Long Run Co-integration Relationships in the Three Asian and the U.S. Stock Markets before, during and after the global financial crisis

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Abstract

We did not find cointegration among the stock markets of Asain countries and the U.S. for the period from December 1997 to April 2016. However once we take structural changes into consideration (pre-financial crisis, during financial crisis, post-financial crisis), each sub period has cointegrations on its own. Bi-variate and tri-variate cointegration tests confirmed that the financial crisis triggered cointegrations and the degree of cointegration among the four countries has increased after the financial crisis. However the cointegration has become a very calm type after the crisis when we treat KOPSI as dependent variable in the VECM. However it is worthy to note that the speed of adjustment of China and the U.S. have become significant after the financial crisis, while that of Japan has become insignificant after the financial crisis. It may imply the advancement of Chinese economy in the world financial market.

1. Introduction

Financial integration, both domestically and internationally, has increased vastly last decades. Technological progresses have facilitated transactions of capital and transmissions of news, liberalizations of capital movements have increased cross-border flow of capital, and market deregulations have harmonized the structure of financial markets worldwide.

Understanding the market interdependency is important for a number of reasons. Firstly, it has imperative implications for portfolio managers making asset allocation decisions. The capital asset market theory suggests that international diversification reduces the idiosyncratic risk. However, a higher degree of comovements among the international markets negatively affects the scope of cross-border diversification. Secondly, interdependencies among financial markets have significant consequences for policy makers and regulators working to stabilize financial markets. The risk of financial contagion has been fueled by an increasingly globalized world. To ease these contagious effects policy-makers and regulator have to assess the market interdependencies in order to implement mechanisms that enable effective monitoring of international capital flows.

The collapse of the US sub-prime mortgage market in the summer of 2007 and the ensuing Lehman failure in September of 2008 triggered a financial crisis in the United States that was considered to be the most serious global crisis since the Great Depression.

Our objective in this paper is to probe how the long run causal, cointegrating and equilibrium relationship among the stock markets in Korea, Japan, China and the U.S. has changed during January 1998 and April 2016, which includes the global financial crisis period. More precisely, this study targets the following research questions: (1) Are there any interdependencies among the stock markets in the four equity markets? (2) If yes, has the global financial crisis affected the strength of the long-run dynamic linkages in the region? The application of the Johansen test of cointegration and VECM on monthly data will enable an examination of the long-run relationships.

This study contributes to the literature on financial interdependencies in several respects. Firstly, this study explores how the stock markets in the three Far eastern Asian countries and the U.S. move together. Secondly, by using up-to-date observations, this study captures the effects of global financial crisis, which originated from the U.S. The inclusion of data up to April, 2016 allows for a rigorous analysis of how the global financial crisis has affected the market dependencies in the region.

Section 2 gives a review of the literature and theory. Section 3 introduces the methodology framework used to investigate the research questions. Section 4 describes the data and provides preliminary results. Section 5 presents the empirical results and Section 6 summaries the findings and concludes the study.

2. literature Review

The benefits of international diversification, together with liberalization and deregulation of financial markets, have enticed cross-border investments and globalized financial markets. According to Gagnon and Karolyi (2006), this process has increased the financial linkages among seemly unrelated economies and has triggered the contagious effects experienced in times of financial turmoil. Amongst others, Koutmos and Booth (1995) and Kanas (1998) evidenced that the interdependencies between major stock markets increased after the Crash of October 1987, Chiang et al (2007) and Yilmaz (2010) showed that volatility correlation strengthen among Asian equity markets during the East Asian Crisis of 1997, and Boubaker and Jaghoubi (2011) and Zhou et al (2012) demonstrated that financial markets worldwide experienced contagious effects in the outbreak of the Subprime crisis.

Karolyi and Stulz (1996), in an attempt to explain why stock markets move together, found that macroeconomic announcement and shocks in the foreign exchanges and treasury bills markets had no measurable effects on the comovements between the US and Japanese stock market. However, they showed that shocks in broad market based indices, such as S&P 500 and Nikkei Stock Average, impacted both the persistence and strength of the correlations.

Another course of the literature has targeted the interdependencies among regional stock markets. The main finding from these studies is that markets which are geographically close to each other tend to be more correlated. For instance, Janakirmanan and Lamba (1998) discerned that stock markets in the Pacific-Basin region influence one another and Al-Deehani and Moosa (2006) observed significant correlation among three major stock markets in the Middle East. Johansson and Ljungwall (2008) noticed short-run dynamic linkages among the Greater China´s stock markets, despite significant regulatory impediments that limited cross-border investments, and suggested geographic proximity as a plausible explanation.

The Johansen test of cointegration has been applied in several studies, including Richards (1995), Niarchos et al (1999), Johansson and Ljungwall, (2008), and Badhani (2009). Richards (1995) using the Johansen test of cointegration to investigate whether there exist long-run relationships among the Japanese, the US, and several European stock markets. The purpose of the study was to empirically test the efficient market theory, which suggests that cointegration is unlikely to be observed. Richards (1995) found no evidence of cointegration and argued that each index series includes country-specific components which cause them to behave differently over time. Niarchos et al (1999), Johansson and Ljungwall, (2008), and Badhani (2009) used the Johansen test of integration to examine the long-run relationship between the Greek and the U.S stock market, the stock markets in Greater China, and the Indian and the U.S stock market, respectively. None of these studies found supporting evidence of cointegration.

Huang et al.(2000) allowed for structural breaks and found that there exists no cointegration among theU.S., Japan, and the South China Growth Triangle. Hwang et al. (2013)investeigated the global financial crisis period and found that each country had different patterns in the three distinctive phases of crisis spillover(contagion, herding and post-crisis adjustment). Zhang(2014) found no comovement between the Chinese and U.S. stock markets over the period between January 4, 2000 and January 13, 2012, even when allowing for structural change.

3. Data and Methodology

The presence of a cointegrating vector can be interpreted as the presence of a long-run equilibrium relationship. Therefore, the Johansen test of cointegration is first employed in its multivariate form to identify whether any long-run cointegrating relationships among the stock markets in the area exist. If all return series are cointegrated, a vector error correction model (VEC) model should be specified for the mean equation. Otherwise, if the return series are not cointegrated, the mean equations should be specified by using a standard vector autoregressive (VAR) model. Furthermore, Niarchos et al (1999) state that the lack of cointegration suggests that if mean spillovers exist, they are, at most, short-run in nature. In other words, the lack of cointegration, but evidence of mean spillovers implies that these are of short-run character.

a. Bai-Perron Structural break test

Bai and Perron(1998) have developed a method to check whether a structural break is occurring. For a standard multiple linear regression model with T periods and m potential breaks(producing m+1 regimes), we have regression model in regime j as follows

$$y_t = c_j + \sum_{i=1}^{p} \alpha_i^j \, y_{t-i} + \epsilon_t \tag{1}$$

where j = 1 for t < T_B, and j = 2 for t ≥ T_B. The term T_B denotes the break point. We apply the Bai and Perron test (1998) to find the existence of multiple structural breaks in the time series. For this test, we use the same model as above, where j = 1 for t <T_{B1}, j = 2 for T_{B1}≤ t < T_{B2}, ..., and j = m + 1 for T_{BM} ≤ t. We set the number of structural breaks at 2 in order to differentiate the pre-crisis, during crisis and post crisis periods.

b. Long Run Granger Causality Test

Granger causality test is applied to check for presence of any long run causal relationship between stock prices. A time series X is said to Granger-cause Y if it can be shown, usually through a series of t-tests and F-tests on lagged values of X (and with lagged values of Y also included), that those X values provide statistically significant information about future values of Y. The test is based on the following regressions:

$$Y_t = \alpha_{10} + \alpha_{11} Y_{t-1} + \ldots + \alpha_{1p} Y_{t-p} + \beta_{11} X_{t-1} + \cdots + \beta_{1p} X_{t-p} + \varepsilon_{1t} \tag{2}$$

$$Y_t = \alpha_{20} + \alpha_{21} Y_{t-1} + \ldots + \alpha_{2p} Y_{t-p} + \varepsilon_{2t}$$

Where, the two variables are Yt and Xt . Error terms are ϵ_{1t} , ϵ_{2t}. and the number of lags is denoted by p whereas time period is denoted by t. H_0 (X does not granger cause Y) is $\beta_{11} = \cdots = \beta_{1p} = 0$. Granger causality test establishes short run causality if we take stationary values. "Causality tests by the level Vector Auto Regression (VAR) (non-stationary) can complement the result of the cointegration tests in terms of long-run information" (Worthington & Higgs, (2007). So, non-stationary level time series data of variables have been used to determine long run causality. Optimal lag length for conducting granger causality test has been determined as per the Akaike Information Criterion (AIC) within the VAR framework.

c. Johansen Co-integration test

The Johansen test of cointegration commences with a vector autoregression (VAR) representation of the variables. Each variable is handled symmetrically with an equation explaining its process based on its own past values and the past values of the other variables included in the model. The variables are assumed to be integrated of order one, usually denoted I(1). The VAR p-dimensional process VAR(p), is given by equation (3):

$$y_t = \mu + A_1 y_{t-1} + \cdots + A_P y_{t-p} + \epsilon_t \tag{3}$$

Where y_t is a $\mathrm{n} \times 1$vector of the dependent variables; μ is a vector of constants, and ε_t is a $\mathrm{n} \times 1$vector of innovations. This VAR process can be transformed to a vector error correction (VEC) model by using the difference operator $\Delta y_t = y_t - y_{t-1}$: . The VEC model is given by equation (4):

$$\Delta y_t = \mu + \Pi y_{t-1} + \sum_{t=1}^{p-1} \Gamma_i \Delta y_{t-i} + \epsilon_t \tag{4}$$

Where Π and Γ_i are matrixes of variables in accordance with equation (5) and (6) respectively:

$$\Pi = \sum_{t=1}^{p} \mathrm{A}_t - \mathrm{I} \quad (5)$$

$$\Gamma_i = -\sum_{j=i+1}^{p} \mathrm{A}_j \quad (6)$$

The Johansen test statistic, commonly derived by a trace test, is calculated with equation (7):

$$J_{trace}(r) = -T \sum_{i=r+1}^{n} \ln(1-\lambda_i) \quad (7)$$

Where T is the sample size, n is the number of stationary relationships in y_t, and λ_i is the real number of eigenvalues of Π. The test procedure begins with the test for no cointegrating relationships and then accepts the first null hypothesis that is not rejected. The first null hypothesis that is not rejected specifies the number of cointegrating relationships. The critical value for each rank can be found in Johansen (1995).

d. Vector Error Correction Model

A Vector Error Correction Model (VECM) is a restricted VAR that has Cointegration restrictions built into the specification, so that it is designed for use with non-stationary series that are known to be cointegrated. The VECM specification restricts the long run behavior of the endogenous variables to converge to their cointegrating relationships while allowing a wide range of short-run dynamics. The cointegration term is known as the error correction term since the deviation from long-run equilibrium is corrected gradually through a series of partial short-run adjustments. A Vector Error Correction Model (VECM) can lead to a better understanding of the nature of any non-stationarity among the different component series and can also improve longer term forecasting over an unconstrained model. The coefficient of the VECM describes whether a particular variable leads or lags the other variable in times of any destabilization.

According to Granger representation theorem, if the rank(r) of Π in equation(4) is less than number of variables in y_t (r$\leq \mathrm{n}-1$), then there exists $\mathrm{n} \times \mathrm{r}$ matrix α and β, where $\Pi = \alpha \beta'$ that makes all the components of $\beta' X_t$ stationary. By replacing Π with $\alpha \beta'$ in equation (4), Granger representation theorem is represented in equation (10).

$$\Delta y_t = \mu + \alpha\beta' y_{t-1} + \sum_{t=1}^{p-1} \Gamma_i \Delta y_{t-i} + \epsilon_t \tag{10}$$

Matrix β is composed of cointegrated vectors. Componets in Matrix α are interpreted as weights on matching component of cointegrated vector. Equation (8) shows short-term dynamic characteristics of the cointegrated variables to recover long-term equilibrium so that we call equation (8) as vector error correction model.

Matrix $\beta' y_{t-1}$ is composed of r stationary processes. The cointegrated variables in the r processes have long term equilibrium relations. If there is any random shock that breaks the long-term equilibrium, error correction mechanism begins to work to restore long-term equilibrium. Matrix α shows the adjustment speed and is called as coefficients of adjustment speed or adjustment coefficients. Bigger component in α implies higher speed of adjustment to restore equilibrium. If a component in α is close to zero, then that variable does not respond to the breakage of the long term equilibrium.

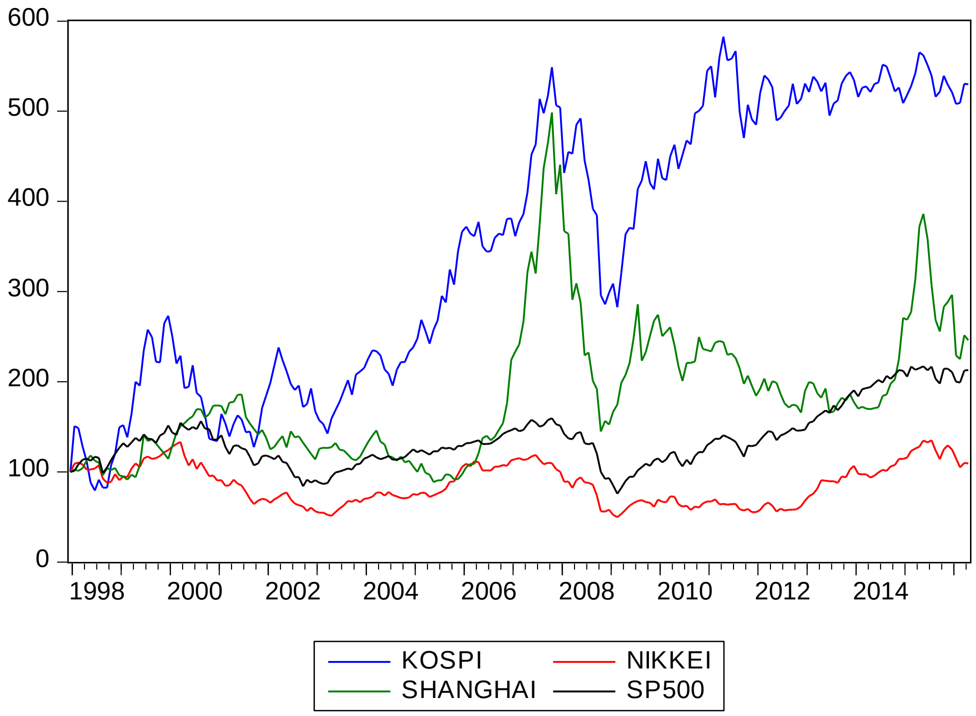
4. Basic Results

The data are consisted of monthly stock market index return series from Korean KOSPI, China SSE, Japan Nikkei 225 and U.S.S&P500 covering the period December 1997 to December 2016. Using Bai and Perron(1998) approach in equation(1), the period is further decomposed into three sub-periods to enable an analysis of how the global financial crisis has impacted the interdependencies in the region

Monthly data is used instead of daily data in order to investigate long term relationships. The data for these index series are collected from Bank of Korea, Korean stock exchange, and Federal Reserve Bank of Saint Louis. Each data set includes 221 observations.

We normalized the observations on December 1997 to 100 so that we can compare the changing patterns to one another. Each index series is plotted against time. The result is demonstrated in Figure 1.

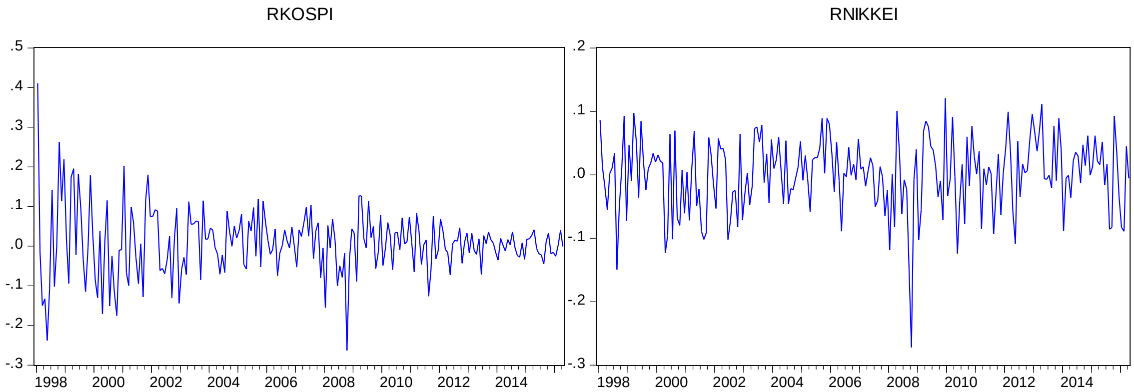
Figure 1. KOSPI, Nikkei, SSE, and SP500(1997.12-2016.04)



The development of the index series over the full sample period diverge significantly, where the KOSPI is at the upper extreme with a positive return and the Nikkei225 is at the lower extreme with a negative return. The levels of the indices indicate non-stationarity, a well-observed characteristic of stock markets. The indication of non-stationarity increases the likelihood of cointegration among the four return series.

Figure 2 shows the daily returns for each return series. The rate of return $R_{i,t}$is computed as continuously compounded with $(R_{i,t} = 100 * \log(\frac{P_{it}}{P_{i,t-1}})$) for index *i* at time t and P_{it} is the price level of index *i* at time *t*. The continuous compounded return series exhibit no trend, which is an indication of stationary. However, the volatility seem to be clustered, which means that large swings tend to be followed by large swings and small swings tend to be followed by small swings. The latter is an indication of GARCH effects. Figure 1 and 2 support the sectioning of the subsamples since the period ending in 2009 is characterized by positive returns

Figure 2 Return (1997.12-2016.04)



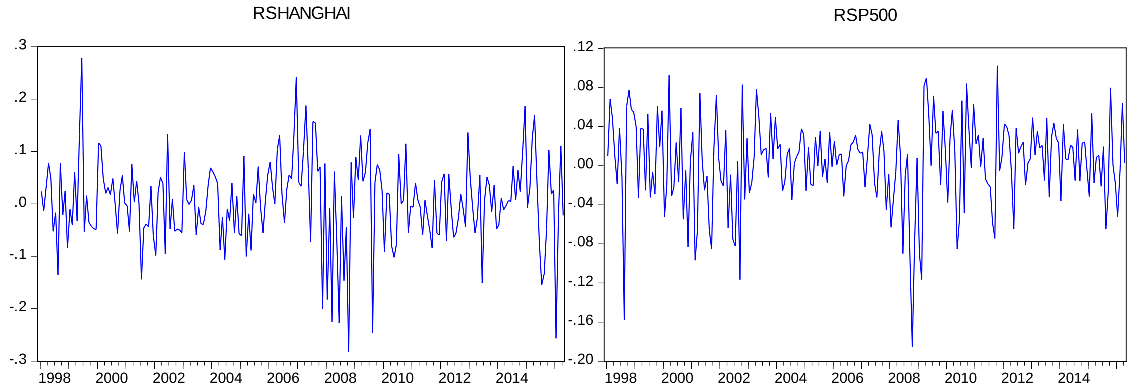


Table 1 gives the descriptive statistics for the full sample return series. The monthly mean returns range from 0.0869% in Japan to positive 0.764% in Korea, while the standard deviations range from 4.5% in the U.S. to 8.2% in Korea. The latter indicates that the U.S. is the least volatile market, while the Korean stock market is the most volatile market. Japanese market shows least mean return, while the volatility is not the least. Moreover, during the sample period, the Japanese market has experienced the largest one-month drop in the index, with negative 28.5%, and the Korean market the largest one-month hike in index, with positive 41.06%.

Table 1 : Summary Statistics for full sample return series

	KOSPI	Nikkei	SSE	SP500
Mean	0.008	0.000	0.004	0.003
Median	0.007	0.005	0.007	0.009
Maximum	0.411	0.121	0.278	0.102
Minimum	-0.263	-0.272	-0.283	-0.186
Std. dev.	0.082	0.058	0.082	0.045
Skewness	0.456	-0.717	-0.323	-0.800
Kurtosis	6.113	4.379	4.593	4.535
JB	96.470(0.00)	36.273(0.00)	27.080(0.00)	45.054(0.00)
LB(40)	38.216(0.55)	25.055(0.97)	70.879(0.00)	36.070(0.65)
LB2(40)	137.04(0.00)	32.467(0.80)	72.948(0.00)	56.060(0.05)

ADF	-1.339(0.61)	-1.534(0.51)	-1.974(0.30)	-0.475(0.89)
PP	-1.383(0.59)	-1.817(0.37)	-2.520(0.11)	-0.602(0.87)

Note: Summary statistics for monthly return data, covering the period January, 1997 to April, 2016. LB (Ljung-Box statistic) tests for serial correlation in the return and LB2 tests for serial correlation in the squared return. The number of lags is specified in the parenthesis. ADF is augmented Dicky and Fuller test and PP is Phillip-Perron test for log(level). Numbers in ( )are p-values

The measures for skewness imply that all return series are skewed but in different directions. Korea is positively skewed, while Japan, China and the U.S. are negatively skewed. A negative skew indicates that negative shocks occur more frequently than positive shocks, while the opposite is true for a positive skew. The measures for excess kurtosis also demonstrate that all return series are leptokurtic, which indicates that large shocks are more frequent than expected in all markets. Most of the measures for skewness and excess kurtosis are statistically significant at 1% level, which means that the null hypothesis of normal distribution can be convincingly rejected for all return series. Jacque-Berra statistics reject normality for every series.

The Ljung-Box Q statistic tests for serial correlation up to 40 lags lengths. Only the Chinese result report the Q statistic to be significant at 40 lags, which implies serial correlation in the return. For squared return, only Japanese return series shows no significance. Significant squared return series indicates non-randomness and the presence of ARCH effects in the returns.

The Augmented Dickey-Fuller (ADF) and Phillips- Perron(PP) tests are used to examine whether the index series contain a unit root or not. Most researchers agree that the financial times series are integrated of order 1 and thus share a unit root, which in turn is an indication of cointegration. The level of integration in each index series must, however, be identified before they can be tested for cointegration. The ADF test-statistics and PP test-statistics for the levels fail to reject the null hypothesis of non-stationarity. The results suggest that the four index series are integrated of order 1.

Consequently, the Johansen test of cointegration is an appropriate method for testing whether the four stock markets are cointegrated. We are also interested at how the cointegration patterns change over time[1].

5. Empirical Findings

a. Long term Granger causality test

Before performing the Granger causality and error correction causality test, let's look at the correlation patterns. Table 2 shows that the correlation has strengthened as time goes on. Before the crisis Chinese market was not correlated with any other countries[2]. However, the global financial crisis put the Chinese market to be correlated with the neighboring markets and the U.S. Japan and Korea are correlated with the U.S. market all through the years.

Table 2: Correlation Coefficient Patterns Chnage

		RK	RN	RS	RSP
1997/12-2016/04	RK	1.000			
	RN	0.513	1.000		
		(8.813)			
		[0.000]			
	RS	0.221	0.324	1.000	
		3.340	5.059		
		0.001	0.000		
	RSP	0.523	0.599	0.297	1.000
		9.061	11.036	4.592	
		0.000	0.000	0.000	

[1] Furthermore, the preliminary results also imply that each return series exhibits ARCH and GARCH effects. This suggests that the DCC-MGARCH model fits the purpose for the investigation of the spillovers.

[2] The whole period was divided into three sub-periods using Bai and Perron(1998) approach. As the crisis was originated from the U.S., the sub-periods were estimated for the U.S. market. The other markets were assumed to follow the U.S. sub-periods assignments.

		RK	RN	RS	RSP
1997/12-2006/04	RK	1.000			
	RN	0.527	1.000		
		6.142			
		0.000			
	RS	0.041	0.188	1.000	
		0.404	1.891		
		0.687	0.062		
	RSP	0.481	0.441	0.125	1.000
		5.435	4.866	1.245	
		0.000	0.000	0.216	
2006/05-2009/03		RK	RN	RS	RSP
	RK	1.000			
	RN	0.727	1.000		
		6.078			
		0.000			
	RS	0.624	0.518	1.000	
		4.589	3.481		
		0.000	0.001		
	RSP	0.705	0.829	0.493	1.000
		5.714	8.512	3.251	
		0.000	0.000	0.003	
2009/04-2016/04		RK	RN	RS	RSP
	RK	1.000			
	RN	0.455	1.000		
		4.658			
		0.000			
	RS	0.350	0.354	1.000	
		3.401	3.447		
		0.001	0.001		
	RSP	0.642	0.618	0.383	1.000
		7.631	7.168	3.777	
		0.000	0.000	0.000	

Note : values in ( ) are standard deviations.   Values in [ ] are p-values.

Table 3: Long Run Granger Causality test

Causality Direction	1997/12-2016/04		1997/12-2006/04		2006/05-2009/03		2009/04-2016/04	
LN does not Granger Cause LK	1.114	0.344	0.657	0.581	5.417	**0.004*** **	0.185	0.906
LK does not Granger Cause LN	0.642	0.589	0.803	0.495	5.126	**0.006*** **	0.618	0.605
LS does not Granger Cause LK	0.406	0.749	2.085	0.108	3.013	**0.047** **	1.357	0.262
LK does not Granger Cause LS	2.648	**0.050** **	1.169	0.326	1.455	0.248	0.590	0.623
LSP does not Granger Cause LK	3.220	**0.024** **	2.145	0.100	4.334	**0.012** **	0.175	0.913
LK does not Granger Cause LSP	0.796	0.498	0.729	0.537	3.585	**0.026** **	2.834	**0.044** **
LS does not Granger Cause LN	3.433	**0.018** **	5.604	**0.001*** **	1.657	0.199	3.875	**0.012** **
LN does not Granger Cause LS	0.853	0.466	2.458	**0.068* **	0.142	0.934	0.438	0.726
LSP does not Granger Cause LN	1.636	0.182	1.206	0.312	0.597	0.622	0.308	0.819
LN does not Granger Cause LSP	1.419	0.238	1.009	0.393	3.568	**0.027** **	1.493	0.223
LSP does not Granger Cause LS	0.759	0.518	1.332	0.269	0.345	0.793	0.024	0.995
LS does not Granger Cause LSP	1.620	0.186	2.562	**0.060* **	1.569	0.219	2.573	**0.060* **

Note: * denotes 10% significance. ** denotes 5% significance, and *** denotes 1% significance.
LN is log(Nikkei) LK is log(KOSPI), LS is log(SSE), LSP is log(SP500)

The results of Long run Granger Causality tests for Total, Pre Crisis, during crisis and Post Crisis Periods for all nations are shown in Table 3. We used the lag order of 3 selected according to Akaike information criterion (AIC) within the Vector Auto Regression (VAR) framework. We have seen that China was correlated with Japan only in the pre-crisis period in Table 2. However, we can see in Table 3 that China and Japan are not only correlated but granger cause each other. China granger causes Japan with 1% significance level, while Japan granger causes China with 10% significance level. In table 2 we have seen there is no correlation whatsoever between China and the U.S in the pre-crisis period. But table 3 shows that China granger causes the U.S. with 10% significance level. However Korea does not have any granger causality relationship with any of the other countries.

During the crisis period, we see that the mutual granger causality has become significant with 1% significance level between Korea and Japan. But it loses its significance in the post crisis period. While China has correlation with other countries as we have seen in table 2, it does not have any granger causality relationship with other countries during the crisis period except Korea.

It is also worthy while to note that the U.S. does not granger cause any of Asian countries at the post crisis period. While China granger causes Japan and the U.S. and Korea granger causes the U.S.

In summary table 3 shows that the Granger causality pattern is changed during the crisis. China has begun to granger cause Korea during the crisis and has expanded its range to Japan and the U.S. after the crisis. While the role of the U.S. as a shock originator has shrunken all through the years. The only country that the U.S. kept on granger causing in Korea and that is restricted to the period to before and during the crisis. The observation so far motivates further study to look into cointegrations among the four countries.

b. Johansen cointegration test

Since the four index series are found to be integrated of order one, a Johansen test of cointegration is performed for the four variables combination. The lag length is selected as 2, which is based on Akaki information criterion. Due to the sensitivity of the test to the specification of trend and intercept in the VAR-model, all five combinations of the test are applied. Table 4 shows that there is no cointegration for the whole period. However we can see that at least one cointegration exists for each sub periods. Especially, for the during the crisis period, there are two cointegrations. This observation shows that longer period of observations with structural changes does not guarantee the existence of cointegration. Once the structural changes are considered, we can see that each period is cointegrated.

Table 4 : Johansen quadra-variate cointegration test

	Period	Eigen value	Trace Stat	5% critical value	P-value
1997/12-2016/04	None	0.097	45.445	54.079	0.234
	At most 1	0.071	23.187	35.193	0.516

	At most 2	0.023	7.149	20.262	0.888
	At most 3	0.009	2.029	9.165	0.772
1997/12-2006/04	None *	0.249	54.109	54.079	**0.050***
	At most 1	0.107	26.008	35.193	0.342
	At most 2	0.097	14.888	20.262	0.233
	At most 3	0.048	4.851	9.165	0.300
2006/05-2009/03	None *	0.642	71.266	54.079	**0.001*****
	At most 1 *	0.397	35.352	35.193	**0.048****
	At most 2	0.278	17.621	20.262	0.111
	At most 3	0.163	6.244	9.165	0.173
2009/04-2016/04	None *	0.299	58.218	54.079	**0.020****
	At most 1	0.151	27.974	35.193	0.242
	At most 2	0.116	14.019	20.262	0.288
	At most 3	0.041	3.533	9.165	0.486

Note :The presented numbers are trace-statistic which testing the null hypothesis of R cointegrating relationships. The chosen specification includes a restricted trend. The Akaiki information criterion is used to select the number of lags.

In order to find out how the cointegration is structured. We need to check out the cointegrations in two countries pairs and three countries sets. Table 5 is the results from Johansen bivariate test for all combinations of pairs. All tests involving two countries fail to reject the null hypothesis of no cointegration for the whole period. This means that there is no evidence of any long-run relationship between the stock markets in pairs just as we have seen in the case of four countries in table 4.

Table 5 : Johansen bivariate cointegration test 1997/12-2016/04

	Countries	Period	Eigen value	Trace Stat	5% critical value	P-value
1997/12-2016/04	Korea-Japan	None	0.027	9.977	20.262	0.642
		At most 1	0.018	4.047	9.165	0.405

	Korea-China	None	0.038	11.637	20.262	0.482
		At most 1	0.014	3.180	9.165	0.548
	Korea-U.S	None	0.015	5.386	20.262	0.972
		At most 1	0.009	2.054	9.165	0.767
	Japan-china	None	0.042	15.714	20.262	0.188
		At most 1	0.029	6.447	9.165	0.159
	Japan-US	None	0.036	10.308	20.262	0.610
		At most 1	0.011	2.386	9.165	0.700
	China-U.S.	None	0.032	8.992	20.262	0.737
		At most 1	0.008	1.834	9.165	0.810

However for the sub periods, some cointegrations begin to appear. Table 6 shows that there is no cointegration in the pre-crisis period. During the crisis period, there is just one cointegration between Japan and the U.S. The other countries show no cointragration whatsoever. However in the post crisis period every pair except Japan and China shows cointegrations. This implies that the process of financial crisis solutions triggered cointegrations in the post crisis period. In other words financial crisis forced the world capital market to move toward the same direction.

Table 6: Johansen bivariate cointegration test at 5% significance level

	Countries	Period	Eigen value	Trace Stat	5% critical value	P-value
1997/12-2006/04	Korea-Japan	None	0.078	10.706	20.262	0.571
		At most 1	0.028	2.750	9.165	0.628
	Korea-China	None	0.079	10.735	20.262	0.568
		At most 1	0.027	2.710	9.165	0.636
	Korea-U.S	None	0.024	4.453	20.262	0.991
		At most 1	0.020	2.028	9.165	0.772
	Japan-china	None	0.119	18.142	20.262	0.095
		At most 1	0.056	5.674	9.165	0.217
	Japan-US	None	0.121	14.131	20.262	0.281
		At most 1	0.015	1.453	9.165	0.882
	China-U.S.	None	0.123	18.197	20.262	0.094
		At most 1	0.053	5.323	9.165	0.250

2006/05-2009/03	Korea-Japan	None	0.201	10.830	20.262	0.559
		At most 1	0.082	2.988	9.165	0.583
	Korea-China	None	0.239	15.859	20.262	0.181
		At most 1	0.165	6.291	9.165	0.169
	Korea-U.S	None	0.229	12.522	20.262	0.403
		At most 1	0.093	3.397	9.165	0.509
	Japan-china	None	0.182	10.434	20.262	0.597
		At most 1	0.093	3.408	9.165	0.507
	Japan-US	None *	0.436	23.513	20.262	**0.017****
		At most 1	0.094	3.460	9.165	0.499
	China-U.S.	None	0.220	11.816	20.262	0.465
		At most 1	0.086	3.133	9.165	0.556
2009/04-2016/04	Korea-Japan	None *	0.275	28.481	20.262	**0.003*****
		At most 1	0.014	1.159	9.165	0.930
	Korea-China	None *	0.270	30.155	20.262	**0.002*****
		At most 1	0.039	3.398	9.165	0.509
	Korea-U.S	None *	0.264	32.831	20.262	**0.001*****
		At most 1	0.076	6.754	9.165	0.140
	Japan-china	None	0.089	9.793	20.262	0.660
		At most 1	0.021	1.825	9.165	0.812
	Japan-US	None *	0.205	22.249	20.262	**0.026****
		At most 1	0.032	2.762	9.165	0.626
	China-U.S.	None *	0.214	23.421	20.262	**0.018****
		At most 1	0.034	2.915	9.165	0.597

Table 7 is the results when tri-countries sets are considered. For the whole period there is cointegration for the three Asian countries only. If we combine this observation with that in table 5, we may conclude that the geographical proximity is the main reason for the cointegration.

Table 7: Johansen trivariate cointegration test 1997/12-2016/04

	Countries	Period	Eigen value	Trace Stat	5% critical value	P-value
1997/12-2016/04	Korea Japan China	None	0.087	33.405	35.193	**0.077***
		At most 1	0.040	13.509	20.262	0.325
		At most 2	0.021	4.658	9.165	0.323
	Korea Japan U.S.	None	0.046	18.519	35.193	0.813
		At most 1	0.028	8.240	20.262	0.804

		At most 2	0.009	1.954	9.165	0.787
	Korea China U.S.	None	0.049	16.557	35.193	0.904
		At most 1	0.015	5.557	20.262	0.966
		At most 2	0.010	2.156	9.165	0.747
	Japan China U.S.	None	0.093	30.671	35.193	0.142
		At most 1	0.030	9.409	20.262	0.698
		At most 2	0.012	2.715	9.165	0.635

J However we see that once we take into structural change into consideration, three countries set cointegrate. Just as we did in table 5 and 6, we need to investigate the sub periods. Table 8 shows that for the pre-crisis period only Japan-China-US set is cointegrated, while there is no cointegration in the three Asian countries set. During the crisis period, the role of the U.S. becomes eminent. The Asian countries cointegration disappears and US-Japan-China, US-Korea-China, US-Japan-Korea set cointegration appears. The most interesting observation is in the post crisis period. Namely every three countries set that includes the U.S. as a member from among the four countries shows cointegration. From the observations in table 5,6,7 we can conclude that the financial crisis triggered four countries cointegration.

Table 8: Johansen trivariate cointegration test

	Countries	Period	Eigen value	Trace Stat	5% critical value	P-value
1997/12-2006/04	Korea Japan China	None	0.135	26.196	35.193	0.331
		At most 1	0.070	11.971	20.262	0.451
		At most 2	0.049	4.883	9.165	0.297
	Korea Japan U.S.	None	0.143	27.449	35.193	0.267
		At most 1	0.104	12.367	20.262	0.417
		At most 2	0.016	1.618	9.165	0.852
	Korea China U.S.	None	0.133	22.086	35.193	0.590
		At most 1	0.060	8.044	20.262	0.821
		At most 2	0.020	1.984	9.165	0.781
	Japan China U.S.	None *	0.200	37.593	35.193	**0.027****
		At most 1	0.105	15.734	20.262	0.187
		At most 2	0.048	4.833	9.165	0.302
2006/05-2009/03	Korea Japan China	None	0.351	28.711	35.193	0.211
		At most 1	0.197	13.563	20.262	0.321
		At most 2	0.155	5.894	9.165	0.199
	Korea Japan U.S.	None *	0.600	44.069	35.193	**0.004*****
		At most 1	0.229	11.984	20.262	0.450
		At most 2	0.079	2.872	9.165	0.605
	Korea China U.S.	None *	0.400	36.659	35.193	**0.035****
		At most 1	0.286	18.767	20.262	**0.079***
		At most 2	0.180	6.956	9.165	0.129
	Japan China U.S.	None *	0.605	43.461	35.193	**0.005*****
		At most 1	0.191	10.973	20.262	0.545
		At most 2	0.096	3.544	9.165	0.484
2009/04-2016/04	Korea Japan China	None *	0.274	37.987	35.193	**0.024****
		At most 1	0.084	10.793	20.262	0.562
		At most 2	0.039	3.382	9.165	0.512
	Korea Japan U.S.	None *	0.293	47.146	35.193	**0.002*****
		At most 1	0.118	17.666	20.262	0.110
		At most 2	0.079	6.995	9.165	0.127
	Korea China U.S.	None *	0.286	45.577	35.193	**0.003*****
		At most 1	0.123	16.991	20.262	0.133
		At most 2	0.066	5.806	9.165	0.206
	Japan China U.S.	None *	0.273	35.618	35.193	**0.045****
		At most 1	0.058	8.573	20.262	0.775
		At most 2	0.041	3.521	9.165	0.488

c. VECM

In table 4 we have seen that that there is one(or two)specific long-term relationship among the four stock markets that have to be modeled with a VECM for each sub periods. The efficient market theory suggests that financial time series are a random walk process which, in turn, precludes cointegration. The index series may react analogously to global shocks in the short-run but it is also reasonable to believe that they will develop differently in the long-run due to country-specific conditions and shocks. Yet, the results from Johansen quadra-variate cointegration test reveal a cointegrating relationship among the three Asian markets and the U.S. This means that these four markets must react analogously to country-specific shocks as well, which indicates that a country-specific shock in one market is followed by an offsetting shock in the other market.

Table 9 VECM test- KOSPI

		KOSPI	Nikkei	SSE	SP500	Constant
1997/12-2016/04	Coef.	1.000	-4.194	-3.011	4.556	22.676
	std. error		1.321	0.728	1.678	9.356
	t-value		-3.175	-4.135	2.715	2.424
1997/12-2006/04	Coef.	1.000	4.750	3.440	-8.055	-19.841
	std. error		0.901	0.716	1.494	6.927
	t-value		5.271	4.806	-5.394	-2.865
2006/05-2009/03	Coef.	1.000	13.286	1.395	-18.189	-15.135
	std. error		2.394	0.505	4.070	6.460
	t-value		5.550	2.762	-4.469	-2.343
2009/04-2016/04	Coef.	1.000	-0.324	0.299	0.408	-9.925
	std. error		0.286	0.200	0.298	1.483
	t-value		-1.132	1.494	1.369	-6.694

Table 9 shows the normalized cointegration coefficients for the whole period and three sub periods. We can see that Japan and China have positive and significant coefficients, while the U.S. has negative and significant coefficient, for the pre- crisis period and during the crisis period. However we observe that Japan and the US's opposite signs change in the post crisis period, while Chinese coefficient has the positive coefficient all through the periods. Also we observe that the coefficients are not statistically significant any more in the post crisis period. The financial crisis seems to have forced the structural changes in the pattern of cointegration[3].

Table 10 shows the speed of adjustment. KOSPI and Nikkei in the pre- crisis period show negative sign and statistically significant. Equilibrium in the long run is recovered by the opposite movement of KOSPI and Nikkei, while SP500 does not have significant movement. During the crisis no action is found to recover the equilibrium, meaning that the long term equilibrium was very fragile during the crisis.

Table 10: Speed of adjustment-KOSPI

		KOSPI	Nikkei	SSE	SP500
1997/12-2016/4	Coef.	0.007	0.015	0.008	0.005
	Std. Error	0.005	0.003	0.005	0.003
	t-Statistic	1.512	4.484	1.495	1.718
	Prob.	0.132	*0.000*	0.137	*0.087*
1997/12-2006/04	Coef.	-0.059	-0.036	-0.012	-0.008
	Std. Error	0.015	0.009	0.011	0.008

[3] In this context, it is worthy while to look into the pattern of exchange rate change during the period. Under the current floating exchange rate system, major proportion of the shock in the U.S. market is reflected in the exchange rate before it is reflected in the Korean equity market. The exchange rate may act as a shock absorber so as to dampen the impact on the Korean equity market. Same argument may be applied to Japan and China. This is another topic which is worthy while to pursue.

	t-Statistic	-3.868	-4.121	-1.105	-1.064
	Prob.	**0.000*** **	**0.000*** **	0.272	0.290
2006/05-2009/03	Coef.	0.036	0.015	0.066	0.046
	Std. Error	0.017	0.020	0.037	0.012
	t-Statistic	2.171	0.739	1.803	3.760
	Prob.	*0.040*	0.467	*0.084*	*0.001*
2009/04-2016/04	Coef.	-0.125	-0.044	-0.101	-0.085
	Std. Error	0.027	0.040	0.059	0.026
	t-Statistic	-4.615	-1.105	-1.720	-3.298
	Prob.	**0.000*** **	0.273	**0.090***	**0.002*** **

Note : speed of adjustment is calculated when KOSPI is dependent variable. * denotes 10% significance level. ** denotes 5% significance level. *** denotes 1% significance level.

In the post crisis period Nikkei and SP500 act to recover long term equilibrium, while that of SEE is not active.

Table 11 is about the short run behavior of the variables. In the whole period US and Chinese market lead Korean Market for two months. In the pre- crisis period, US market lead Korean market for two months, while Chinese market lead Korean market for one month. However during the crisis, we can see that all the three markets lead Korean markets two months. These short term behavior is changed after the crisis. In post crisis period only Chinese has two months' lead, while other markets show no market lead.

Table 11b: VAR coefficients in the VECM-KOSPI

		lk(-1)	lk(-2)	ln(-1)	ln(-2)	ls(-1)	ls(-2)	lsp(-1)	lsp(-2)	constant
1997/12-2016/04	Coef.	0.129	0.054	-0.023	-0.024	-0.002	0.127	0.083	-0.459	0.007
	t-value	1.533	0.700	-0.196	-0.199	-0.036	1.805	0.533	-3.014	1.297
	P-value	0.127	0.485	0.845	0.843	0.971	**0.073***	0.595	**0.003*** **	0.196

1997/12-2006/04	Coef.	0.138	0.003	-0.036	0.176	0.260	0.017	-0.198	-0.800	0.006
	t-value	1.142	0.029	-0.178	0.857	1.704	0.108	-0.792	-3.301	0.653
	P-value	0.257	0.977	0.859	0.394	**0.092***	0.914	0.430	**0.001*****	0.515
2006/05-2009/03	Coef.	0.156	0.443	0.214	-0.669	-0.362	0.270	0.425	-0.716	-0.010
	t-value	0.688	2.146	0.742	-2.418	-2.996	2.351	1.088	-1.920	-0.905
	P-value	0.498	**0.042****	0.465	**0.023****	**0.006*****	**0.027****	0.287	**0.066***	0.374
2009/04-2016/04	Coef.	-0.096	-0.338	-0.040	-0.118	0.024	0.130	0.043	0.081	-0.004
	t-value	-0.756	-2.614	-0.396	-1.240	0.423	2.220	0.260	0.516	-0.878
	P-value	0.452	**0.011****	0.694	0.219	0.674	**0.030****	0.795	0.607	0.383

Note: the dependent variable is log(KOSPI)

6. Conclusion

We did not find cointegration among the stock markets of Asain countries and the U.S. for the period from December 1997 to April 2016. However once we take structural changes into consideration(pre-financial crisis, during financial crisis, post-financial crisis), each sub period has cointegration on its own. Bi-variate and tri-variate cointegration tests confirmed the existence of cointegration and increasing degree of cointegration after the financial crisis. However the cointegration has become a very calm type after the crisis, showing insignificant coefficient in the cointegration equation. However the speed of adjustment from disequilibrium form China and the U.S. have become more significant after the financial crisis, while the speed of adjustment from Japan was significant only in the pre-crisis period.

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