Asymmetric Information Flow between market index and individual stocks in various stock markets

Okyu Kwon[1] and Gabjin Oh[2]

[1] *Asia Pacific Center for Theoretical Physics, Pohang 790-784, Korea*
[2] *Department of Business, Chosun University, Gwangju 501-759, Korea*

Abstract. - We observed the asymmetric information flow between stock market index and composing stocks using transfer entropy. We found that the amount of information flow from index to stock is larger than from stock to index. It indicates that the market index plays a role of major driving force to individual stock. Interestingly, such asymmetry occurs with identical direction to every market from mature to emerging market. However, the strength of the asymmetry in mature market is higher than it in emerging market.

Introduction. – Financial and economic systems have been studed by many physicists as a good example of complex system by using various tools and methodologies of statistical physics [1, 2, 3, 4, 5, 6, 7, 8, 9]. The availability of a huge amout of financial and economic data which are recorded in computer have motivated such studies.

Most studies on stock market have focused on analysis of market index to find out its statistical properties and to infer market properties [1, 9] or focused on analysis of correlation between individual stocks to find out their interactions using network [6, 7, 8] or random matrix [4, 5] theory. In this study, we are focued on interaction between index and individual stocks. Recently, there are a few studies which investigate it using transfer entropy [10, 11] and various correlation method [12]. They verified that the stcok index can hold a special role in the market.

A stock market index is a method of measuring the general condition of a stock market. Many indices are cited by various information channels representing the performance of the stock market and refleting traders' sentiment on the state of the economic conditions. The most traders in the stock market consider various indeices as important and basic information to analyze and predict the perspective of market. Therefore, we can naturally guess that the fluctuation of price of individual stocks is affected by the fluctuation of stock market index. In this paper, we want to show that the stock market index plays the major role of driving force in stock market. We conjecture that the fluctuation of index provides more information to traders who invest individual stock. Consequently, individual stock can be derived by the index. Hence, there must be asymmetric information flow between them. To investigate the amount of information flow between them, we adpoted transfer entropy (TE) which is introduced by Schreiber [13].

Transfer Entropy. – The transfer entropy (TE) has been proposed to detect asymmetry in the interaction between two systems and to distinguish driving and responding elements. Let us consider two discrete and stationary processes X and Y. The transfer

Table 1: The world stock markets

Nation	Index	# of stocks
Australia	ASX	122
Canada	TSX	130
China	SSE	226
Italy	MIB	100
Korea	KOSPI	466
Thailand	SET	79
UK	FTSE	349
US	S&P500	407
US	NASDAQ	1096

entropy which relates k previous samples of process X and l previous samples of process Y is defined as follows:

$$TE_{Y\to X} = \sum p\left(x_{t+1}, x_t^{(k)}, y_t^{(l)}\right) \log \frac{p\left(x_{t+1} \mid x_t^{(k)}, y_t^{(l)}\right)}{p\left(x_{t+1} \mid x_t^{(k)}\right)}, \tag{1}$$

where x_t and y_t represent the discrete states at time t of X and Y, respectively. $x_t^{(k)}$ and $y_t^{(l)}$ denote k and l dimensional delay vectors of sequence of observations from systems X and Y, respectively. The joint PDF $p(x_{t+1}, x_t^{(k)}, y_t^{(l)})$ is the probability that the combination of $x_{t+1}, x_t^{(k)}$ and $y_t^{(l)}$ have particular values. The conditional PDF $p(x_{t+1} \mid x_t^{(k)}, y_t^{(l)})$ and $p(x_{t+1} \mid x_t^{(k)})$ is the probability that x_{t+1} has a particular value when the value of the previous samples $x_t^{(k)}$ and $y_t^{(l)}$ are known and $x_t^{(k)}$ are known, respectively.

The transfer entropy with index $Y \to X$ measures how much the dynamics of process Y influences the transition probabilities of another process X . The reverse dependency is calculated by exchanging x and y of the joint and conditional PDFs. The transfer entropy is explicitly asymmetric under the exchange of x_t and y_t. It can thus give the information about the direction of interaction between two time series.

The transfer entropy is quantified by information flow from Y to X. The transfer entropy can be calculated by subtracting the information obtained from the last observation of X only from the information about the latest observation X obtained from the last joint observation of X and Y. This is the main concept of the transfer entropy. Therefore, the transfer entropy can be rephrased as

$$TE_{Y\to X} = h_X(k) - h_{XY}(k,l), \tag{2}$$

where

$$h_X(k) = -\sum p(x_{t+1}, x_t^{(k)}) \log p(x_{t+1} \mid x_t^{(k)}) \tag{3}$$

$$h_{XY}(k,l) = -\sum p(x_{t+1}, x_t^{(k)}, y_t^{(l)}) \log p(x_{t+1} \mid x_t^{(k)}, y_t^{(l)}). \tag{4}$$

The datasets. – In this study, we used daily closing price data of 9 stock markets ranging from mature to emerging market. They are listed in Table 1. All data sets has same time period from Jan. 2000 to Dec. 2008. We considered only survived individual stocks for each index among its constituting stocks during the time period. The numbers of survived constituting stocks for each market are also listed in Table 1.

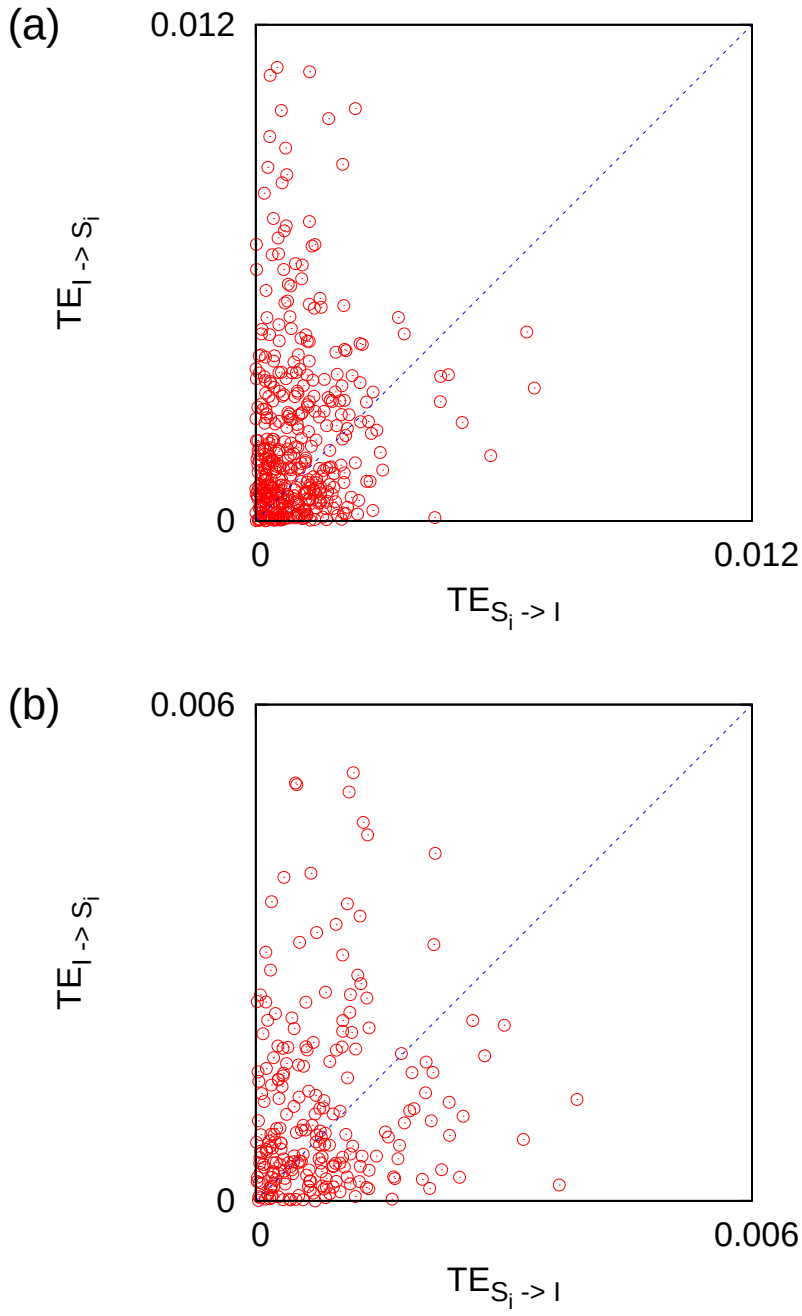

Fig. 1: The transfer entropy between each component stock and index for (a) US (S&P500) and (b) China market. The blue dotted line in each plot indicates $y = x$ line. The open circle above (below) this line indicates that there is stronger information flow from index (stock) to stock (index) than inverse direction.

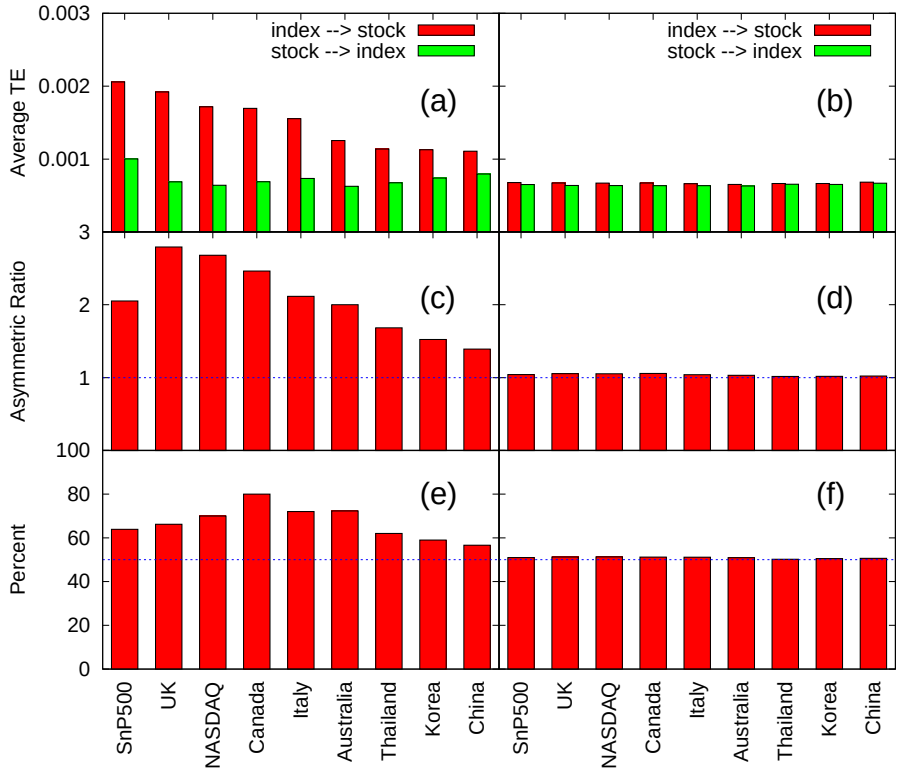

Fig. 2: Asymmetric infromation flow between stock market index and individual stocks for various stock markets. Plots of left panel are generated from empirical resutls. Plots of right panel are generated from randomly shuffled data corresponding with left plots. Each data of right panel are calculated by averaging over 1000 ensembles of shuffled data.

The discrete fluctuation of stock and index time sereis is needed to calculate TE. We constructed binary return time series in which 1 represents increment and 0 represents decrement or no change in price. Although the amount of increment or decrement provides more accurate information, we believe whether it goes up or down provides essential information to traders.

Asymmetric information flow. – We have measured TE from index I to each individual stock S_i ($TE_{I\to S_i}$) and TE from each individual stock S_i to index ($TE_{S_i\to I}$) for all composed stocks for each market. As shown in Fig. 1 (a), there are some stocks which have larger information flow from stock to index than the flow of inverse direction, but most stocks have larger information flow from index to stock for S&P500 of US stock market. In the Chinese stock market, tendency of information asymmetry is weaker than US market as shown in Fig. 1 (b). However, we can see slightly that larger stocks have larger infromation flow from index to stock as well.

To compare the entire information flow from market to market, we calculated average TE over all stocks which are composing index. The average information flow between index to stocks are defined by $TE_{I\to S} = \sum_i TE_{I\to S_i}$ and $TE_{S\to I} = \sum_i TE_{S_i\to I}$. The former (later) one represents average information flow from index (stock) to stock (index). These results are shown in Fig. 2 (a). We can obviously information asymmetry betwee index and stocks. Interestingly, most mature markets have larger asymmetry than emerging markets. To verify that these results can be obtained by chance, we compared corresponding results

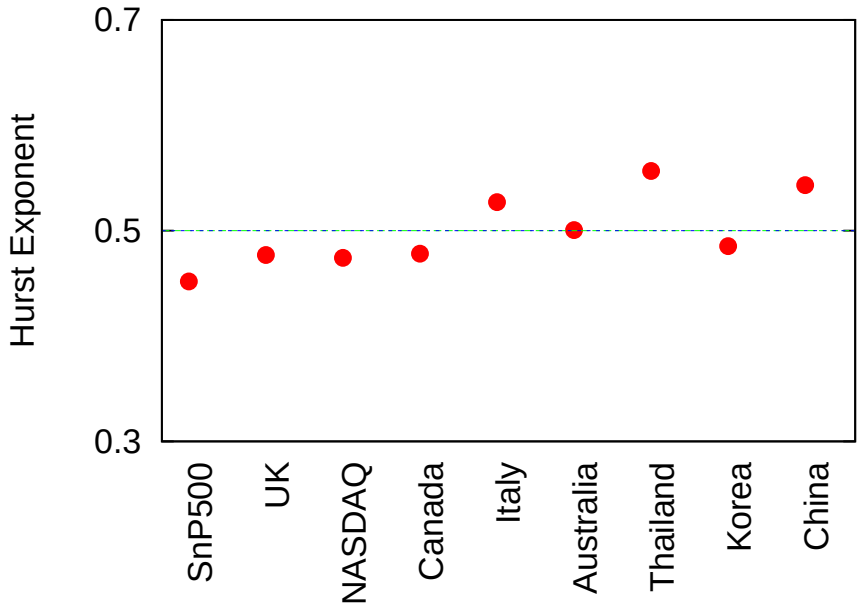

Fig. 3: Hurst exponent for various stock markets

which obtained from randomly shuffled binary return data. Each data in Fig. 2 (b) are estimated by averaging over 1000 ensembles. The information asymmetry disappears in shuffled data sets. Moreover, differences from market to market also disappears. Figrue 2 (c) display the asymmetric ratio which is calculated by dividing $TE_{I\to S}$ by $TE_{S\to I}$. The US (Nasdaq), UK and Canada markets which are considered as mature markets have higher asymmetric ratio. On the other hand, The Thailand, Korea, and China marekts which are considered as emerging markets have lower asymmetric ratio. We also counted how much percent of all stocks in a market have larger information flow from index to stock (to see Fig. 2 (d)). For every markets, over half of all stocks hold larger information flow in such direction.

Hurst exponent. – The Hurst exponent H is a numerical estimate of the persistence of a time series. This measure have commonly used to quantify the degree of long-term memory properties in stock market. [14, 15, 16] The value of the Hurst exponent ranges between 0 and 1. A Hurst exponent value close to 0.5 indicates a random walk in which there is no correlation between a present and a future value in a time series. The future value will go up or down with probability 0.5 like the fair coin tossing process. A Hurst exponent value below 0.5 indicates that there is anti-persistent behaviour in the time series. This means that an increment (decrement) will tend to be followed by a decrement (increment). Therefore it shows mean reversion behavior. A Hurst exponent value above 0.5 indicates persistent behavior. In that value, time series has trend which indicates herding behavior. Thus, this quantity of Hurst exponent provides a classification of market properties. To classify stock market according to H, we measured data for each market using daily index data. There are a variety of methods to estimete H. Although the acuracy of the estimation is a complicated issue, we adopted detrended fluctuation analysis (DFA) method [17] which the efficient method for estimating Hurst exponents accurately.

Figure 3 displays the Hurst exponent for each stock market. As you can see, most mature markets show Hurst exponent below 0.5. On the contrary, most emerging markets

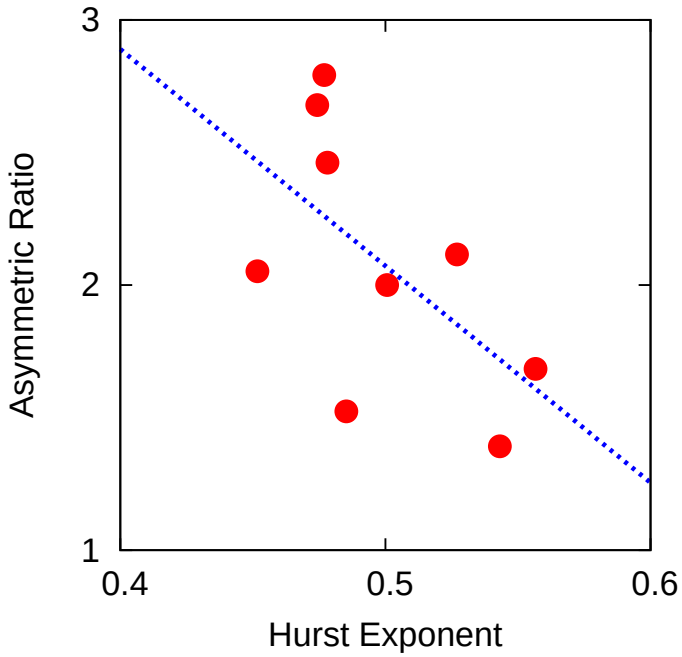

Fig. 4: The correlation between asymmetric ratio and Hurst exponent. The dotted line indicates the best fitted line which slope is -8.17347 by linear regression. It shows negative correlation.

show Hurst exponent above 0.5. The mature markets reveals anti-persistent behaviour in fluctuation of index. There may be the tendency that traders of mature markets persue stabilization of market. Thus if market index goes up (down), traders want to pull down (push up) it. The mature markets may have various factors and mechanisms to stabilize market. On the contrary. emerging market reveals a so-called herding behavior which generates persistent trand in market. There are many jealousy traders who pursue high return with taking high risk. Their speculating attitude induces such persistent behaviour on stock index.

Asymmetric information flow and Hurst exponent. – In Fig. 4, we found the anti-correlation beteeen asymmetic ratio and Hurst exponent. The mature markets which have H value below 0.5 exhibit stronger asymmetric informatio flow between index and stocks, whereas the emerging market which have H value above 0.5 exhibit weaker asymmetric information flow between index and stocks. With this results, we may expect that the traders who are in mature markets more strongly reflect and refer to market index as a primary information with which they measure market state than the traders who are in emergin markets. Probably, immature traders have inclination toward trading on misinformation by which positive feedback loop can be created [18]. This positive feedback induces larger Hurst exponent then 0.5.

Summary. – We have investigated information flow between stock market index and individual stock using transfer entropy measure. The information flow from index to stocks has more superiority than it with inverse direction. The index which are yielded from composing stocks can hold a role of major driving force to determine future price of stocks which yield future index. This result reveals that stock market has self-driving mechanism. Additionally, we found that this role of index decreases from mature market to emerging market. This tendency may originate in more speculated intension of the traders in emerging market. They are often shaked on misinformation which creates positive feedback loop on

the market.

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