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Group dynamics of the Japanese market

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Abstract

We investigated the network structures of the Japanese stock market using the minimum spanning tree. We defined a *grouping coefficient* to test the validity of the conventional grouping by industrial categories, and found a decreasing in trend for the coefficient. This phenomenon supports the increasing external influences on the market due to globalization. To reduce this influence, we used S&P500 index as the international market and removed its correlation with every stock. We found stronger a grouping in this measurement when compared to the original analysis, which agrees with our assumption that the international market influences to the Japanese market.

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Keywords: Correlation-based clustering; Emerging market; Minimum spanning tree; Econophysics

1. Introduction

The network theory is generally used to investigate complex systems with many interacting agents. The financial market, where all listed companies are correlated with each other, has received attention as a typical complex system [1,2]. A popular method is the minimum spanning tree (MST), which constructs the asset tree using correlations between stock prices [3–10]. It gives us the characteristic features of the market in the simple way. In a 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 every node has at least one link. Also, the grouping of companies in the MST can be identified and extended to portfolio optimisation, and the companies of the US market are clearly grouped with the industry category or business sector [11].

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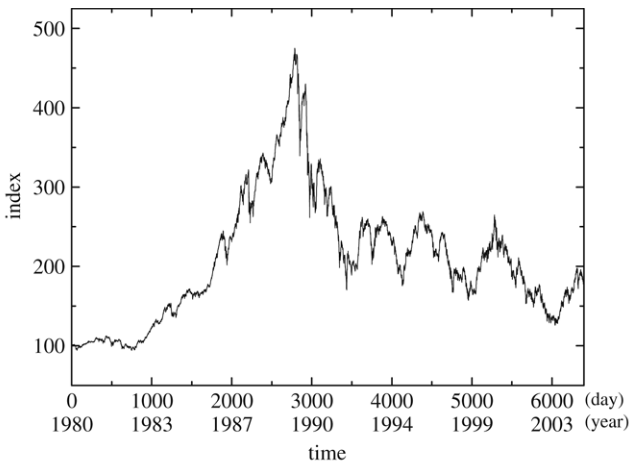

Fig. 1. The custom-made index for 624 Japanese companies listed on the Tokyo Stock Exchange from 1980 to 2004.

Several papers show that the characteristics of a mature market cannot be simply extended to an emerging market [12,13], and that they change dynamically due to the globalization [14]. Especially, the Korean market is synchronized to external markets due to globalization, and the tendency of grouping by industry categories has disappeared [15]. In addition, the Korean market forms clusters according to the MSCI index since 2000, and the tendency to synchronization with the US market is stronger and stronger [16].

The Japanese market attracts many econophysicists due to its unique character [17–19]. It is not an emerging one, but it has a strong connection with the Asian emerging markets. For instance, the Korean market has many common features with the Japanese market. Korea and Japan have developed a close interdependence of their economic systems for a long time. The two countries have experienced very high rates of economic growth. Their economies were commonly driven by the government-directed investment model and protective trade policies at first. In addition, integration into the global economy has much developed in the recent days, especially in Asia. Such violent changes make studies of the Asian financial markets very interesting.

We investigated characteristics of the Japanese stock market using the history of the market. First, we compared our analysis of the Japanese market with that of the Korean market and found common features of these two markets, such as their decreasing of grouping by industry categories. Second, we used S&P500 index as the international market to reduce external influences due to globalization. This study showed that the international market obviously influences the Japanese market.

2. Characteristics of the Japanese market

There are several stock exchange markets in Japan, and we selected the Tokyo Stock Exchange (TSE), the largest Japanese market. We used the daily closing stock price from 1980 to 2004, and a total of 624 companies that were listed for the full 25 year-period were selected for our analysis. To demonstrate the trend of the Japanese market, we plot the index which averages over these 624 companies in Fig. 1.

The logarithmic return is defined as $S_i(t) \equiv \ln J_i(t + \Delta t) - \ln J_i(t)$, where $J_i(t)$ is the closing price of a given Japanese company i. And, the cross-correlation coefficient between stock i and j is defined as:

$$\rho_{ij} \equiv \frac{(\langle S_i S_j \rangle - \langle S_i \rangle \langle S_j \rangle)}{\sqrt{(\langle S_i^2 \rangle - \langle S_i \rangle^2)(\langle S_j^2 \rangle - \langle S_j \rangle^2)}}. \tag{1}$$

To explore the evolution of the market, we construct MSTs with time windows of width T corresponding to daily data for 3 *years*, sliding the window with 20 trading days, approximately 1 month. Each node of the MST corresponds to a company, and each link has a weight $\rho_{ij}(= \rho_{ji})$, which is simply the value of the cross-correlation coefficient.

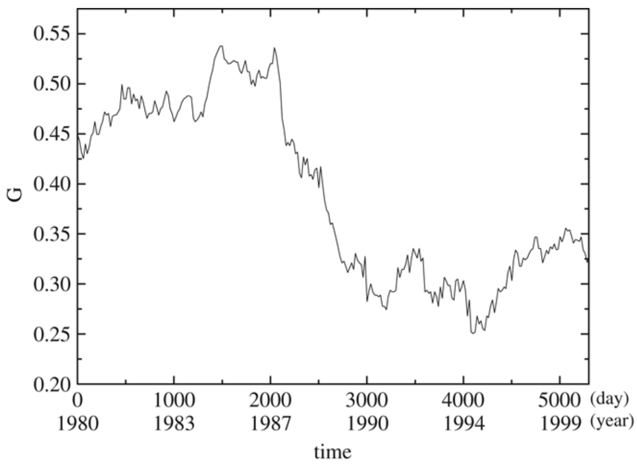

Fig. 2. Plot of the grouping coefficient for all categories as a function of the starting time of the moving window from 1980 to 2004.

To investigate the group dynamics of the financial market in more detail, we define a quantity, the *grouping coefficient*, to measure how well it groups with the industry categories,

$$G = \frac{n\left(\sum_{i\in C}\right)}{n\left(\sum_{i}\right)}, \tag{2}$$

where $n(\sum_i)$ represents the number of whole links in the network, and $n(\sum_{i\in C})$ is the number of links between companies in the same industry category.

In our previous study [15], we found that the grouping coefficient of the recent Korean market decreases with elapsing time. In other words, the recent Korean market does not group by industry categories, even though the recent US market's MST is grouped well by industry categories [11]. As expected, we observe a similar trend in the Japanese market (Fig. 2). Before the mid-1980s, the coefficient G of the Japanese market shows no special movement. However, the coefficient tends to decrease after the mid-1980s, and this tendency is strengthened more and more by the bursting of the bubble in the 1990s. It is natural for groups of industry categories to form, because companies included in the same category are highly related to each other in comparison to companies in other categories. However, these groups of industry categories are breaking down in recent times, and this is related to the globalization of Asian markets. We will explain further in the following section.

3. Correlation with the US market

The US stock market is a dominating one over the whole world, especially in relation to the Asian markets. Thus, we choose the US market as a representative of the international market in the section. Recently, the US market's influence on Japan is more powerful in comparison with the opposite direction [20–23]. We assume the $(n-1)$-th day's US market (represented by S&P500 index) and n-th day's Japanese market are highly correlated, and in total we have 4126 days from the 25-year data set. We use these days' closing data of each Japanese company and S&P500 index, and Fig. 3 shows the indexes and logarithmic returns for new data set of the Japanese and US markets, respectively.

We define the *modified logarithmic return* for a given Japanese company i at time t, $M_i(t)$, to minimize the influence of the US market,

$$M_i(t) \equiv S_i(t) - \alpha\beta_i(t)U(t-1), \tag{3}$$

where $S_i(t)$ represents a given Japanese company i's log return at time t and $U(t-1)$ is the S&P500 index's log return at time $(t-1)$. The $\beta_i(t)$ value represents the cross-correlation defined in Eq. (1) between the Japanese company i and S&P500 index within 3 years from time t, and α is the rescaling coefficient.

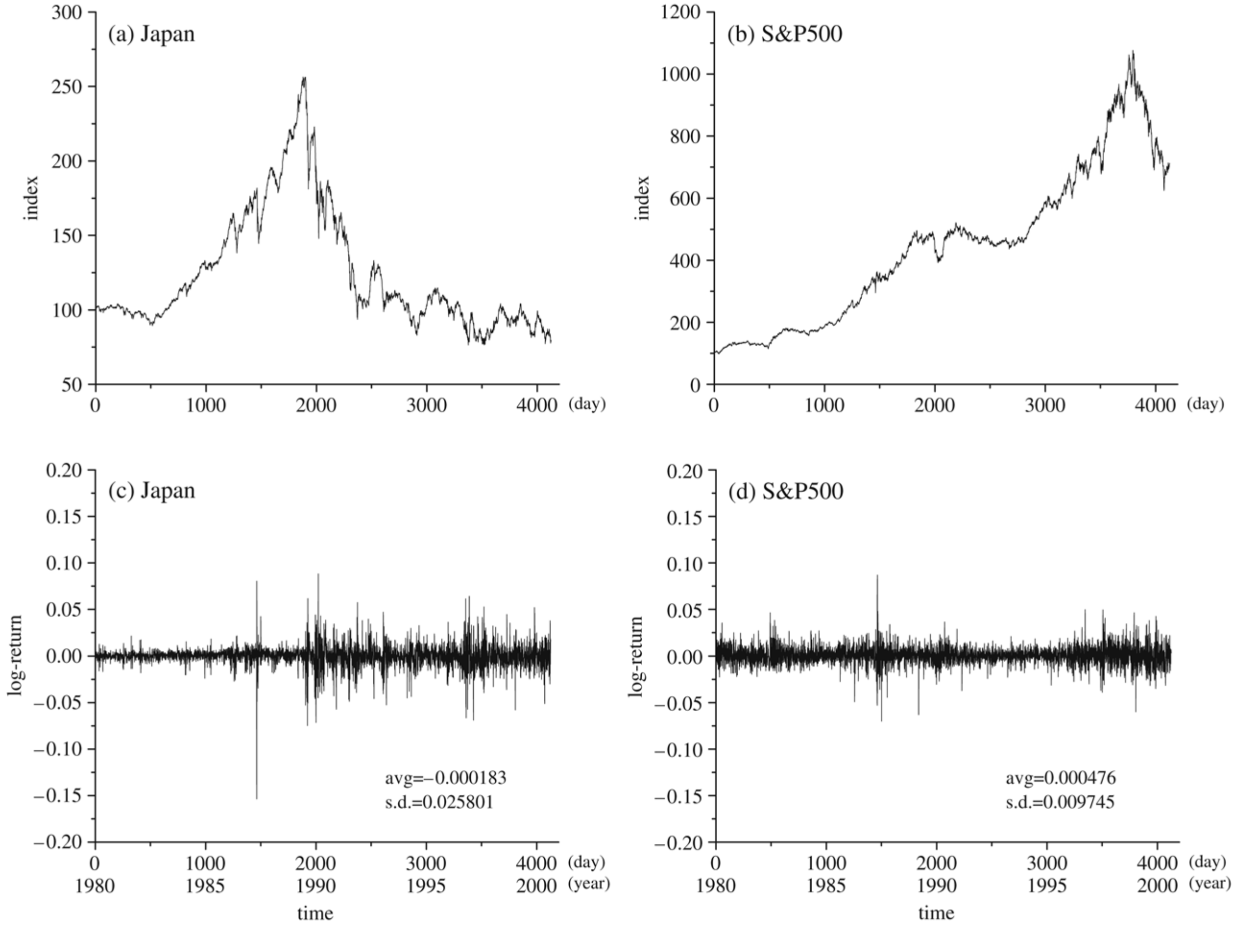

Fig. 3. The indexes and log returns of the Japanese and US markets for selected dates.

We calculate the cross-correlation between a Japanese company stock i's logarithm return or modified one at time t and the S&P index at time $t-1$, and then take the average of these cross-correlations at the same time. Fig. 4(a) shows these averages as a function of time (the dot line is for the original return while the solid line is for the modified one). If the US market's influence on the Japanese market is minimized, the correlation between the modified logarithm return of the Japanese market and the S&P500 index approaches zero. Thus, we search for the proper α value in Eq. (3), and find that a value of 2.25 makes these cross-correlations almost zero. The meaning of the alpha value remains an open question. Other financial markets that synchronize with foreign markets might have their own alpha values.

According to Fig. 4(a), the US market and the original Japanese market are rather anti-correlated from dy 750 to day 1500. It is from a big crash of the Japanese market. In Fig. 3(a), it is found a crash at this period in the Japanese market. However, the index of the US market does not decrease (Fig. 3(b)), and the width of time windows T in this paper is 3 $years$. Therefore, the cross-correlation between the two markets has a rather bigger negative value in this 3-year period which contains the Japanese market crash. That is why the sharp fall and jump appear in Fig. 4(a). It is interesting that the *alpha* value of 2.25 also makes the cross-correlations zero through this anti-correlated period.

Fig. 4(b) represents the *relative* grouping coefficients, $G(t)/G(t=0)$, calculated by $M_i(t)$ and $S_i(t)$, respectively. We use the relative values to compare two grouping coefficients' dynamical features together. Both of the grouping coefficients with $S(t)$ and $M(t)$ decrease after 1990. However, the tendency of the coefficient's decrease with $M(t)$ is smaller than that of $S(t)$. It means the decreasing of the grouping coefficient is related to globalization. Nowadays, the Japanese market is synchronized to the US market [21–23], and the groups (by industry categories) are broken down like the Korean market. In addition, the recent Korean market can be grouped in terms of the MSCI Korea Index [16]. The companies included in the MSCI Korea index are more synchronized with a foreign market, and these companies

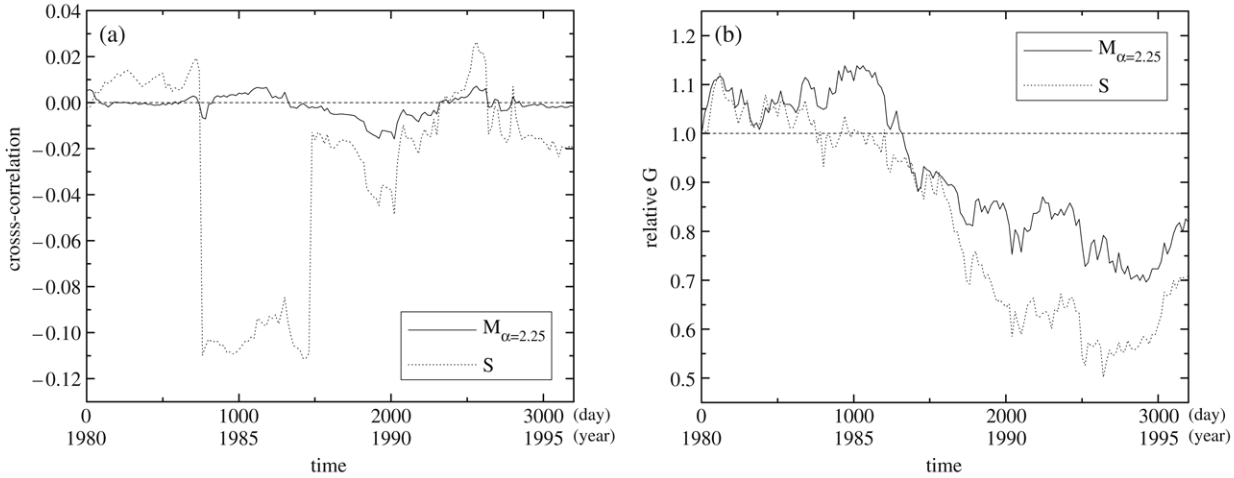

Fig. 4. (a) The cross-correlations between the Japanese companies' original logarithmic return, $S_i(t)$, or modified one, $M_i(t)$, and the S&P500 index, $U(t-1)$. The dashed line is a guideline of the value of 0.0. (b) Rescaled grouping coefficients as a function of time for the Japanese market. They are calculated by $M_i(t)$ and $S_i(t)$, respectively. The dash line is a guideline of the value of 1.0.

make a group. The other groups consist of companies not included in the MSCI index. Thus, the grouping coefficient of the Korean market is decreasing in recent [15].

4. Conclusions

We investigated the Japanese stock market networks using the daily closing stock price. We show that the grouping coefficients of the market have decreased with elapsing time and the number of groups according to industry categories has also decreased. It is similar to the analysis of the Korean market, which has many features in common with the Japanese one.

And, we defined the modified logarithmic return to minimize the external US market's influence. When it is minimized, the grouping coefficient is rather increased in comparison with the original coefficient. It means the decreasing of the coefficient is correlated with the external influences on the market. Currently, most world markets synchronize with the US market, and they are sensitive to foreign factors. The grouping coefficient could be a good measurement to quantify this phenomenon.

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