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Stock Market Linkages in Asian Countries

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Abstract: This study attempts to analyze the stock market linkages among Asian countries using the multivariate EGARCH model. In addition, this study attempts to consider the time differences between opening and closing stock markets in Japan, China, South Korea, and Hong Kong after the global financial crisis. This study examines volatility spillover effects among Asian stock markets during the period July 1, 2009 to December 29, 2016.

Major findings are as follows: First, South Korea and Japan's close-to-open returns had a significantly positive influence over China and Hong Kong's close-to-open returns, with Hong Kong's being more affected by South Korea and Japan than China was. Second, China and Hong Kong's close-to-open returns did not have any significant impact on Japan's open-to-close return. However, they did have a significant impact on South Korea's open-to-close return, with Hong Kong's particularly having a significantly positive impact on them. Third, while China and Hong Kong's close-to-open returns and Japan's open-to-close return all significantly influenced South Korea's open-to-close return, Hong Kong's had the largest significantly positive influence on South Korea's even when Japan's were controlled for. Fourth, neither the close-to-open returns nor open-to-close returns of South Korea or Japan had any significant impact on China's open-to-close return. However, the open-to-close returns of Japan and China both had a significantly impact on Hong Kong's open-to-close return, with the open-to-close return of China, recently closed in the middle of day, wielding the largest influence. Fifth, the conditional variance of open-to-close returns increases as the size of market innovation is larger than expected in all of the four Asian stock markets, and there are asymmetric volatility effects.

The portfolio managers and investors should consider this Asian stock market linkages information when making investment decisions and reflect them in their international portfolios.

Keywords: Stock market linkages; Asian countries; Open-to-Close Return; Close-to-Open return.

I. INTRODUCTION

The stock linkages of the global stock market refer to the interactive effects between stock markets. With globalization and expanding trade, the global stock market is increasingly experiencing linkages. Asian

countries are geographically close and share similar oriental cultures. Further, they are close trade partners, which makes their stock market relationships more interactive. Therefore, it is only natural that Asian stock markets—closely located, culturally similar and highly dependent on each other in trade—experience strong spillover effects.

There are many studies of stock price synchronicity in the global stock market. Engle *et al.* (1987) suggest that information revealed that one country market's opening affect the return volatility of the next market to open. Eun and Shim (1989) identified spillover effects in nine advanced markets, including the US, while Hamao *et al.* (1990) identified them in the US, Japan and the UK stock markets. Barclay *et al.* (1990) found that there are volatility spillover effects among developed countries' capital markets, and Karolyi (1995) also reported spillover effects in the US and Canadian markets. Li (2007) found that there are no spillover effects between China and the US using multivariate GARCH model. Johansson and Ljungwall (2009) examined the spillover effects between China, Hong Kong and Taiwan stock markets and found that the high degree of correlation among those three markets. Moon and Yu (2010) found a symmetric and asymmetric volatility spillover effect from the US to the Chinese stock market. Meric *et al.* (2012) found that among 13 Asian markets, China, Australia, and South Korea's stock markets were relatively more affected by other Asian stock markets. Jung *et al.* (2014) found that China's opening price is affected by the close-to-close return of the U.S, while open-to-close return of South Korea affect the closing price of the Chinese stock market.

In general, Asian stock markets, including Japan, China, South Korea, and Hong Kong, are assumed to be open over the same range of hours. However, the four stock markets have different opening and closing hours. South Korea and Japan open at 9:00 Korean time, but close at 15:30 and 15:00, respectively. China and Hong Kong both open at 10:30 Korean time, but close at 16:00 and 17:00 respectively. Therefore, the opening prices of South Korea and Japan can affect the build-up of opening prices of China and Hong Kong. In addition, the closing prices of Japan can affect those of South Korea, which, in turn, can affect those of China, which can then impacts on the closing price of Hong Kong. Therefore, it is necessary to understand the dynamics of the consecutive influences among the four stock markets.

This study seeks to provide new information on the spillover effects among the stock markets of Japan, China, South Korea, and Hong Kong by factoring in the time differences in opening and closing hours of the stock markets. The spillover effects caused by time differences may be useful for Asian stock market investors to help them improve their returns by considering the information when they make investment strategy and portfolio adjustment decisions.

This paper is comprised of the following: in chapter 2, data studied is described and models used to examine the spillover effects of the four stock markets are developed; in chapter 3, study results using the EGARCH model are presented; and in chapter 4, the findings are explained and the suggestion of this study is presented.

II. METHODOLOGY

This study used daily opening prices and closing prices of the NIKKEI225 index in Japan, the KOSPI index in Korea, the SSE index in China, and the HSI index in Hong Kong. The time period examined is July 1, 2009 to December 29, 2016, which is the period after the global financial crisis. The closing prices

of the S&P500 index in the US were used as control variables. Data needed for the study were derived from FnGuide.

To consider the time differences of opening and closing hours of the stock markets among the four countries, which are often assumed to operate within the same range of hours, this study separated close-to-close returns (daily returns) into close-to-open returns (overnight returns) and open-to-close returns (daytime returns), defining the three types of returns in the following formulas.

$$R_{cc} = \ln P_{c,t} - \ln P_{c,t-1} \quad (1)$$

$$R_{co} = \ln P_{o,t} - \ln P_{c,t-1} \quad (2)$$

$$R_{oc} = \ln P_{c,t} - \ln P_{o,t} \quad (3)$$

Where, R_{cc}, R_{co} and R_{oc} denote close-to-close returns, close-to-open returns and open-to-close returns respectively. $P_{o,t}$ denotes an opening price at time t, and $P_{c,t}$ denotes a closing price at time t.

In the Ljung-Box Q-statistics analysis, performed to identify the volatility clustering properties of the four returns, the properties were found to be significant and suitable for the GARCH model. The descriptive statistics of the index returns are as follows:

Table 1
Descriptive statistics of the stock returns of South Korea, China, Japan, Hong Kong, and the US

Index	*Mean*	*Maximum*	*Minimum*	*Std. Dev.*	*Skewness*	*Kurtosis*	*J-B*
KR	–.0006	.0436	–.0405	.0075	–.3624	6.0358	789.3***
CN	.0005	.0475	–.0547	.0093	–.3252	9.0286	2978.3***
JP	.0002	.0928	–.1035	.0098	.5993	21.9939	9338.5***
HK	–.0007	.0400	–.0373	.0083	–.0574	4.5064	184.9***
US	.0004	.0835	–.0857	.0105	–.3187	11.2831	5590.3***

Note: JP, KR, CN, HK, and US each represent the Nikkei225, the KOSPI, the Shanghai Stock Exchange Composite, the Hang Seng Index, and the S&P500 index respectively, and *** indicates a significance level of 1%.

Over the analysis period, South Korea and Hong Kong showed negative returns while Japan, China, and the US recorded positive figures. As shown in the standard deviations, China, Japan, and the US showed more fluctuations than South Korea and Hong Kong. The skewness recorded negative values for all except for Japan, while the kurtosis was higher than 3 for all countries, and Jaque-Bera values for all rejected a normal distribution at a 1% significant level. Therefore, it can be concluded that all of the five stock markets display the leptokurtic distributions.

Prior to analysis, a unit root test needs to be run to confirm the stationarity of the time-series data. As it may be possible that each time-series variable is a non-stationary process, the stationarity of the variables must be examined prior to analysis of time-series data. The Schwart information criterion-based Augmented Dickey Fuller (ADF) test and the Phillips-Perron (PP) test were used to perform unit root tests. Separate tests were run for intercept-only cases and trend-and-intercept cases, with two lags applied. As shown in Table 2, the test results of first-differenced variables reject the null hypothesis that all variables have a unit root when both the ADF test and the PP test. Accordingly, the variables subject to analysis are confirmed

to have stationary time-series at a significance level of 1% and constitute an I(1) process. Based on the test results, this study used first-differenced variables for analysis. In addition, the Johansen cointegration test was performed to see whether there is a cointegration relation between the first-differenced variables. The lags of cointegration were set to 2 based on Schwart information criterion, and the results showed that there is a cointegration relation at a significance level of 5%, proving a long-term relation between the variables. Due to Kurtosis, autocorrelation and the volatility clustering property of the data, this study adopt the GARCH-family model developed by Bollerslev (1986) and Nelson (1991) for analysis. The AIC, BIC, and HQIC information criteria-based analyses were performed to determine a suitable model to examine the returns of the stock markets of South Korea, China, Japan, and Hong Kong, and the results showed that the EGARCH(1,1)-student's t model would be most suitable. Accordingly, this study uses that model to examine the spillover effects of the four stock markets.

To consider the time differences in opening and closing hours among the four markets, multiple models are set up. First, Model 1 examines the effects close-to-open returns of South Korea and Japan, which open an hour and a half earlier than China and Hong Kong, have on China and Hong Kong's close-to-open returns.

Model 1

$$CN_{co,t}(\text{or } HK_{co,t}) = a_0 + b_1 KR_{co,t} + b_2 JP_{co,t} \tag{4}$$

$$\ln h_t = a_1 + \beta \ln\left(\sigma_t^2\right) + \gamma \left|\frac{\varepsilon_{t-1}}{h_{t-1}}\right| + \delta \frac{\varepsilon_{t-1}}{h_{t-1}} + c_1 \ln\varepsilon^2_{KR_{co,t}} + c_2 \ln\varepsilon^2_{JP_{co,t}} + c_1 \ln\varepsilon^2_{US_{oc,t-1}} \tag{5}$$

Where, $CN_{co,t}$(or $HK_{co,t}$) indicates the close-to-open returns of the China SSEC index (or Hong Kong HIS index) at time t. a_0 and a_1 are constant terms. b_1, b_2 and b_3 are parameters of the KOSPI, NIKKEI225 and S&P500's close-to-open returns respectively, and c_1, c_2 and c_3 each represent the parameters of the log values of the square of the residual of close-to-open returns of the KOSPI, NIKKEI225 at time t and S&P500 close-to-close returns at time $t-1$. Parameter γ and δ denote leverage effects. This means if δ is a positive value, the conditional variance increases when the size of market innovation is larger than expected; if is a negative value, it indicates the presence of an asymmetric volatility effect.

Model 2 looks into the impact of the close-to-open returns of China and Hong Kong on Japan and Korea's open-to-close returns. Model 3 examines the effects of Japan's open-to-close return on South Korea's open-to-close return. Model 4 examines the effects of Japan and Korea's open-to-close returns on China's open-to-close return. Model 5 examines the effects of Japan, Korea and China's open-to-close returns on Hong Kong's open-to-close return.

Model 2

$$JP_{oc,t}\left(\text{or } KR_{oc,t}\right) = a_0 + b_1 CN_{co,t} + b_2 HK_{co,t} + b_3 US_{cc,t-1} + \varepsilon_t \tag{6}$$

$$\ln h_t = a_1 + \beta \ln\left(\sigma_t^2\right) + \gamma \left|\frac{\varepsilon_{t-1}}{h_{t-1}}\right| + \delta \frac{\varepsilon_{t-1}}{h_{t-1}} + c_1 \ln\varepsilon^2_{CN_{co,t}} + c_2 \ln\varepsilon^2_{HK_{co,t}} + c_1 \ln\varepsilon^2_{US_{oc,t-1}} \tag{7}$$

Model 3

$$KR_{oc,t} = a_0 + b_1 JP_{oc,t} + b_2 CN_{co,t} + b_3 HK_{co,t} + b_4 US_{cc,t-1} + \varepsilon_t \quad (8)$$

$$\ln h_t = a_1 + \beta \ln\left(\sigma_t^2\right) + \gamma \left|\frac{\varepsilon_{t-1}}{h_{t-1}}\right| + \delta \frac{\varepsilon_{t-1}}{h_{t-1}} + c_1 \ln\varepsilon^2_{JP_{oc,t}} + c_2 \ln\varepsilon^2_{CN_{co,t}} + c_3 \ln\varepsilon^2_{HK_{co,t}} + c_1 \ln\varepsilon^2_{US_{cc,t-1}} \quad (9)$$

Model 4

$$CN_{oc,t} = a_0 + b_1 KR_{co,t} + b_2 JP_{co,t} + b_3 JP_{oc,t} + b_4 KR_{oc,t} + b_5 US_{cc,t-1} + \varepsilon_t \quad (10)$$

$$\ln h_t = a_1 + \beta \ln\left(\sigma_t^2\right) + \gamma \left|\frac{\varepsilon_{t-1}}{h_{t-1}}\right| + \delta \frac{\varepsilon_{t-1}}{h_{t-1}} + c_1 \ln\varepsilon^2_{KR_{co,t}} + c_2 \ln\varepsilon^2_{JP_{co,t}} + c_3 \ln\varepsilon^2_{JP_{oc,t}} + c_4 \ln\varepsilon^2_{KR_{oc,t}} + c_5 \ln\varepsilon^2_{US_{cc,t-1}} \quad (11)$$

Model 5

$$HK_{oc,t} = a_0 + b_1 KR_{co,t} + b_2 JP_{co,t} + b_3 KR_{oc,t} + b_4 JP_{oc,t} + b_5 CN_{oc,t} + b_6 US_{cc,t-1} + \varepsilon_t \quad (12)$$

$$\ln h_t = a_1 + \beta \ln\left(\sigma_t^2\right) + \gamma \left|\frac{\varepsilon_{t-1}}{h_{t-1}}\right| + \delta \frac{\varepsilon_{t-1}}{h_{t-1}} + c_1 \ln\varepsilon^2_{KR_{co,t}} + c_2 \ln\varepsilon^2_{JP_{co,t}} + c_3 \ln\varepsilon^2_{KR_{oc,t}} + c_4 \ln\varepsilon^2_{JP_{oc,t}} + c_5 \ln\varepsilon^2_{CN_{oc,t}} + c_6 \ln\varepsilon^2_{US_{cc,t-1}} \quad (13)$$

III. EMPIRICAL RESULTS

Table 2 shows that the US close-to-close returns of the previous day and the close-to-open returns of South Korea and Japan, in that order, influence China's close-to-open returns. South Korea's close-to-open returns have the biggest influence on Hong Kong's close-to-open returns, followed by the US's close-to-close returns of the previous day and Japan's close-to-open returns. When the previous day's close-to-close returns of the US are controlled, South Korea's close-to-open returns had a larger and more significant influence on China's close-to-open returns than Japan's close-to-open returns did. Hong Kong's close-to-open returns were more significantly affected by South Korea and Japan's close-to-open returns than China's close-to-open returns were. In particular, South Korea's close-to-open returns had almost 10 times more influence on Hong Kong's close-to-open returns than Japan's close-to-open returns did, confirming that the opening prices of South Korea have a strong influence on Hong Kong's opening price. And recorded a significant positive value, indicating that the conditional variance of China and Hong Kong's close-to-open returns increases when the size of market innovation is larger than expected.

In Table 3, neither China or Hong Kong's close-to-open returns nor the US's close-to-close returns of the previous day had a significant influence on Japan's open-to-close returns. On the other hand, even when the US close-to-close return of the previous day is controlled for, Hong Kong's close-to-open return had the largest and most significant impact on South Korea's open-to-close return. This finding is in line with the finding in Model 1 that Hong Kong's close-to-open return is most affected by South Korea's

Table 2
The effects of close-to-open returns of Korea and Japan on China and H's close-to-open returns

	$KR_{co,t}$ *and* $JP_{co,t} \rightarrow CN_{co,t}$	$KR_{co,t}$ *and* $JP_{co,t} \rightarrow HK_{co,t}$
a_0	–0.0010***	0.0002
b_1	0.0869***	0.5549***
b_2	0.0154*	0.0592***
b_3	0.1850***	0.2602***
a_1	–0.2625***	–0.4109***
β	0.9899***	0.9712***
γ	0.2376***	0.1445***
δ	0.0141	–0.0266
c_1	6.7080	6.2375**
c_2	0.9908	0.3602
c_3	–8.2882	–13.2166***
$\bar{R}^2$	0.0590	0.5478
Log-L	7161.65	7555.60

Note: *, ** and *** indicate a significance level of 10%, 5% and 1% respectively.

close-to-open return, and it can be concluded that the close-to-open returns of the two markets have the largest influence on one another. And recorded a significant positive value, indicating that the conditional variance of Korea and Japan's open-to-close returns increases when the size of market innovation is larger than expected.

Table 3
The effects of close-to-open returns of China and Hong Kong on Japan and Korea's open-to-close returns

	$CN_{co,t}$ *and* $HK_{co,t} \rightarrow JP_{oc,t}$	$CN_{co,t}$ *and* $HK_{co,t} \rightarrow KR_{oc,t}$
a_0	0.0003***	0.0004***
b_1	0.0012	–0.0125**
b_2	0.0006	0.3503***
b_3	0.1796	0.2466***
a_1	–0.4636	–1.5699***
β	0.9743***	0.8757***
γ	0.3494***	0.2941***
δ	0.1852***	0.0329
c_1	–4.0979*	–4.9418**
c_2	2.2564	–10.8291***
c_3	–5.8158	–11.0692***
$\bar{R}^2$	0.0120	0.5197
Log-L	7579.60	8092.04

Note: *, ** and *** indicate a significance level of 10%, 5% and 1% respectively.

In the second column of Table 4, China and Hong Kong's close-to-open returns and Japan's open-to-close returns both significantly influenced South Korea's open-to-close returns, with Hong Kong's had the largest and most significant impact on South Korea's open-to-close return. It is in line with the finding in Model 1 that Hong Kong's close-to-open return is most affected by South Korea's close-to-open. Also, recorded a significant positive value, indicating that the conditional variance of Korea's open-to-close return increases when the size of market innovation is larger than expected while showed a significantly negative value, indicating the presence of an asymmetric volatility effect.

In the third column of Table 4, neither the close-to-open returns nor open-to-close returns of South Korea and Japan had any significant impact on China's open-to-close returns. However, in the fourth column of Table 4, the open-to-close returns of Japan and China both have a significantly positive influence on Hong Kong's open-to-close returns, with those of China, most recently closed in the middle of day, having the largest influence. Also, recorded a significant positive value, indicating that the conditional variance of China and Hong Kong's open-to close returns increases when the size of market innovation is larger than expected while showed a significant negative value, indicating the presence of an asymmetric volatility effect.

Table 4
The results of model 3, 4 and 5

	$JP_{oc,t} \rightarrow KR_{oc,t}$	$JP_{oc,t}$ *and* $KR_{oc,t} \rightarrow CN_{oc,t}$	$JP_{oc,t}$, $KR_{oc,t}$ *and* $CN_{oc,t} \rightarrow HK_{oc,t}$
a_0	–0.0004	0.0006***	–0.0007***
b_1	0.0332**	0.0002	–0.0251
b_2	0.0282**	–0.0001	–0.0055
b_3	0.1209***	–0.0057	0.0108
b_5	0.1721***	0.0023	–0.1167***
b_5		0.0087	0.2830***
b_6			–0.0371
a_1	–0.3994***	–0.4700***	–0.2589***
β	0.9685***	0.9895***	0.9773***
γ	0.1062***	0.5093***	0.0422***
δ	–0.0423***	–0.0875***	–0.0412***
c_1	4.2804**	–5.6183	4.5447
c_2	–2.2004*	4.6981	–1.8866
c_3	0.5200	–4.5139	–3.3981
c_4	–8.3511	–0.7487	0.6299
c_5		3.5272	–1.2911
c_6			–5.9925**
$\bar{R}^2$	0.0666	0.0552	0.1371
Log-L	7067.32	8613.84	6862.65

Note: *, ** and *** indicate a significance level of 10%, 5% and 1% respectively.

IV. CONCLUSION

This study used the EGARCH (1,1)-student's t model to consider the time differences in opening and closing hours among stock markets in South Korea, China, Japan, and Hong Kong and examined spillover effects among the four Asian stock markets. Over a post-global financial crisis period from July 1, 2009 to December 29, 2016, opening prices and closing prices of the NIKKEI225 index in Japan, the KOSPI index in Korea, the SSE index in China, and the HSI index in Hong Kong were put to analysis.

The findings are as follows: first, South Korea and Japan's close-to-open returns had a significantly positive influence over China and Hong Kong's close-to-open returns, with Hong Kong's being more affected by South Korea and Japan than China was. Hong Kong's was almost ten times more influenced by South Korea's close-to-open returns than Japan's, confirming the great influence of South Korea's opening price over Hong Kong's opening price.

Second, China and Hong Kong's close-to-open returns did not have any significant impact on Japan's open-to-close return. However, they did have a significant impact on South Korea's open-to-close return, with Hong Kong's particularly having a significantly positive impact on them. These findings are aligned with a results that Hong Kong's close-to-open return were most affected by South Korea's close-to-open return, South Korea's close-to-open return had a significantly positive impact on Hong Kong's close-to-open return, and Hong Kong's close-to-open return then have a significantly positive influence over South Korea's open-to-close return.

Third, while China and Hong Kong's close-to-open returns and Japan's open-to-close return all significantly influenced South Korea's open-to-close return, Hong Kong's had the largest significantly positive influence on South Korea's even when Japan's were controlled for.

Fourth, neither the close-to-open returns nor open-to-close returns of South Korea or Japan had any significant impact on China's open-to-close return. However, the open-to-close returns of Japan and China both had a significantly impact on Hong Kong's open-to-close return, with the open-to-close return of China, recently closed in the middle of day, wielding the largest influence.

Fifth, in all four Asian stock markets subject to this study, showed that the conditional variance of open-to-close returns increases when the size of market innovation is larger than expected. And there is the presence of an asymmetric volatility effect.

Drawing upon the findings above, this study suggests that investors need to consider the spillover effects among Asian stock markets, and make investment decisions and build their portfolios accordingly.

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