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:symbolic Transfer Entropy 방법을 중심으로

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이 논문을 경영학 석사학위 신청논문으로 제출함

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2013년 02월

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ABSTRACT

한국 주식 시장에서 산업 부문들 사이의 정보흐름의 비대칭성

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재무 분야에서 정보흐름은 자산들 간의 복잡한 상호작용과 가격결정 과정을 이해하는데 도움이 된다. 많은 연구들은 주로 시장 간의 정보흐름을 연구해 왔으나 본 논문에서는 우리나라의 산업 부문들 사이의 정보흐름의 비대칭성에 대해 실증분석을 시도하였다. 이 논문에서는 2000년 1월 3일부터 2012년 3월 30일까지의 KOSPI의 일일 수익률 자료를 사용하고 있다. 전체 기간을 서브프라임 위기 때, 위기 이전과 이후로 나누어 정보흐름의 비대칭성과 산업 부문들 사이의 연결 네트워크를 살펴본 결과 KOSPI 시장은 서브프라임과 같은 시장 위기 때 비대칭 정보흐름의 양이 많아졌고, 산업 부문들 간의 연결 개수도 많아지는 것을 확인했다.

Ⅰ. Introduction

The information flow, characterized an interactions between units in financial systems, have been studied for economists as well as scientists of diverse fields because it is helpful to understanding fundamental features created by internal and external environment, in particular Markowitz's portfolio theory and systemic risk. Even though most social scientists and scientists accept that information flow can play a crucial role in understanding underlying inherent mechanism of financial system as a one of the complex system, a precise measurement method on information flow created from economic systems appears remarkably elusive. Since the world financial systems are quickly globalizing more and more recently, connectedness between ingredients in financial system, e.g., stocks, foreign exchange rates, commodity, and interest rate, are decisive factor in terms of understanding route to financial crisis. The Granger causality method proposed by Granger (1969) was used to measurement the causal relationship between the ingredients of financial system. However, information flow estimated by the traditional Granger causality method is given just binary information on the causality relationship. To address a weakness in the customary method such as Granger causality method, we employ symbolic transfer entropy (STE) to estimate the degree of asymmetry information between industry sectors, and we use shuffling tests to identify the connectedness with respective to statistically significance among industry sectors in the KOSPI (Korea Composite Stock Price Index) stock market. In this paper, we focus on our attention to publicly industry sectors and use their daily log-return time series. We study the connectedness with directionality of sector indices and consider 22 industry sectors in KOSPI stock market from January 3rd, 2000 to March 30th, 2012.

To observe on whether the asymmetry information is related to the financial crisis, we divide the time series into three periods before, during and after the subprime crash and calculate their symbolic transfer entropy, respectively. We find that the degree of asymmetry information flow during the sub-prime crisis increased significantly rather than those for both before and after the market crisis, while regardless the data sets used in this paper those for shuffling data set removed the temporal correlation from the original time series did not. According to above observed results, we argue that the temporal correlation plays an important role in the formation of causality relationship between industry sectors.

We also find that the number of connected links with statistically significance also increases. In other words, the financial crisis has played a crucial role in terms of the formation process of directed network generated through the information flows between industry sectors. In the next section, we review literature related with information flow. In Section 3, we describe the financial data and our methodology. Section 4, we present our results observed in this paper. Finally, section 5 discuss and concludes the article.

Ⅱ. Literature review

Many researchers have studied information flow in financial fields. Because, Information flow is helpful to understand many complicated interaction between assets and the markets in the stock markets. Many existing study regarding information flow has interest to information flow at financial affairs.

Eun and Shim (1989) used Vector Auto Regression (VAR), and studied relation to appear between stocks markets of international main 9 countries. According to the analysis results an influence the information that occurred at US market having on in other country is large, on the other hand, an influence other country having on to US market appeared to slight things.

Liu and Pan (1997) studied transmission effect in the US and pacific-basin stock market. According to the analysis results transmission effect from US and Japan stock market to Hong Kong, Singapore, Taiwan and Thailand stock market is more increased after black Monday, influence of US is larger than Japan.

Hsiao, Hsiao, and Yamashita (2003) used Vector Auto Regression (VAR), and studied information transmission effect between stock market of Asia-Pacific region. According to the analysis results an slump of American stock market can be the cause of slump of Japan, Korea and Taiwan stock markets, but did not affect in Chinese stock market.

Sochun (2010) studied information transmission effect between each of stock markets using GJR-GARCH. One group is China, Hong Kong and Taiwan stock market belong to China Region and the other group is China, America, Japan stock markets. According to the analysis results, all of two group after Asian economic crisis become active information transmission. It means that the impact of one market increases as influence to different market.

Thus, existing literature studied information flow between nations to major. It is important that we study information flow between nations in an era of internationalization. We would like to know how the direction of the information flow in Korea would be changed after the crisis through the analysis of the information flow among the industry sector in nations.

We used symbolic transfer entropy and network measure in studying to information flow. We review literatures which studied information flow as we use this methodology.

Okyu and Gabjin (2012) used Transfer Entropy (TE), and found that TE from index to stock is larger than TE from stock to index. It can regard the important force that an index decides on future price of individual stocks.

Onnela, Chakraborti and Kaski (2003) used minimum spanning tree (MST), and found that the stocks included in minimum risk portfolio according to Markowitz portfolio tend to located periphery of the asset tree.

Ⅲ. Data and methodology

A. Data

We analyze the degree of asymmetry information flows between industry sectors from January 3rd, 2000 to March 30th, 2012 for 22 industry sectors : Foods & Beverages, Textile & wearing apparel, Paper & wood, Chemicals, Medical supplies, nonmetal, Iron & metal products, Machinery, Electrical & electronic, Medical & precision, Transportation equipment, Distribution, Electricity & gas, Construction, Transportation & storage, Communication, Financial companies, Banking, Securities, Insurance, Service, Manufacturing. The detail description on the 22 industry sector is given in TableⅠ. The data are obtained from the FnGuide. The return time series is calculated from log-difference of daily prices and given by, where $P(t)$ is the price on day t. In order to the effect of subprime crisis in the formation process of information flows, in the sequel, we divide the whole data into three sub-periods : before, during, and after the subprime crisis. We employ the symbolic (STE) method to quantify the information flows between industry sectors.

B. Methodology

1. Measurement of information flow

a. Granger Causality

The problem that anything is independent variable, and anything is dependent variable, in regression analysis, consider predetermined by economy theory and It was general to confirm causality using real data. However, if cause and effect are uncertain, we cannot make a specific decision regarding functional relation. The test method which used lag distribution model, and did about this problem so as to recognize cause and effect was proposed by Granger (1969) as causality test.

According to definition of Granger, it is concluded that, if the application of past values of X with those of Y is more accurate than that of only those of Y in estimating? Y, there is a causality direction from X to Y. Similarly, if X' s estimation based on Its own past values gets better by including those of Y, it is concluded that there is a causality direction from Y to X. if this relation is in both directions, it could be seen that there is two-way causality direction due to interdependency of X and Y. Test of Granger causality could be said to be a test of null hypothesis that a variable does not help other variable estimation.

Granger test is an analysis model to confirm which of X and Y became cause and represented by two regression equations as follows;

$$Y_t = \sum_{i=1}^{p} \alpha_i X_{t-i} + \sum_{j=1}^{p} \beta_j Y_{t-j} + \varepsilon_{1t} \qquad (1)$$

$$X_t = \sum_{i=1}^{n} \gamma_i X_{t-i} + \sum_{j=1}^{p} \delta_j Y_{t-j} + \varepsilon_{2t} \quad (2)$$

F test is used to determine that X's past values significantly increase the explanation power of the 1st regression equation.

$$F = \frac{(RSS_0 - RSS_1)/p}{(RSS_1)/(T - 2p - 1)} \quad (3)$$

T : total observed value number

p : number of the regression coefficient which constraints was given

RSS_0 : residual square-sum when we give constraints

RSS_1 : residual square-sum when we did not give constraints

If F value is greater than critical value for F distribution, it rejects the null hypothesis that Y does not Granger-cause X. In other words, in the above equation, RSS_0 and RSS_1represent RSS value, respectively, when estimated under the condition of $\alpha_i = 0$ or $\delta_j = 0$ and without such a condition. If the value of this test statistic is greater than the critical value, it is seen that the condition's influence is great so that a null hypothesis, $H_0 : \alpha_i = 0$ or $H_0 : \delta_j = 0$ is rejected.

b. VAR

Var(Vector Auto Regression) model is a model without loss of actually useful information as it does not restrict structural relation between variables hased on a certain economics theory. That is, it is a general type which excludes model maker's subjective restriction, accepts all possibilities without pre-application of a certain economics theory, determines the relation between economic variables by economic data, and would exclude the arbitrary application of theory.

VAR was introduced by Sims in 1980 for the first time and could be said that it is a dynamic model of simultaneous equations to mutually influence between variables to analyze multiple time series data. Mostly, dynamic equations are needed to represent proper data generation process because the relation between variables is not represented by a form of single equation in a dynamic system, In VAR, a vector of endogenous variables is represented by a precedent function of their own and lagged values of other variables. And, exogenous variable or lagged exogenous variable at the simultaneous point in a system could be included. As lag is set more broadly in a VAR model, autocorrelation of residual decreases, but efficiency gets worse, which is a trade-off. For this reason, lag needs to appropriately be selected.

VAR model is as follows;

$$\triangle y_{1t} = a_0 + \sum_{i=1}^{k} a_{1i} \triangle y_{1t-i} + \sum_{i=1}^{k} a_{2i} \triangle y_{2t-i} + \varepsilon_{1t} \qquad (4)$$

$$\triangle y_{1t} = b_0 + \sum_{i=1}^{k} b_{1i} \triangle y_{1t-i} + \sum_{i=1}^{k} b_{2i} \triangle y_{2t-i} + \varepsilon_{2t} \qquad (5)$$

VAR model has an advantage to provide more useful information through impulse response function and variance decomposition.

Based on VAR’s estimated coefficients, impulse response function shows how all variables of a model respond when a certain magnitude of shock is applied to a variable in the model. This is used for the analysis of mutual causality between variables and spillover effect by the change of a policy.

c. Symbolic Transfer Entropy

The STE method was proposed by Staniek et al., and can be explained by the following process. There are two time series (each x_i, y_i). The two time series are symbolized according to size of embedding dimension. Symbolic time series are formed like $X_i = (x(i), x(i+t), \cdots, x(i+(embedding\ \mathrm{dim}ension-1)t))$ (t = time delay). These time series to ascending order rearranged is $((x(i+k_{i1}-1)t) \leq (x(i+k_{i2}-1)t) \leq \cdots \leq (x(i+k_{i\,embedding\ \mathrm{dim}ension}-1)t))$. If prices were same, they ordered according to be compared size of k (if $k_{i1} \leq k_{i2}, x(i+(k_{i1}-1)t) \leq$) $x(i+(k_{i2}-1)t)$. Symbolic time series is indicated and , and symbolic transfer entropy is as follow

$$STE_{X \to Y} = \Sigma p(\hat{Y}_{t+\delta}, \hat{X}_t, \hat{Y}_t) \log \frac{p(\hat{Y}_{t+\delta} | \hat{X}_t, \hat{Y}_t)}{p(\hat{Y}_{t+\delta} | \hat{Y}_t)} \quad (6)$$

We can measure directionality of information flow with difference of STE

$$D^s = STE_{X \to Y} - STE_{Y \to X} \quad (7)$$

When this price is a positive number, information flows, and can make a story to y at x, and when it is a negative number, information flows to x at reverse y, and can do. In the sequel, we set the parameter set as embedding dimension = 2, the time delay t = 1, and δ = 1 in this paper.

2. Network

Network analysis is based to relation shared between components of a system than an individual object, and focus on concrete property of a system. A network is composed to 'node' and 'link'. In this paper, we define a node as an industry sector and a link as asymmetric information flow. A link connect according to degree of asymmetric information flow between two node (industry sectors) in whole systems. If any two nodes (two industrial sectors) are connected by one links (asymmetric information flow), it means that there was asymmetric information flow between two industry sectors.

Ⅳ. Result

In this section, we analyze the fundamental mechanism of directed interactions between financial subjects in terms of information flows for the 22 industry sector indices of KOSPI stock market from January 3st, 2000 to March 30, 2011. To improve the statistical reliability, we establish the surrogate method that is able to eliminate the temporal correlation from the original data set by using the random shuffling. Our verification procedure is implemented using the symbolic transfer entropy method (STE) that can be measured the strength of information flows in the complex time series. Table 1 reports linear statistical properties for the return time series of 22 industry sectors. There are two worth noticing. First, regardless of data sets used in this paper, the skewness of return time series are significantly different from zero. Second, its kurtosis has a larger value than 3, suggesting deviated from the statistics of Gaussian distribution based on the efficiency market hypothesis (EMH)

< Table 1 > The statistical properties of 22 KOSPI industry sectors used in this paper.

Sector	Mean	Standard deviation	Skewness	Kurtosis
Foods & Beverages	1.1480	1.1133	-0.2780	8.0430
Textile & wearing apparel	1.2200	1.2359	-0.6789	8.1265
Paper & wood	1.3091	1.3470	-0.7491	9.0828
Chemicals	1.3626	1.2916	-0.3173	6.1637
Medical supplies	1.2444	1.3733	-0.1014	10.4808
nonmetal	1.3661	1.3844	-0.3363	7.3702

Iron & metal products	1.3188	1.5454	0.0235	7.0189
Machinery	1.7578	1.7639	-0.3366	7.5114
Electrical & electronic	1.7007	1.6432	0.0340	6.9276
Medical & precision	2.1789	2.0902	0.0611	5.6753
Transportation equipment	1.7082	1.6118	-0.1733	6.5966
Distribution	1.4663	1.4499	-0.2062	7.4703
Electricity & gas	1.3535	1.3377	0.0921	7.8046
Construction	1.8591	1.9182	0.0818	7.7080
Transportation & storage	1.8155	1.7627	-0.1670	6.2730
Communication	1.3370	1.3871	0.0410	8.7937
Financial companies	1.6415	1.6512	0.1517	7.3938
Banking	1.7446	1.6999	0.2525	7.3111
Securities	2.1929	2.2125	0.2927	6.6791
Insurance	1.7213	1.6996	0.1909	6.8446
Service	1.3731	1.4331	-0.4494	8.6796
Manufacturing	1.3456	1.3320	-0.2855	7.3120

Understanding to what information flows in economics system or financial market are fundamentally driven by both endogenous and exogenous shocks is especially important during periods includes the diverse market status. In order to analyze inherent features of the dynamics created by interrelationship among the economic or the finance units, we need to understand the formation mechanism of information flows created by the change of the various economic statuses over time. Here, we establish the symbolic transfer entropy (STE) method to calculate the strength of information flow between 22 industry sectors during the whole period. In the sequel, we set the parameter sets as (embedding dimension = 2 and time delay = 1).

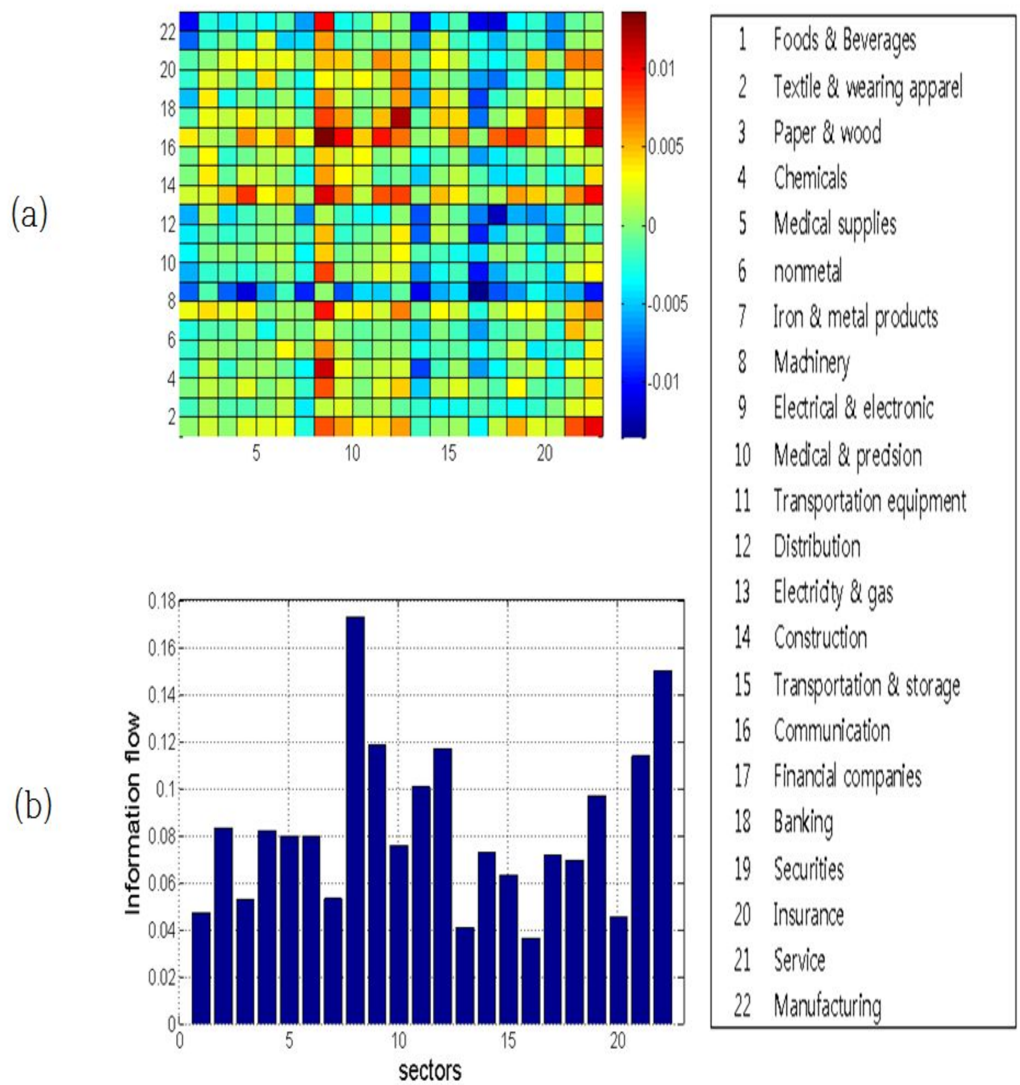
Figure 1(a) shows amount of information flows between each industry sectors by color using whole data sets. Each cell show amount of information flows from X sector to Y sector. The color that is filling each cell stand for that blue series is positive value and red series is negative value. According to results in Figure 1(a), the ranges of amount of information flows between industry sectors appear to differ markedly across industry sector indices, indicating differential strengths of interactions among industry sectors created by the various common factors.

We wonder why there are an asymmetry of information flows across industry sectors, although it has essential functions in economics systems. Indeed, financial markets are governed by a diverse ingredients, including heterogeneous traders, nonlinear interactions, and adaptation to new environments. Therefore, we will consider whether the asymmetry of information flows exists as well as its possible causes.

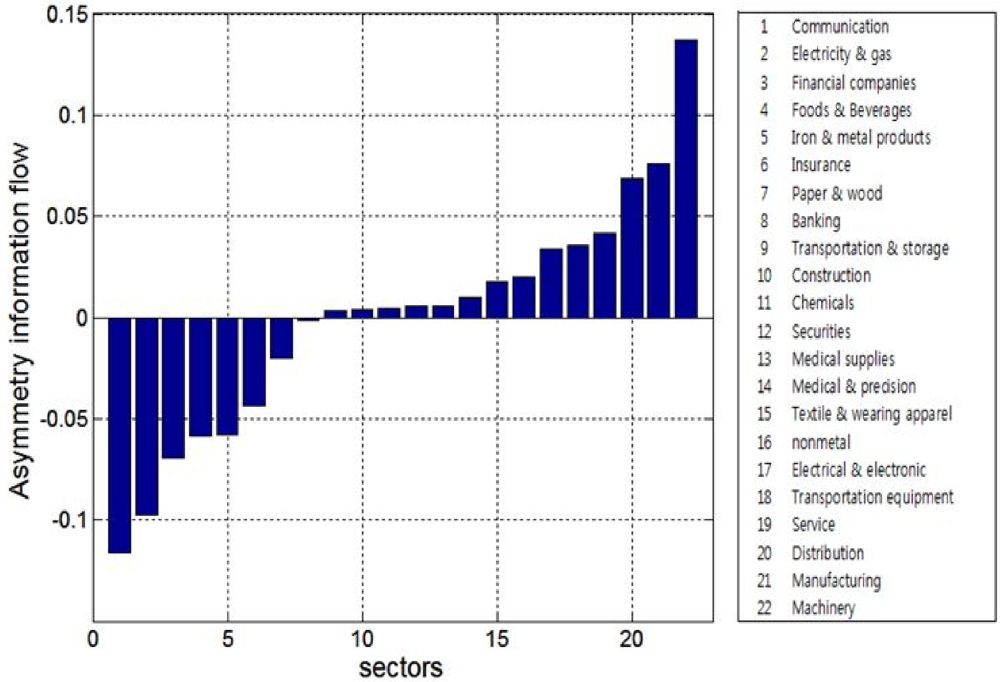
In order to recognize whether or not sectors where outflow is a lot of sector, we calculate amount of outflow each sectors and show in Figure 1(b) and found that the Machinery and the Manufacturing sectors are a lot of outflow, while the Communication and the Electricity & gas sectors are small outflow, indicating Machinery and Manufacturing will be able to have an influence on the other sectors. Degree of information flow between each industry sectors is not a symmetry as we see in Figure 1. Then we recognize whether or not the sectors where asymmetry of information flow is large are what kind of sectors. In order to examine asymmetry of information flows between industry sectors, we calculate directionality defined by equation 2 and shown in the Figure 2 in ascending order. If degree of asymmetric information flow is positive, that is a lot of outflow information than amount of inflow information; otherwise, that is a lot of amount of inflow information than amount of outflow information, i.e. the Machinery, the distribution, and the Manufacturing sectors have an influence on the other industry sectors, while the Communication and the electricity & gas sectors are affected from the other industry sectors. According to the results on the degree of information flows reported in Figure 2, we should recognize that what is industry sectors having a crucial role in terms of the creating information in financial system.

Recently, to understand the principle mechanism of economy system we need to know what is origin of the global financial crisis as U.S. sub-prime crisis.

<Figure 1> Information flows between 22 industry sectors using whole data sets. Panel (a) is amount of information flow between each industry sectors by a range to pcolor, and panel (b) is amount of average outflow each industry sectors.



< Figure 2 > Average degree of asymmetry information flows between 22 industry sectors using whole data sets.



We then investigate how to relate the market status to their causal relationship. To do this, we divide the whole data sets into three periods such as before (2006 ~ 2007), during (2008 ~ 2009), and after (2010 ~ 2011) the sub-prime crisis and estimate the degree of asymmetry information flows between sectors, respectively.

We calculate a directionality of information flows by using the different periods described three periods and compare to each other in Figure 4, which shows the information flows and the average outflow in the left and the right columns. The difference in the quantity of information flows between industry sectors [(a), (c), (e)] is not easily seen, while the average outflow in the information flows in the right column of Figure

3 exist a clear difference. In Figure 3 (b), (d), (f), we find that the quantity of average information flows is significantly increase in global financial crisis. Our finding of an increasing pattern in the information flows indicates that the quantity of information flows is closely related to the financial market crisis. To increase the robustness of the above results, we check the degree of asymmetry information flows for different periods. Figure 4 (a), (b), and (c) show that the average degree of asymmetry information flows during the financial crisis period have higher values than those of normal market status.

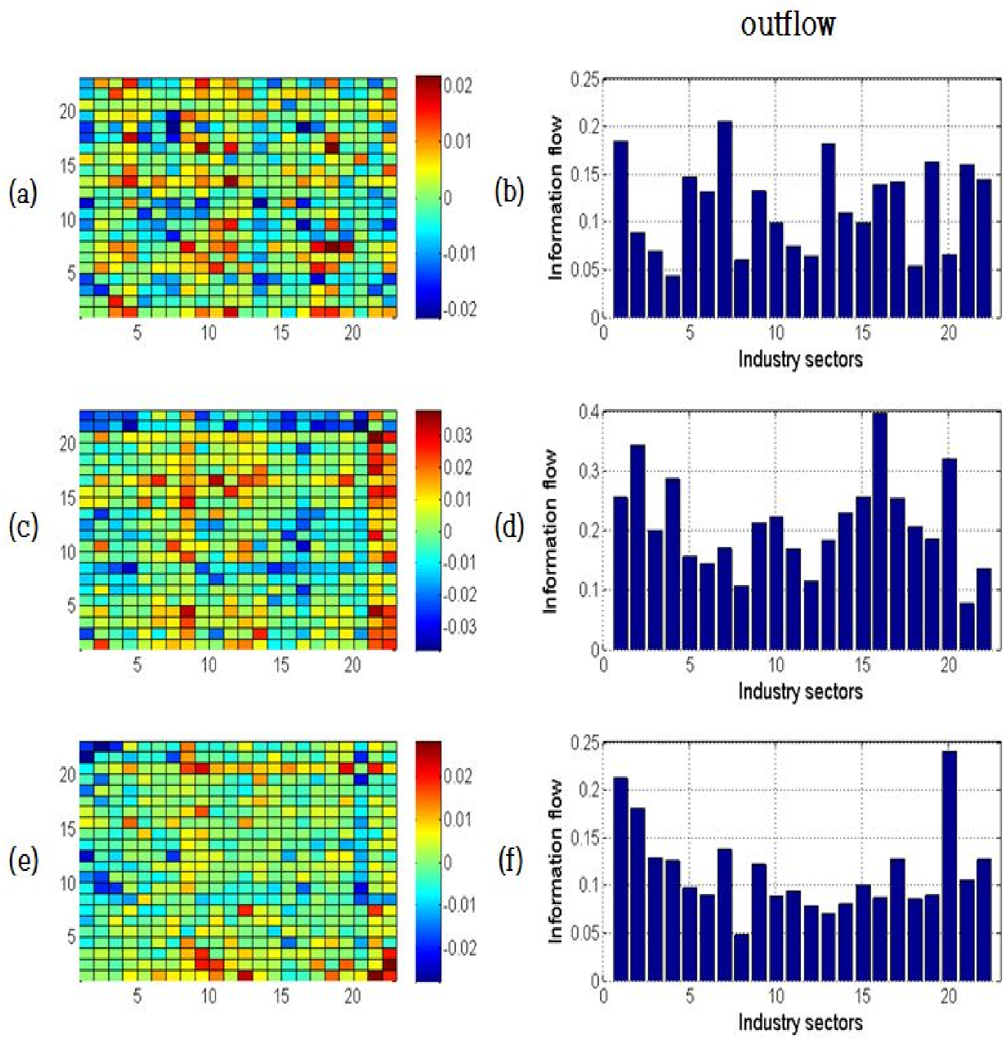
For example, the movement of particle are produced when difference in potential energy between any two places at the same space is great and the flow of the river was streamed when there is a asymmetry between inflows and outflows in any place as well.

Likewise, when a difference in the asymmetry of information flows increases, information will flow more quickly, but otherwise the information flow is stagnant, i.e. the financial system have become significantly more stable. Especially, during financial crisis the degree of asymmetry of information flows steeply increases it has become more complex and increasingly risk averse.

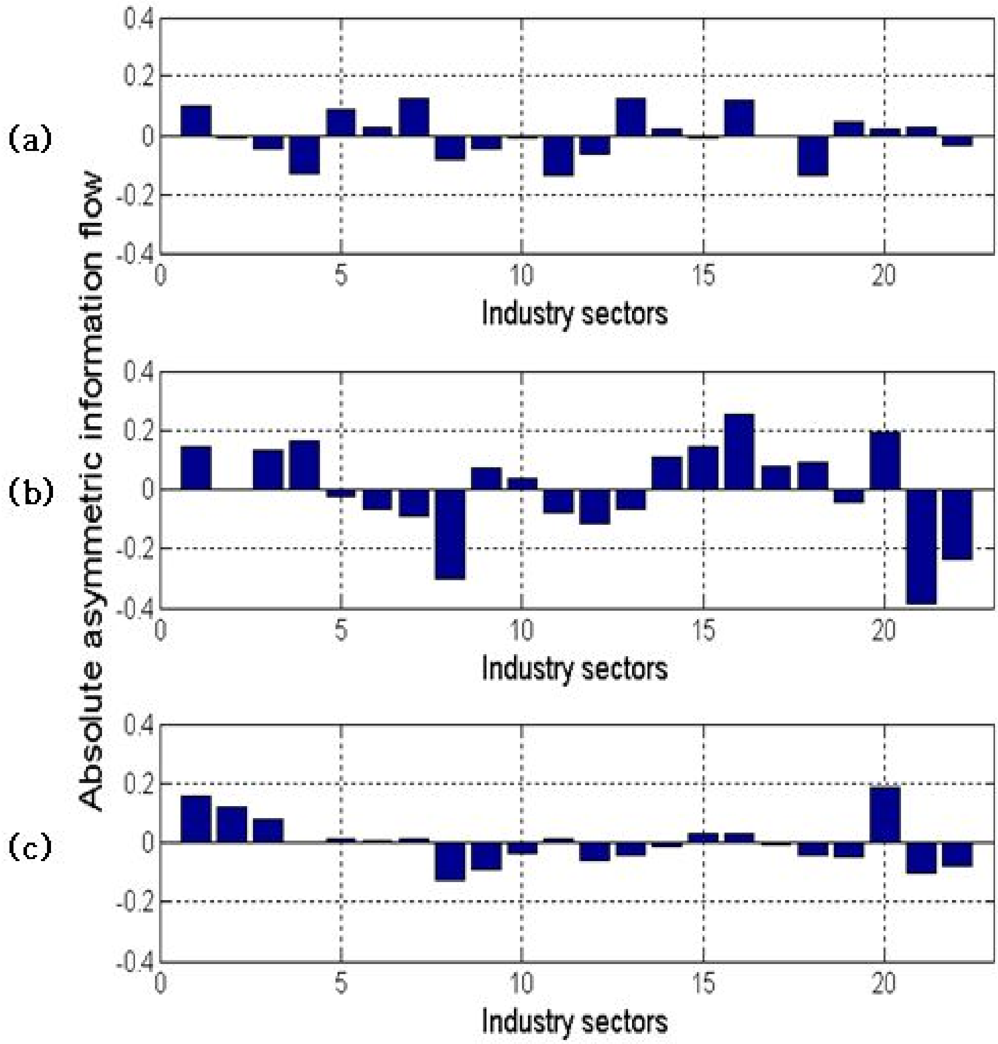
The difference of asymmetric information flow is larger (before:0.2631, during:0.6368, after:0.3129) because the information flow stream should be increased more quickly between the industry sectors. In Figure 4, we find that the sectors, having an important role in terms of the formation of information flows, are different according to the diverse status of the financial market; the dominant sectors in terms of information flows are the iron & metal products sector and electricity & gas sector during 2006 to 2007, are the communication and insurance sectors during the market crisis from 2008 to 2009, and are the insurance sector after sub-prime crisis. In addition we find that insurance sector from among financial sector did not decrease after market crisis. As insurance is branch related to risk management because increases of interest regarding the risk management was reflected after market crisis.

These results seem to suggest that both the quantity of information flow and its asymmetry should play an important role in terms of the diagnosis of market stability.

< Figure 3 > Amount of information flow between industry sectors by a range. The six panels to refer to before (a, b), during (c, d), and after (e, f) the subprime crisis. Panel (a, c, e) is amount of information flow between each industry sectors by a range to pcolor, and panel (b, d, f) is amount of average outflow each industry sectors. Sectors are same as a Figure 1.



< Figure 4 > Average degree of asymmetry information flows between 22 industry sectors. The three panels range to before (a), during (b), and after (c) the subprime crisis. Sectors are same as a Figure 1.



Network structure of economic systems based on the asymmetry of information flows is likely to alter due to corporation with industry sector activity. Understanding the complexity of network topology in economy system is difficult because it should be changed due to unpredicted events which are created by both the endogenous and the exogenous economic variables. Nevertheless, massive data set on economic system with various time scales from ultra high frequency (Trade and Quote) to low frequency (Year) provide some motivation for choosing a network approach and for risk management. We consider an asymmetry of information flow to construct the network between industry sectors. We established the network by using the conventional method of defining of link, which needs a given threshold for connection strength proposed by Onnela (2004). If a threshold is larger than a maximum value among the strength of possible connection, the established structure shows nothing at all on a link on the network, i.e. all node is island. This concept is established in figure 5.

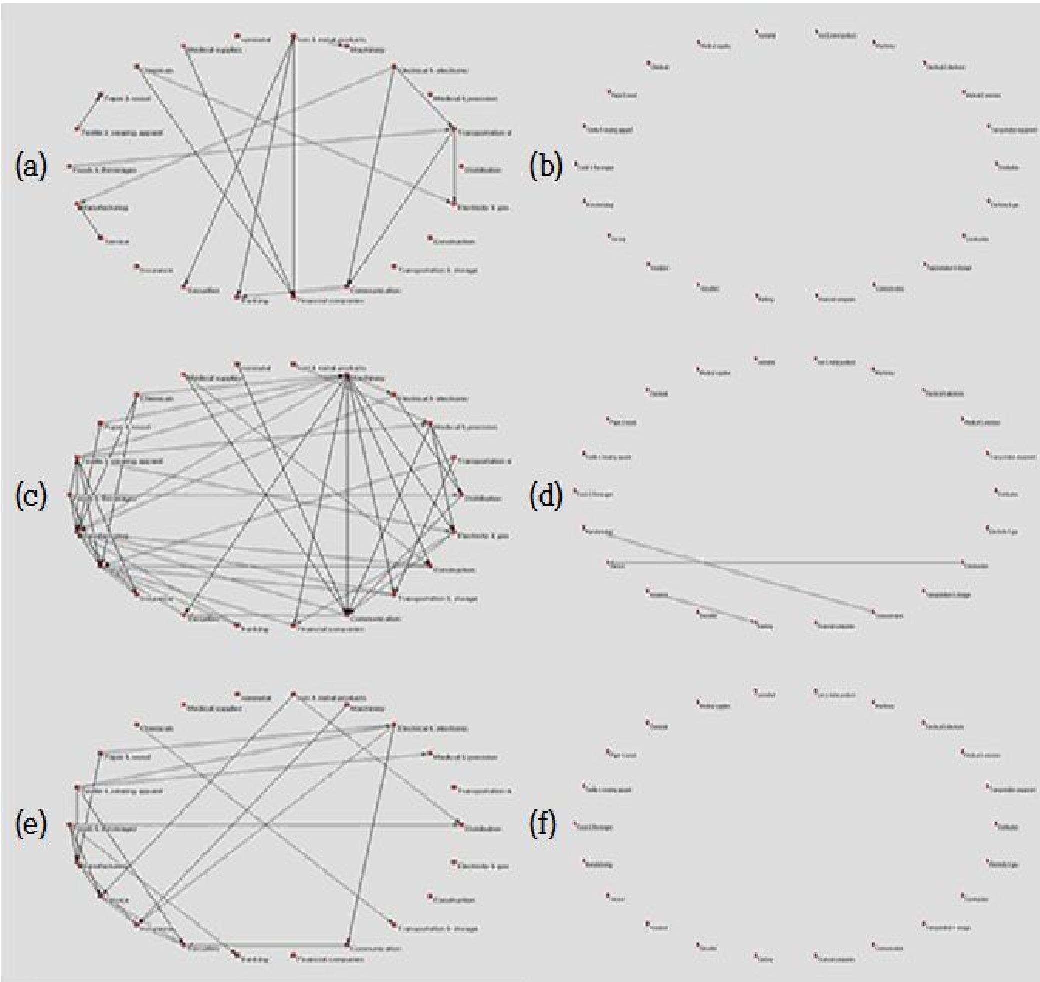
To investigate whether the network topology that are constructed by the asymmetric information flow is related to the financial market status as the U.S. subprime crisis. We construct the network structure of the asymmetric information flows by using the industry sectors for three different sub-periods as defined in methodology part and compare them with artificial time series, eliminating the temporal correlation from original time series by using shuffling method in figure 5, which shows the original data and artificial data in the left and the right columns. The network topology in the left column constructed from an original data exhibits a clear difference from those for artificial time series, i.e. the temporal correlation play an important role in terms of the formation of network structure of the asymmetric information flows.

We established the network connection with respective to the threshold 0.011 for sub-periods, including before, during, and after the U.S. subprime crisis. In figure 5 (a), (b), and (c) for the original time series for a each periods, one can recognize facts: Number of connection between industry sectors having a larger value than given threshold value during financial market crisis shows very significant increase compared to two normal status such as before and after the subprime crisis, suggesting information should be quickly transported in financial crisis period containing network which is established in more complex economic environment and that may lead to the higher systemic risk.

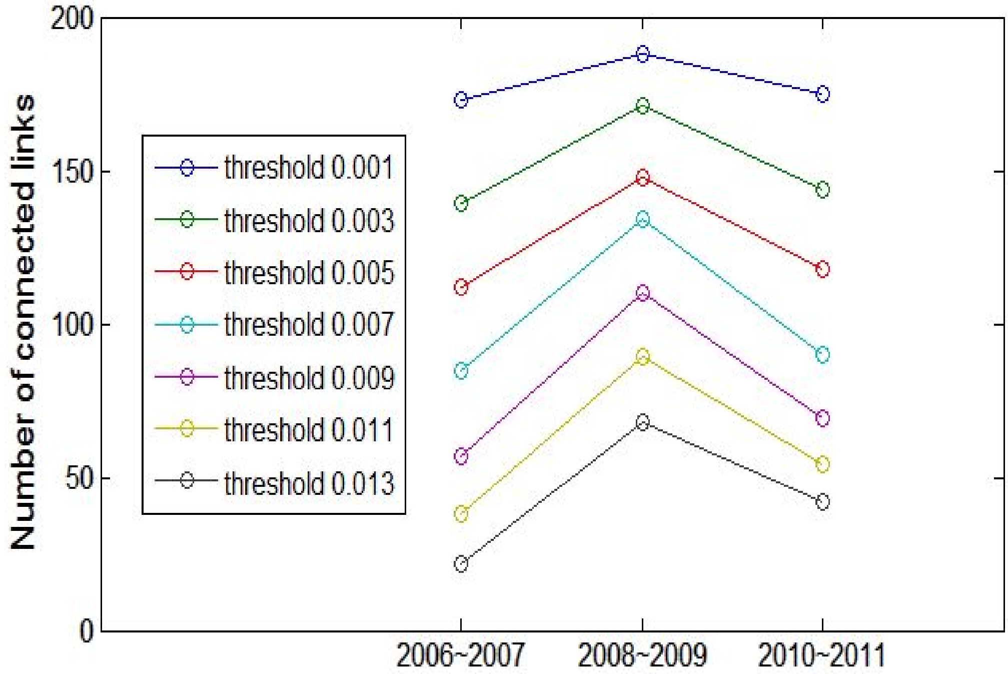
For example, if communicate information to sector A at sector B. If there are a little the number of connection link, information is diffused through a lot of steps. On the other hand if there are a lot of the number of connection link, information is diffused through fewer steps. Although the results observed in figure 5 have a significance, the established network are very sensitive to the threshold parameter.

To improve the robust of above results, we make a diverse network according to the several threshold values and estimated the network features as the number of connection. The results is reported in Figure 6. In Figure6, regardless of the threshold parameter values there is an increasing trend in the number of connection during the financial crisis period even though the number of connection is different according to threshold value. Our results suggest that the connected structure during the market crisis shows a more complex than a normal status. These results seem to suggest that the network structures which are based on the asymmetric information flows is affected by the market states.

< Figure 5 > Directed network of information flows between 22 industry sectors by using the symbolic transfer entropy method. The six panels to refer to before (a, b), during (c, d), and after (e, f) the subprime crisis. The panel (a, c, d) is network of original data and the panel (b, d, f) is network of shuffled data.



< Figure 6 > Number of connected links between industry sectors according to the various threshold values for three regions such as before, during, and after the subprime crisis.



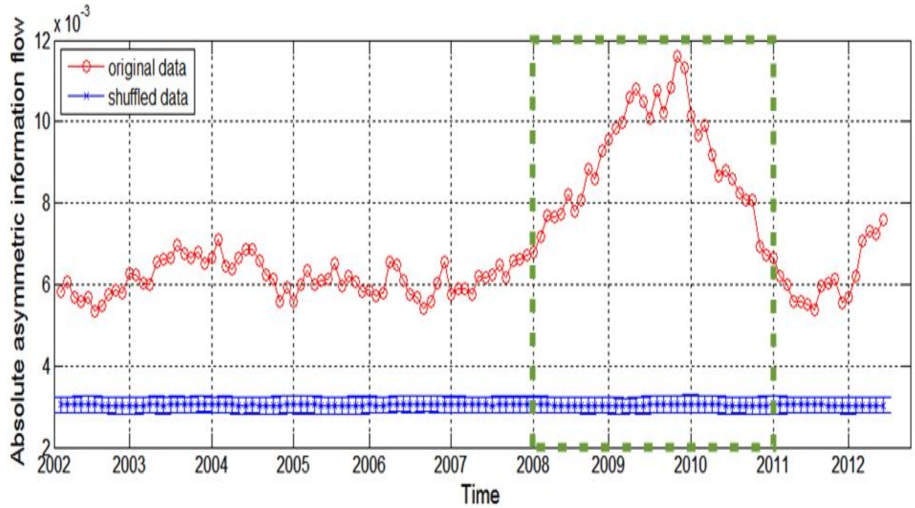
To verify whether the degree of information flow, the asymmetry information flows and the connected structure between industry sectors are related to financial market status affected over the time, we then calculates the symbolic transfer entropy values with 500 days (approximately two years) by shifting 21 days. Figure 7 (a) and (b) display the degree of average asymmetric information flow and the number of connected links of the network for original data and artificial data sets, respectively. In Figure 7, we find that the average absolute value of the asymmetric information flows and the number of connection between industry sectors in the Korean stock market during the financial crisis induced by the U.S. sub-prime event are higher than those of relatively normal market status and it is very statistically significant value compared to artificial time series that are eliminated the temporal correlation from original time series by using shuffling method.

Finally, we calculate asymmetric information flow for each industry sector in Figure 8 and measure the correlation between the average absolute value of asymmetric information flows and the asymmetric information flows of each industry sector in Figure 9, respectively.

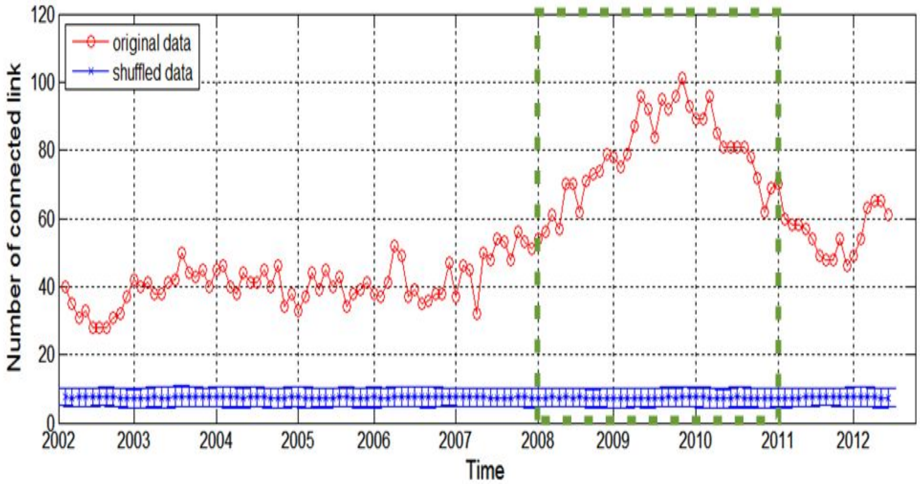
Figure 8 display to change along time of degree of asymmetry information flow of sectors. In Figure 8, it is clear that the asymmetric information flow of each industry sector respond directly to market instability, especially financial crisis. Our finding suggest that machinery, service and manufacturing sectors generate a lot of information set, i.e. those sectors have influence on the other sectors. In Figure 9, for bank, transportation & storage, insurance and chemicals the correlation between the average absolute value of asymmetric information flow by all in the industry sectors between the asymmetric information flow of each industry sector show positive significantly, while the service, machinery, and manufacturing sectors show anti-correlation. From the these results, one can expect that there are sources and sinks structure on the network of the asymmetric information flows.

< Figure 7 > Panel (a) and (b) displays the degree of average asymmetry information flows and the number of connected links between industry sectors estimated with 500 data points by shifting 21 days.

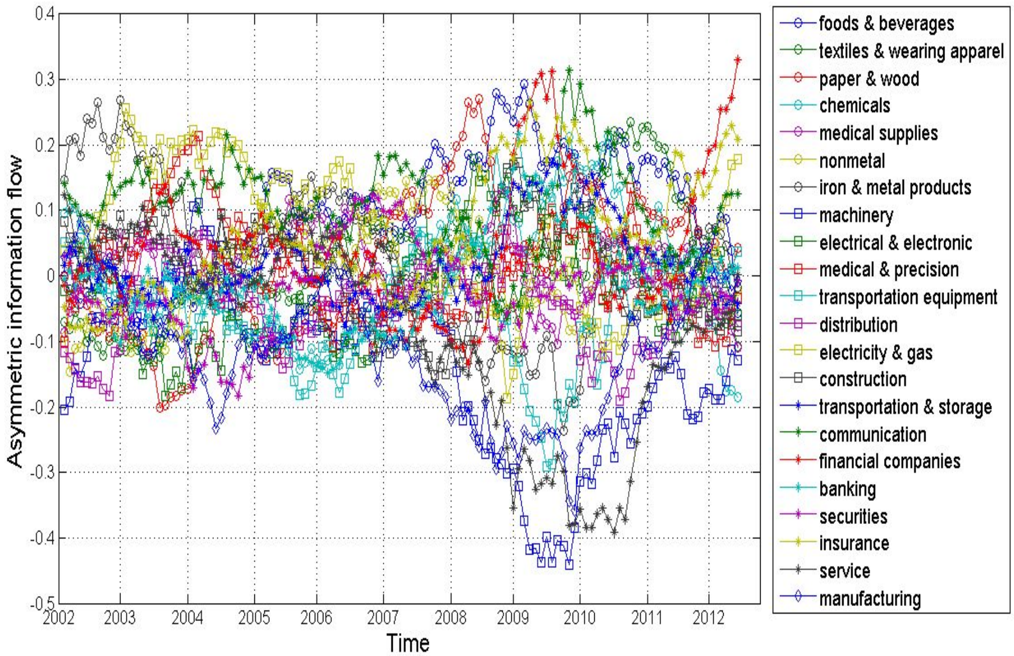
(a)



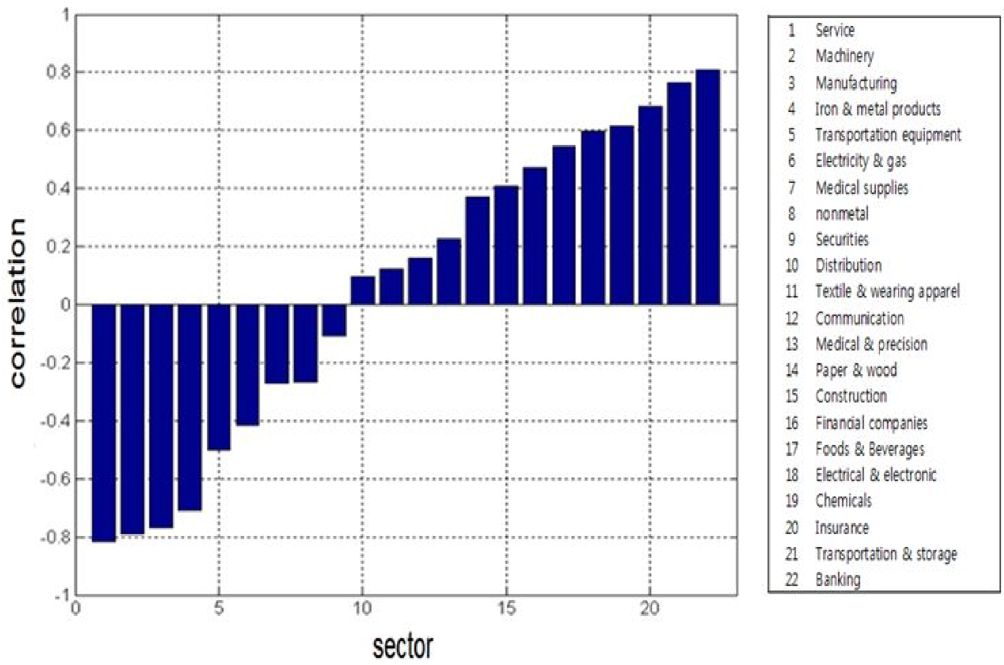
(b)



< Figure 8 > Degree of asymmetry information flows of industry sectors estimated with 500 data points by shifting 21 days.



< Figure 9 > Correlation between each sector and markets.



Ⅴ. Conclusion

In this paper, we investigated the properties of the information flow between industry sectors in the KOSPI market. We used daily price of 22 industry sectors in KOSPI stock market from January 3st, 2000 to March 30st, 2012. We used the symbolic transfer entropy in order to quantify the asymmetry information flow. We found that the degree of asymmetry information (DAI) and the number of connection link during a financial crisis such as sub-prime crisis is large compared to the those in both before and after the financial crisis, in particular the financial sector has played a very important role in generating the information flow during financial crisis period. Financial sectors, in particular, show that degree of asymmetric information flow increased at before crisis compare with during, and decreased after crisis. However, insurance sector did not decrease after crisis. It might be interpreted into because insurance is sector related to risk management. On the other hand, the sectors except financial sectors not appear a noticeable effect. It might be Influences of the companies which does not specialized to one sector, and there is over a lot of sectors. In addition, we found that based on the network property, the connectedness relationship between sectors during the market crisis showed more complex behavior rather than those for both before and after the sub-prime crisis.

Reference

Ancona, N., Marinazzo, D., Stramaglia, S., 2004, Radial basis function approach to nonlinear Granger causality of time series, *Physical Review E* 70, 056221.

Bahraminasab, A., Ghasemi, F., Stefanovska, A., McClintock, P. V. E., Kantzs, H., 2008, Direction of Coupling from Phases of Interacting Oscillators: A Permutation Information Approach, *Physical Review Letters* 100, 084101.

Chavez, M., Martinerie, J., Le Van Quyen, M., 2003, Statistical assessment of nonlinear causality: application to epileptic EEG signals, *Journal of Neuroscience Methods* 124, 113-128.

Diks, C., Mudelsee, M., 2000, Redundancies in the Earth's climatological time series, *Physics Letters A* 275, 407-414.

Diks, C., Panchenko, V., 2006, A new statistic and practical guidelines for nonparametric Granger causality testing, *Journal of Economic Dynamics and Control* 30, 1647-1669.

Eom, C., Jung, W., Choi, S., Oh, G., Kim, S., 2008, Effects of time dependency and efficiency on information flow in financial markets, *Physica A* 387, 5219-5224.

Eun, C., Shim, S., 1989, "International Transmission of Stock Market Movement," *Journal of Financial and Quantitative analysis*, 24, 241~256

Fama, E. F., 1991, Efficient capital markets II, *Journal of Finance* 46, 1575-1617.

Granger, C. W., 1969, Investigating causal relations by econometric models and cross-spectral methods, *Econometrica* 37, 424-438.

Granger, C., Huang, B., Yang, C., 2000, A bivariate causality between stock prices and exchange rates: evidence from recent Asian flu, *Quarterly Review of Economics and Finance* 40, 337-354.

Hiemstra, C., Jones, J., 1994, Testing for Linear and Nonlinear Granger Causality in the Stock Price- Volume Relation, *Journal of Finance* 49, 1639-1664.

Hlaváčková-Schindler, K., Paluś, M., Vejmelka, M., Bhattacharya, J., 2007, Causality detection based on information-theoretic approaches in time series analysis, *Physics Reports* 441, 1-46.

Hsiao, S. T., Hsiao, M. W., Yamashita, A., 2003, The Impact of the US Economy on the Asia-Pacific Region: Does It Matter?, *Journal of Asian Economics* 14, 219-241

Kwon O., Yang, J., 2008, Information flow between stock indices. *Europhysics Letters* 82, 68003.

Kwon, O., Oh, G., 2012, Asymmetric information flow between market index and individual stocks in several stock markets, *A Letters Journal Exploring the Frontiers of Physics* 97, 28007.

Liu, Y. A., Pan, M. S., 1997, Mean and Volatility Spillover Effects in the U.S. and Pacific-basin Stock Markets, *Multinational Finance Journal* 1, 47-62.

Ma, Y., Kanas, A., 2000, Testing for nonlinear Granger causality from fundamentals to exchange rates in the ERM, *Journal of International Financial Markets, Institutions and Money* 10, 69-82.

Marschinski, R., Kantz, H., 2002. Analysing the information flow between financial time series, *European Physics Journal b* 30, 275-281.

Oh, G., Kim, S., Eom, C., 2007. Market efficiency in foreign exchange markets, *Physica A* 382, 209-212.

Onnela, J. P., Chakraborti, A., Kaski, K., 2003. Dynamics of market correlations: Taxonomy and portfolio analysis, *Physical review E* 68, 056110-12

Paluš, M., Komárek, V., Hrnčíř, Z., Štěrbová, K., 2001. Synchronization as adjustment of information rates: Detection from bivariate time series, *Physical Review E* 63, 046211.

Pincus, S. M., 1991, Approximate entropy as a measure of system complexity, *Proceeding of the National Academy of Sciences* 88, 2297-2301.

Schreiber, T., 2000, Measuring Information Transfer, *Physical Review Letters* 85, 461-464.

Silvapulle, P., Choi, J. S., 1999, Testing for linear and nonlinear granger causality in the stock price-volume relation: Korean evidence, *Quarterly Review of Economics and Finance* 39, 59-76.

Staniek, M. Lehnertz, K., 2008, Symbolic Transfer Entropy, *Physical Review Letters* 100, 158101.

Wang, Z., Kutan, A. M., Yang, J., 2005, Information flows within and across sectors in Chinese stock markets, *The Quarterly Review of Economics and Finance*, 45, 767-780.