maximum value when the nodes are linked linearly. The maximum value of the coefficient for Korean category 17 (Securities, include only four companies, is only 0.6 (=3/5) because of the properties of the MST. Fig. 3c,d shows the ratio of the grouping coefficient to the maximum value for each category. Fig. 3 confirms that the categories mentioned are well-defined groups. There are some errors in the plots. For example, there are only three companies in Japanese category 1, and its value increases when we consider the maximum value. However, it is not meaningful because of the small sample size.

3 Conclusion

We investigated the Japanese and Korean stock market networks using the daily closure stock price. Our analysis shows that the grouping coefficients of the two markets decreased with elapsing time and the number of groups according to industry categories decreased. During the same period, the coefficient of the US market did not decrease (Fig. 4). Currently, most world markets, especially the Japanese and Korean markets, synchronize to the US market, and they are sensitive to foreign factors. The grouping coefficient represents a good parameter for measuring this phenomenon. Our future work will involve analysis of other markets, which should confirm the usefulness of the grouping coefficient. Also, we confirmed that the MST is a good analysis tool for investigating the stock market.

Acknowledgements

We wish to thank J.-S. Yang for active discussion. We also thank W. Lee, G. Oh, W.C. Jun, and S. Kim for useful support.

References

[1] R. N. Mantegna, H. E. Stanley, *An Introduction to Econophysics: Correlations and Complexity in Finance* (Cambridge University Press, Cambridge, 1999).
[2] W. B. Arthur, S. N. Durlauf, D. A. Lane, *The Economy as an Evolving Complex System II* (Perserus Book, Massachusetts, 1997).

[3] R. N. Mantegna, Eur. Phys. J. B 11 (1999) 193.

[4] S. Micciché, G. Bonanno, F. Lillo, R. N. Mantegna, Physica A 66 (2003) 66.

[5] J.-P. Onnela, K. Kaski, J. Kertész, Eur. Phys. J. B 38 (2004) 353.

[6] C. Coronnello, M. Tumminello, F. Lillo, S. Micciche, R. N. Mantegna, Acta Physica Polonica B 36 (2005) 2653.

[7] G. Bonanno, G. Caldarelli, F. Lillo, R.N. Mantegna, Phys. Rev. E 68 (2003) 046130.

[8] T. Mizuno, H. Takayasu, M. Takayasu, Physica A (in press), doi:10.1016/j.physa.2005.08.079.

[9] J.-P. Onnela, A. Chakraborti, K. Kaski, J. Kertész, A. Kanto, Phys. Rev. E 68 (2003) 056110.

[10] K. Matia, M. Pal, H. Salunkay H. E. Stanley, Europhys. Lett. 66 (2004) 909.

[11] C. Yan, J. W. Zhang, Y. Zhang, Y. N. Tang, Physica A 353 (2005) 425.

[12] W.-S. Jung, S. Chae, J.-S. Yang, H.-T. Moon, Physica A 361 (2006) 263.

[13] S.-M. Yoon, J. S. Choi, K. Kim, Y. Kim, J. Korean Phys. Soc. 46 (2005) 719.

[14] S.-M. Yoon, K. Kim, J. S. Choi, J. Korean Phys. Soc. 46 (2005) 1071

[15] J. S. Choi, K. Kim, S. M. Yoon, K. H. Chang, C. C. Lee, J. Korean Phys. Soc. 47 (2005) 171.

[16] T. Kaizoji, Physica A 287 (2000) 493.

[17] T. Kaizoji, M. Nuki, Fractals 12 (2004) 49.

[18] T. Kaizoji, Physica A 343 (2004) 662.

[19] F. Climent, V. Meneu, Int. Rev. Econ. Financ. 12 (2003) 111.

[20] W.-S. Jung, O. Kwon, J.-S. Yang, H.-T. Moon, to be published in J. Korean Phys. Soc. (2006).
Fig. 1. Index of selected companies of (a) the Korean stock market and (b) the Japanese market from 1980 to 2001.
Fig. 2. Plot of the grouping coefficient for all categories as a function of time from 1980 to 2001.
Fig. 3. Plot of grouping coefficients: (a,b) $g$ values; (c,d) ratio of the coefficient to the maximum value of $g$ for the Korean and Japanese markets, respectively.
Fig. 4. Plot of the grouping coefficient for the US, Japanese and Korean markets.
| #  | Industry category                        |
|----|-----------------------------------------|
| 1  | Food & beverages                        |
| 2  | Textiles                                |
| 3  | Apparel                                 |
| 4  | Paper & wood                            |
| 5  | Chemicals & medical supplies            |
| 6  | Rubber                                  |
| 7  | Non-metallic minerals                   |
| 8  | Iron & metals                           |
| 9  | Manufacturing & machinery               |
| 10 | Electrical & electronic equipment       |
| 11 | Transport equipment                     |
| 12 | Construction                            |
| 13 | Distribution                            |
| 14 | Transport & storage                     |
| 15 | Banks                                   |
| 16 | Insurance                               |
| 17 | Securities                              |
Table 2
Industry categories of the Tokyo Stock Exchange in our data set

| #  | Industry category                          | #  | Industry category                          |
|----|-------------------------------------------|----|-------------------------------------------|
| 1  | Fishery, agriculture & forestry           | 18 | Information & communication               |
| 2  | Mining                                    | 19 | Other products                            |
| 3  | Foods                                     | 20 | Construction                              |
| 4  | Textiles & apparel                        | 21 | Land transportation                       |
| 5  | Glass & ceramics products                 | 22 | Marine transportation                      |
| 6  | Pulp & paper                              | 23 | Air transportation                        |
| 7  | Chemicals                                 | 24 | Warehousing & harbor transportation services |
| 8  | Pharmaceuticals                           | 25 | Wholesale trade                           |
| 9  | Oil & coal products                       | 26 | Retail trade                              |
| 10 | Rubber products                           | 27 | Electric power & gas                      |
| 11 | Precision instruments                     | 28 | Real estate                               |
| 12 | Iron & steel                              | 29 | Services                                  |
| 13 | Machinery                                 | 30 | Banks                                     |
| 14 | Metal products                            | 31 | Securities & commodity futures            |
| 15 | Non-ferrous metals                        | 32 | Insurance                                 |
| 16 | Transportation equipment                  | 33 | Other Financing business                  |
| 17 | Electrical appliances                     |    |                                           |