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A Multivariate GARCH Analysis on International Stock Market Integration: Korean Market Case

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ABSTRACT

Financial integration is a phenomenon in which global financial markets are closely connected with each other. This article investigates the integration of Korean stock market with other stock markets using a multivariate GARCH analysis. We chose total seven countries including Korea for this paper based on the amount of export and then we chose major stock indices which can be thought as representative stock markets of those countries. The empirical analysis has shown that countries' financial integration.

Keywords: Stock Market Integration, Cointegration, Stock Index, Multivariate GARCH

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1. INTRODUCTION

The globalization has been effect on the global stock market co-movement. Stock prices and their volatilities are seemed to be strongly related to each other. Especially, markets move more closely tighter during periods of crisis. The 1997~1998 Asian financial crises and the global financial crisis of 2008 are the evidence of market contagion. Market integration and market contagion are related to market efficiency. According to the efficient market hypothesis, if market is efficient, there is no arbitrage opportunity (Chan, 1997). However, if two markets are cointegrated, then there are possible arbitrage profits. In other word, if two stock markets are collectively efficient in the long run, then their stock prices cannot be cointegrated.

Most early researches used Granger-causality testing of market indices to study market interdependencies and contagion effects. However, this method is not effective when phenomenon of volatility clustering which is a common feature of financial data exists (Ling and Li, 1998, Ling *et al*., 2003). Thus, we employ the multivariate generalized autoregressive conditional heteroskedastic (MGARCH) model to study the mean and volatility spill-overs between different countries stock markets.

In this research, we examine the weak-form efficient market hypothesis for each of the seven countries, Korea, USA, Japan, China, Taiwan, Hong Kong, and Singapore. Second, it tests whether these stock markets are collectively efficient by cointegration tests. We also study how stock price changes of other neighboring countries markets influence the stock return and volatility of Korean market. The analysis employs unit root test, Johansen cointegration test, vector-autoregression GARCH model, and impulse response function. This research will give a guideline to the investors how want diversified portfolios to invest world stock market.

The organization of the report is as follows. The analysis methods used in this research are explained in Section 2. Section 3 describes the data sets to be employed in the analysis. The empirical results are presented in Section 4. Then we summarize the results and conclude.

2. METHODOLOGY

2.1 Unit root test

Before analysis, the first thing to do is that grasp characteristics of series. One of the most important characteristics is whether series are stationary or not. If series are stationary we can fit the VAR model to series and otherwise, we should find cointegration or make the series stationary using differencing operator.

This property can be indicated by integrated number, usually represented I(d). The number d means that the number of differencing operator needed to make the series stationary at first.

Unit root test is the test to exam existence of unit root which implies that series is non-stationary using an autoregressive model. The test for this paper is the augmented Dickey-Fuller test (Dickey and Fuller, 1979). The testing procedure is like below.

$$\Delta X_t = \alpha + \beta t + \gamma X_{t-1} + \delta_1 \Delta_{t-1} \cdots + \delta_p \Delta X_{t-p} + \varepsilon_t$$

where α is a constant, β is the coefficient on a time trend and p is the lag order of the autoregressive process. Null hypothesis of the test is that there is unit root test in series X_t and this can be formulated as $\gamma = 0$, so test statistics is got from below equation.

$$DF = \frac{\hat{\gamma}}{SE(\hat{\gamma})}$$

2.2 Cointegration

Cointegration is very useful concept on analysis of financial data. Almost all financial data are not stationary; therefore, some concept was needed to analyze non-stationary data together. Firstly, conintegration was proposed in Granger (1981). If there exists cointegration between non-stationary time series, the linear combination of those time series is stationary. If we find the cointegration vector which makes non-stationary series stationnary, we can analyze non-stationary data.

Some tests have been proposed to find cointegration. One of them is Johansen test (Johansen, 1991) which is extended version of Engle and Granger's cointegration test (Engle and Granger, 1987). Null hyphothesis of this test is that there is no cointegration among series. Johansen test use a general unrestricted error-correction model.

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \cdots + \Gamma_{k-1} \Delta X_{t-k+1} + rX_{t-k} + \mu + \varepsilon_t$$

where X_t is vector of variables at time t and r is parameter matrix and μ is intercept term. Whether there is long-rum equilibrium among series is decided from the parameter matrix. The rank of the parameter matrix implies the number of cointegration vector.

Johansen test use both trace statistics and maximum eigenvalue statistics to find the number of cointegration vector.

2.3 GARCH Model

In the analysis of financial data, it is easy to observe that heteroskedacity which means that variance is not constant over the time. To handle this property, Engle proposed firstly ARCH model considering conditional variance and then generalized ARCH, called GARCH framework was introduced later. Using these methods, the volatility of many financial markets are explained and studied.

In GARCH model, there exist two processes. One is mean process and the other one is variance process which is not usually considered in previous models. Following equations represent mean process and variance process. Mean process is usual ARMA process and only difference ARMA and GARCH is whether variance is set constant or not.

$$\text{Mean } X_t = c + \sum_{i=1}^{r} \phi_i X_{t-i} + \sum_{j=1}^{m} \theta_j u_{t-j}$$

$$\text{Variance } u_t = \sqrt{h_t} \nu_t,\ \nu_t \sim N(0, 1),$$

$$h_t = k + \sum_{i=1}^{p} \delta_i h_{t-i} + \sum_{j=1}^{q} \alpha_j u_{t-j}^2$$

2.4 Multivariate GARCH

To explain relationship between two series, multivariate model is appropriate. Sometimes multivariate model shows better performance on explaining the situation and predicting. However, as previously mentioned a lot of financial time series has heteroscedasticity. Heteroscedasticity should be considered in making models, so multivariate GARCH was firstly proposed by Bollerslev, Engle and Wooldridge (1988).

Multivariate GARCH is the version of multivariate model of GARCH. Multivariate GARCH also consists of two processes, mean and variance, same as univariate GARCH. Mean process is usually explained by VAR model and variance process consists of more than two residual series of VAR process. There are many derivatives of GARCH model with unique variance function assuming different properties.

In this paper, we use the BEKK GARCH model which is a little different from VEC model firstly proposed multivariate GARCH model (Engle and Kroner, 1995). BEKK GARCH model is more convenient than VEC model, because this method guarantees that variance matrix is positive semi-definite. Following equations represents BEKK GARCH model.

$$\text{mean } X_t = c + \sum_{i=1}^{r} \Phi_i X_{t-i} + \sum_{j=1}^{m} \Theta_j u_{t-j}$$

$$\text{Variance } u_t = H_t^{1/2}\nu_t,\ \nu_t \sim N(0, I)$$

Here, X_t, u_t, ν_t are vectors and Φ_t, Θ_t, H_t are matrices. H_t is conditional variance-covariance matrix like univariate GARCH model and it should be positive semi-definite. This matrix is obtained following process.

$$H_t = KK' + \sum_{i-1}^{p} \Delta_i H_{t-i} \Delta_i' + \sum_{j=1}^{q} A_j u_{t-j} u_{t-j}' A_j'$$

In BEKK GARHC, H_t, K are lower triangular matrices, so the total number of coefficients which should be calculated through optimization is the order of square of the number of time series.

2.5 Impulse Response Analysis

Impulse response analysis is the method that analyzes the system through observing the outputs when unit shock called impulse is applied to the system.

To get impulse response from past unit shock, we consider VAR(p) model.

$$X_t = \sum_{i=1}^{p} \Phi_i X_{t-i}\, Z_t \quad Z_t \sim WN(0, \Sigma)$$

If VAR(p) model is invertible, it can be represented as MA representation.

$$X_t = \sum_{i=1}^{p} \Psi_i Z_{t-i}$$

Usually, covariance matrix of Z_t does have covariance terms as well as variance terms and it makes the analysis difficult, because, unit shock of one variable affects on other variables in future. To overcome this problem, Cholesky decomposition is introduced. Cholesky decomposition can applied to positive semi-definite matrix and find lower triangular matrix which satisfy following relationship.

$$\Sigma = PP^T$$

Applying inverse of this lower triangular matrix to noise term makes result standardized and orthogonal.

$$v_t = P^{-1} Z_t \quad \text{cov}[v_t] = I$$

We can get the new MA representation using this property and past unit shock of one variable only affects on own future variable.

$$X_t = \sum_{i=1}^{p} \Psi_i^{*} v_{t-1}$$

Impulse response of this equation is like this.

$$\frac{\partial X_{t+s}}{\partial v_t} = \Psi_s^{*}$$

3. DATA DESCRIPTION

3.1 Major Stock Indices

We chose total seven countries including Korea for this paper based on the amount of export and then we chose major stock indices which can be thought as representative stock market of those countries. Below table shows seven countries and corresponding stock indices. This data is obtained from Yahoo finance and start date is decided to Jan 1st 1997 because the oldest date of TSEC weighted index Yahoo finance offers is that day. We got both daily and weekly data. Daily data is used for impulse response analysis and cointegration test and weekly data is used for GARCH analysis.

Table 1. Data Used in the Research

Country	Stock index	start date	end date
Korea	KOSPI composite index	1997-07-02	2009-12-04
USA	S&P 500 index	1997-07-02	2009-12-04
Japan	NIKKEI 225 index	1997-07-02	2009-12-04
China	SSE composite index	2003-01-02	2009-12-04
Taiwan	TSEC weighted index	1997-07-02	2009-12-04
Singapore	Straits times index	1997-07-02	2009-12-04
Hong Kong	Hang Seng index	1997-07-02	2009-12-04

The series is divided into two sets. One set contains data from Jul 1997 to Dec 2002 and the other set contains data from Jan 2003 to Dec 4th 2009. We call first set old set and latter one new set.

3.2 Data Preprocessing and Simple Tests

Before analysis, all the data is sorted in order of time. Log price is used to stabilize volatility of data and we use centered data subtracted mean. Low variance also causes numerical problems, so multiply 100 to log price and log return is also multiplied by 100 (Wong *et al*., 2005). Different countries have different holidays, so business days of data are not consistent. For this reason, any dates which do not exist as least in one of seven data are removed. The total number of weekly data is 637.

Following table shows statistics of log return of time series data. Kurtosis of all the data is larger than 3 which is for normal distribution. All the data except that of Japan and Taiwan in old set have negative skewness. Standard deviations are also larger than that of normal distribution. In conclusion, all the log return series do not follow normal distribution.

Table 2. Summary Statistics

	country	Mean	S.D.	Skewness	Kurtosis
1997. 7 ~ 2002. 12	Korea	-0.0256	2.6093	-0.2298	3.9635
	USA	-0.0014	1.2259	-0.4102	4.3573
	Japan	-0.1311	1.3974	0.1219	3.4367
	Taiwan	-0.1050	1.8889	0.2574	4.3868
	Singapore	-0.0602	1.8100	-0.3246	9.3700
	Hong Kong	-0.0667	1.9253	-0.2900	5.2552
2003. 1 ~ 2009. 11	Korea	0.1161	1.5833	-0.9100	8.8752
	USA	0.0210	1.1617	-1.0599	13.8002
	Japan	0.0167	1.4543	-1.8210	16.5252
	China	0.1057	1.7632	-0.5918	7.3370
	Taiwan	0.0566	1.3503	-0.7463	4.4770
	Singapore	0.0904	1.3040	-0.5421	9.4303
	Hong Kong	0.1035	1.4789	-0.4780	6.3973

4. EMPIRICAL ANALYSIS RESULTS

4.1 Unit root test

As mentioned in section 2.1, before analysis unite root test is applied for all the series to confirm the integrated number. The results are shown below.

Table 3. Unit Root Test of Log Price Data

Index	# of lags	statistic	5% critical value	unit root
KOSPI composite index	4	-2.6700	-3.4320	O
S&P 500 index	4	-2.1057	-3.4320	O
NIKKEI 225 index	4	-1.9431	-3.4320	O
SSE composite index	4	-1.5633	-3.4200	O
TSEC weighted index	4	-2.7558	-3.4320	O
Straits times index	4	-2.2988	-3.4320	O
Hang Seng index	4	-2.7312	-3.4320	O

Unit root test results of log price data indicate that all the data has unit root, so log price data is differenced one time. Unit root test results of log return data imply that differenced data do not have unit root unlike price data which have unit root. From this results, price data are all I(1). This means the returns of each market are stationary. That is, all stock prices follow a random walk. Therefore, we can conclude that all the stock markets are individually weak-form efficient.

Table 4. Unit Root Test of Log Return Data

Index	# of lags	statictic	5% critical value	unit root
KOSPI composite index	4	-9.5772	-3.4320	X
S&P 500 index	4	-11.0562	-3.4320	X
NIKKEI 225 index	4	-10.8739	-3.4320	X
SSE composite index	4	-7.2138	-3.4200	X
TSEC weighted index	4	-9.9406	-3.4320	X
Straits times index	4	-10.1425	-3.4320	X
Hang Seng index	4	-10.9388	-3.4320	X

4.2 Cointegration Test

From section 4.1, it is known that price data are non-stationary, but log return data are stationary. To handle non-stationary data themselves, cointegration between series should exist.

There exists more than one method to test existence on cointegration. In this paper we use Johansen method widely adopted in a lot of research. Cointegration test applied to old set and new set separately.

Sample (adjusted): 7/14/1997 12/18/2002
Included observations: 556 after adjustments
Trend assumption: Linear deterministic trend
Series: HONGKONG JAPAN KOREA TAIWAN SINGAPORE USA
Lags interval (in first differences): 1 to 4

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.041315	46.50178	95.75366	0.9996
At most 1	0.022790	23.04249	69.81889	1.0000
At most 2	0.014672	10.22480	47.85613	1.0000
At most 3	0.002968	2.006998	29.79707	1.0000
At most 4	0.000381	0.354409	15.49471	1.0000
At most 5	0.000257	0.142787	3.841466	0.7055

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.041315	23.45929	40.07757	0.8544
At most 1	0.022790	12.81769	33.87687	0.9963
At most 2	0.014672	8.217798	27.58434	0.9981
At most 3	0.002968	1.652589	21.13162	1.0000
At most 4	0.000381	0.211621	14.26460	1.0000
At most 5	0.000257	0.142787	3.841466	0.7055

Figure 1. Johansen Cointegration Test Result of Old Set

Both trace statistic and max-Eigen statistic shows that there is no cointegration among series in both old set and new set, because all the statistics are less than 0.05 critical values. This implies that stock markets of six countries do not share long-run equilibrium. Those markets move separately eventually and this represents that stock market of those countries are efficient.

We cannot use VECM model for these data, because there is no cointegration. Although no long-run equilibrium is found in relationship among these stock markets, markets can affect on each other in short term.

Sample (adjusted): 1/28/2003 11/18/2009
Included observations: 677 after adjustments
Trend assumption: Linear deterministic trend
Series: CHINA HONGKONG JAPAN KOREA SINGAPORE TAIWAN USA
Lags interval (in first differences): 1 to 4

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.053572	97.88867	125.6154	0.6672
At most 1	0.032248	60.61274	95.75366	0.9429
At most 2	0.028135	38.42119	69.81889	0.9676
At most 3	0.020420	19.10061	47.85613	0.9948
At most 4	0.005462	5.133256	29.79707	1.0000
At most 5	0.001387	1.425241	15.49471	0.9993
At most 6	0.000717	0.485275	3.841466	0.4860

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.053572	37.27593	46.23142	0.3254
At most 1	0.032248	22.19155	40.07757	0.9100
At most 2	0.028135	19.32057	33.87687	0.8019
At most 3	0.020420	13.96736	27.58434	0.8249
At most 4	0.005462	3.708015	21.13162	0.9997
At most 5	0.001387	0.939966	14.26460	0.9999
At most 6	0.000717	0.485275	3.841466	0.4860

Figure 2. Johansen Cointegration Test result of New Set

4.3 VAR and multivariate GARCH model

We estimate the log return equation using Vector Autoregressive(VAR) model. The following conditional expected return equation includes each market's own returns and the returns of other markets lagged one, two, three and four weeks.

$$\text{mean } R_t = c + \sum_{i=1}^{4} A_i R_{t-i} + \varepsilon_t, \quad \varepsilon_t \mid I_{t-1} \sim N(0, H_t)$$

where R_t is an n by 1 vector of weekly returns at time t for each market. ε_t is the innovation for each market at time t. c is long-term drift coefficients. The estimated coefficient A can provide measures of the significance of the own and cross-mean spillovers. The effect of the innovations in the k period lagged mean return of one market i to market j is measured as $A_k(i, j)$.

The estimated coefficients and their standard errors for mean equation of old set are presented in Table 5. The market we consider is Korean market, so we presented only coefficients related to Korean market. Before 2003, the Korea mean return is significantly influenced by one week and three week lagged Korea own return, one and two week lagged USA return, three week lagged Japan return and three week lagged Taiwan return. The most influence factor is one week lagged USA return and its value is 0.4044. This means that a 1% increase in the USA market is associated with a 0.4044% increase in the Korean market. The overall influence of USA is even greater than Korea own influence. Japan and Taiwan also influence Korea, but the value is relatively small and the lag is large. Singapore and Hong Kong have no significant influence on Korea.

Table 5. Estimated Coefficients for Conditional Mean Return Equations of Old Set

Variable	lag	Significance	Coefficient	t-statistic	p-value
Singapore	1		-0.0984	-0.7947	0.4275
Singapore	2		-0.1504	-1.2328	0.2188
Singapore	3		-0.0874	-0.7210	0.4716
Hong Kong	1		0.1170	0.9865	0.3248
Hong Kong	2		-0.0085	-0.0736	0.9414
Hong Kong	3		0.1014	0.8730	0.3835
Korea	1	***	-0.2037	-2.8812	0.0043
Korea	2		0.0799	1.1103	0.2679
Korea	3	**	0.1562	2.1778	0.0303
U.S.A	1	***	0.4044	2.6999	0.0074
U.S.A	2	**	0.3560	2.2745	0.0238
U.S.A	3		-0.0475	-0.3000	0.7644
Japan	1		-0.1898	-1.4589	0.1458
Japan	2		0.0608	0.4616	0.6448
Japan	3	**	-0.2644	-2.0168	0.0448
Taiwan	1		0.0241	0.2575	0.7970
Taiwan	2		0.0973	1.0369	0.3008
Taiwan	3	*	0.1631	1.7225	0.0862
constant			-0.0093	-0.0593	0.9528

Note: Asterisks indicate significance at the * 0.10, ** 0.05 and *** 0.01 level. All four weeks lagged results are not significant, so they are omitted.

Table 6. Estimated Coefficients for Conditional Mean Return Equations of New Set

Variable	lag	Significance	Coefficient	t-statistic	p-value
Singapore	1		0.1594	1.2417	0.2153
Singapore	2		0.0045	0.0348	0.9723
Singapore	3		0.1316	1.0237	0.3068
Singapore	4	**	0.2716	2.1572	0.0317
Hong Kong	1		-0.0853	-0.7997	0.4245
Hong Kong	2		-0.0519	-0.4866	0.6269
Hong Kong	3		-0.0176	-0.1627	0.8709
Hong Kong	4		-0.0279	-0.2608	0.7944
Korea	1	**	-0.2270	-2.5292	0.0119
Korea	2	***	-0.3389	-3.7807	0.0002
Korea	3		0.0032	0.0353	0.9718
Korea	4		0.0802	0.8911	0.3736
U.S.A	1	***	0.3229	3.0276	0.0027
U.S.A	2	***	0.4695	4.2655	0.0000
U.S.A	3		-0.1179	-1.0275	0.3050
U.S.A	4		-0.0572	-0.5120	0.6090
Japan	1	**	-0.1829	-1.9201	0.0557
Japan	2	**	0.1976	2.0610	0.0401
Japan	3		0.0255	0.2605	0.7947
Japan	4		-0.1336	-1.3674	0.1725
Taiwan	1		0.0904	1.0094	0.3136
Taiwan	2		0.1067	1.1929	0.2338
Taiwan	3		0.0183	0.2080	0.8354
Taiwan	4		-0.0647	-0.7250	0.4690
China	1	*	-0.0920	-1.7558	0.0801
China	2		0.0411	0.7866	0.4321
China	3		-0.0789	-1.5245	0.1284
China	4		-0.0126	-0.2447	0.8069
constant		*	0.1428	1.7418	0.0825

Note: Asterisks indicate significance at the * 0.10, ** 0.05 and *** 0.01 level.

The estimated coefficients and their standard errors for mean equation of new set are presented in Table 6. The results are similar with results of old set, but the overall influence of Japan is increase. Moreover China and Singapore have also influence instead of Taiwan. However the most influence factor is USA. The Granger causality test is conducted for both old set and new set mean equations. The results are presented in Table 7 for old set and Table 8 for new set. With the level of 5%, only Korea and USA are useful in forecasting the Korean market. However, as shown in Table 8, after 2003 Japan begin to show the significant influence on Korea.

Table 7. Granger Causality Test Results for Old Set

Variable	F-value	Probability
Singapore	0.7056	0.5887
HongKong	0.5223	0.7194
Korea	3.7610	0.0054
U.S.A	3.0352	0.0181
Japan	2.1041	0.0808
Taiwan	1.0866	0.3636

Table 8. Granger Causality Test Results for New Set

Variable	F-value	Probability
Singapore	1.6276	0.1670
HongKong	0.2215	0.9263
Korea	5.5947	0.0002
U.S.A	7.5085	0.0000
Japan	2.5827	0.0372
Taiwan	0.7495	0.5590
China	1.7966	0.1292

4.4 Impulse Response Analysis

Impulse response analysis is the method to see the effect of the unit shock in previous time on the future response. Through this analysis, we can observe that which stock market is more related to the Korean stock market.

In this analysis, we use daily series, because we thought that weakly series is not appropriated to detect instant reaction when unit shock is introduced. The series is divided into two sets. One set contains data from Jul 1997 to Dec 2002 and the other set contains data from Jan 2003 to Dec 4th 2009. We call first set old set and latter one new set.

The lag of VAR model used for this analysis is four consistent with other analysis. It cannot be shown all the results of impulse analysis because of lack of space and it is also meaningless. We put results which show significant implication.

The result of impulse response analysis may be different as the way to order variables which is not unique and depends on analysts. The general rule for ordering is to choose variables in the order of significance which means the degree how much one market has an effect on the other markets.

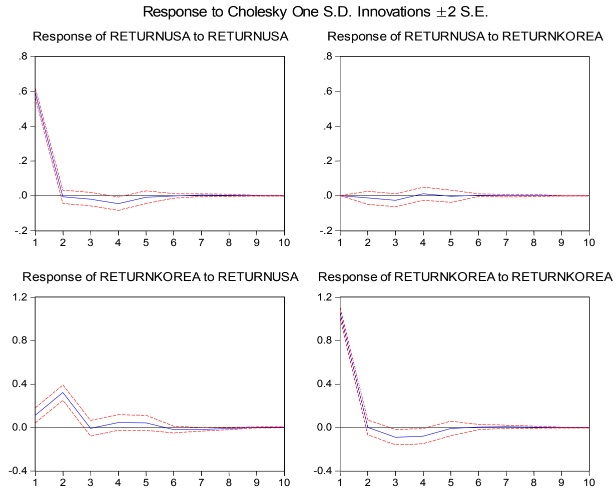

Figure 3. Impulse Response between Korea and USA in Old Set

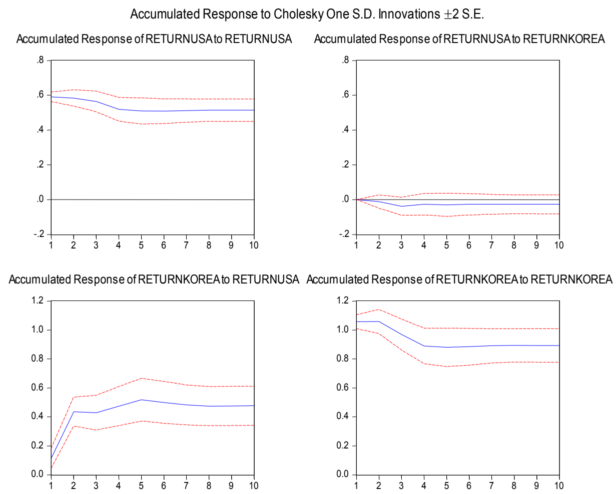

Figure 4. Accumulated Response between Korea and USA in Old Set

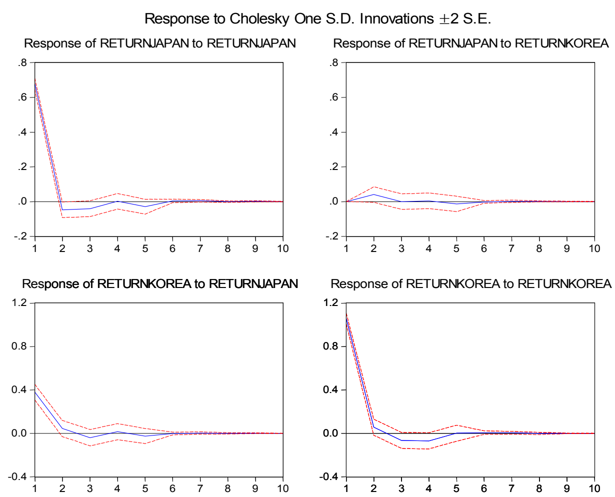

Figure 5. Impulse Response between Korea and Japan in Old Set

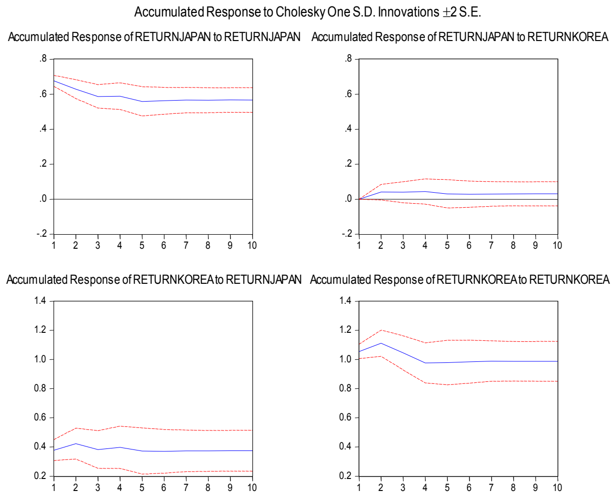

Figure 6. Accumulated Response between Korea and Japan in Old Set

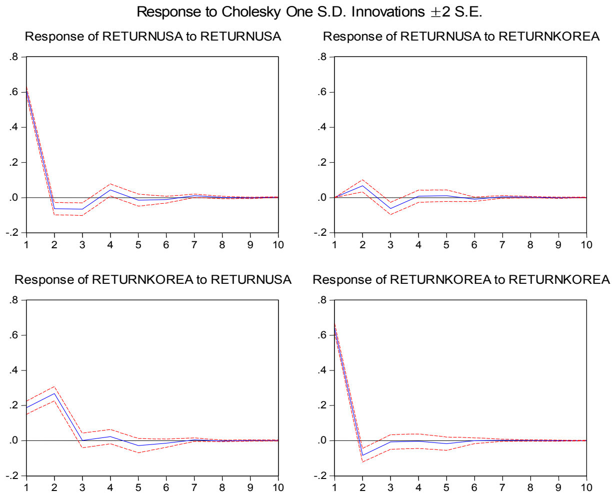

Figure 7. Impulse Response between Korea and USA in New Set

Following result is obtained from old set. First, we choose S&P 500 as the first variable which shows significant value in all the mean function and NIKKEI 225 is set to be ahead of KOSPI composite index. Impulse response analysis of old set tells that only unit shock of S&P 500 draws the response from KOSPI index and this response come out as lag 2 not lag 1. From this result, news in S&P 500 does not affect simultaneously on KOSPI index and it has some time lags. Accumulated response is about 0.4773 unit. NIKKEI 225 also makes response from KOSPI composite index caused by unit shock and its accumulated response at lag 10 is about 0.3743 stable over lags.

The result of impulse response analysis of new set shows different from that of old set a little. Unit shock of S&P 500 and NIKKEI 225 still draws the response. The time to appear response from unit shock of S&P 500 is lag 2 and this is same result in old set. The time to appear response from unit shock of NIKKEI 225 is lag 1, which tells us that unit shock of NIKKEI 225 draws response from KOSPI composite index right after shock was introduced. Accumulated response to S&P is about 0.4407 unit at lag 10 smaller than in old set. This means that the effect of news in USA market has reduced a little bit. Accumulated response to NIKKEI 225 is about 0.4055 unit at lag 10 higher than old set. KOSPI composite index shows response, caused by unit shock of SSE composite index, at lag 1, but the value is lower than response caused by both unit shock of S&P 500 and NIKKEI 225. Accumulated response to SSE composite index is about 0.1498 unit. These results are consistent with order of coefficients of VAR model. In VAR model, log return of S&P 500 is said to Granger cause KOSPI composite index most and log return of NIKKEI 225 is also said to Granger cause KOSPI composite index.

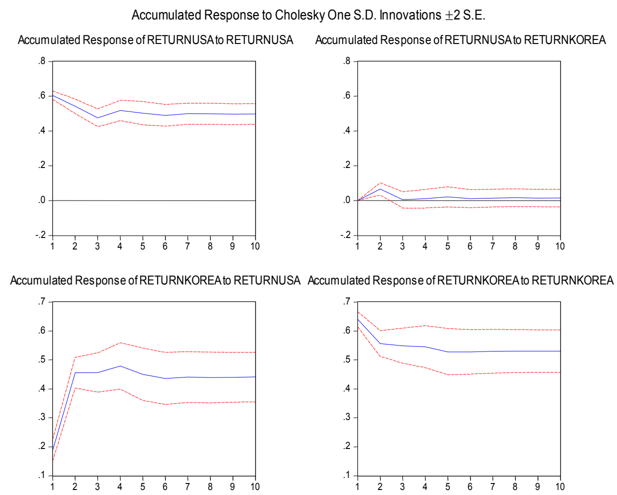

Figure 8. Accumulated Response between Korea and USA in New Set

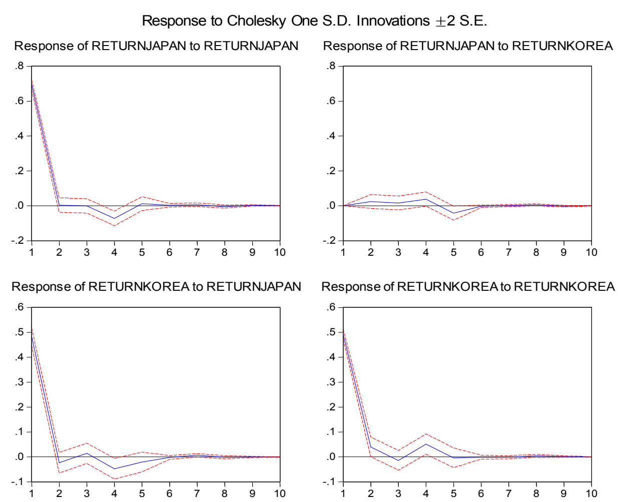

Figure 9. Impulse Response between Korea and Japan in New Set

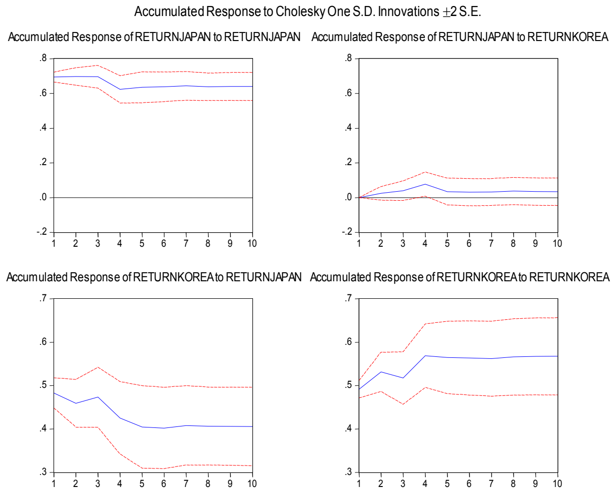

Figure 10. Accumulated Response between Korea and Japan in New Set

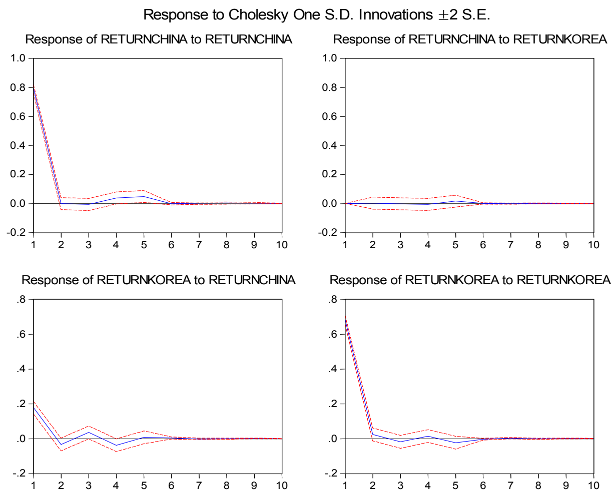

Figure 11. Impulse Response between Korea and China in New Set

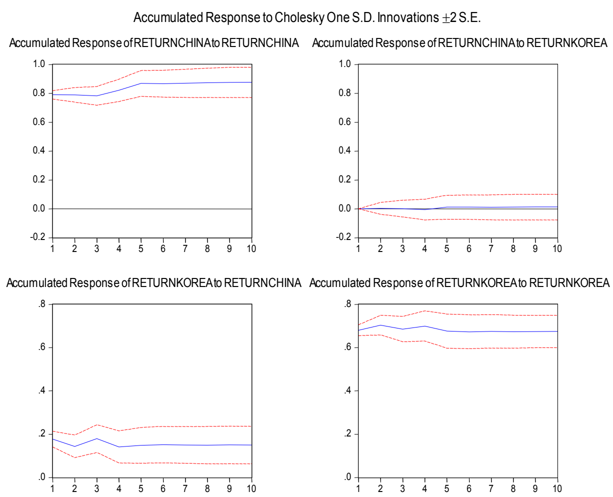

Figure 12. Accumulated Response between Korea and China in New Set

5. CONCLUSIONS

We examined the weak-form efficient market hypothesis for each of the seven countries, Korea, USA, Japan, China, Taiwan, Hong Kong, and Singapore. All of seven countries are weak-form efficient, i.e. their returns follow random process. However, their returns are not collectively efficient. Some of countries affect other countries' returns. USA and Japan have the greatest overall influence on Korea market returns. Yet the influence of China market is weak compared to USA and Japan. In the case of volatility spill-over, Taiwan has the greatest influence on Korea market volatility. This analysis is meaningful to the investors who want diversified their portfolio.

For further research, we can use daily and monthly data. We can also consider other countries stock markets and other markets like art, commodity, option, currency and so on.

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