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SPILLOVER EFFECTS IN DIFFERENT TIME ZONES: EVIDENCE FROM CHINA, KOREA AND USA

This paper examines mean spillover effects and volatility spillover effects among SSE, KOSPI and S&P500. We find that SSE opening prices are strongly impacted by the overnight S&P 500 stock returns and SSE closing prices are strongly impacted by KOSPI daytime returns. This different mean spillover effects can be attributed to time zones difference.

Keywords: *structural break; spillover; volatility; time zones; stock market.*
JEL classification: G31; G35.

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ЕФЕКТ "ПЕРЕЛИВУ" ЗА ЧАСОВИМИ ПОЯСАМИ: ЗА ДАНИМИ ФОНДОВИХ РИНКІВ КНР, П. КОРЕЇ ТА США

У статті продемонстровано явище "переливу" за часовими поясами та зокрема "перелив" волатильності з одного фондового ринку на інший на прикладі головних ринків КНР, Південної Кореї та США. Ціни на момент відкриття Шанхайського фондового ринку суттєво впливають на нічні прибутки у рейтингу S&P 500 у США. Шанхайські ж ціни на момент закриття біржі знаходяться під суттєвим впливом денних прибутків на Корейській фондовій біржі. Дані ефекти "переливу" впливу багато в чому пов'язані з часовими поясами.

Ключові слова: *структурний розрив; ефект "переливу"; волатильність; часові пояси; фондовий ринок.*
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ЭФФЕКТ "ПЕРЕЛИВА" ПО ЧАСОВЫМ ПОЯСАМ: ПО ДАННЫМ ФОНДОВЫХ РЫНКОВ КНР, Ю. КОРЕИ И США

В статье показано явление "перелива" по часовым поясам и в частности перехода волатильности с одного фондового рынка на другой на примере главных рынков КНР, Южной Кореи и США. Цены на момент открытия Шанхайского фондового рынка существенно влияют на ночные прибыли в рейтинге S&P 500 в США. Шанхайские же цены на момент закрытия биржи находятся под значительным влиянием дневных прибылей на Корейской фондовой бирже. Данные эффекты "перелива" влияния во многом связаны с часовыми поясами.

Ключевые слова: *структурный разрыв; эффект "перелива"; волатильность; часовые пояса; фондовый рынок.*

1. Introduction

A spillover effect between countries is that information at one country's stock market is transmitted into another country's stock market. The transmission may show a complex pattern because those countries are located in different time zones, thus their stock markets do not open and close at the same time.

Why do we examine the spillover effects between China, Korea and America? Firstly, it will help us to get a better understanding in the relations in capital markets

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among developed and developing countries. Secondly, it can make one country get prepared when another country's stock market has some important information that affects this country's stock market. For instance, we suppose spillover effect exists between China and America. Then if a big event happens at the American stock market that decreases the S&P 500 index significantly, we have the reason to believe that the SSE may also decrease successively when China's stock market opens in a few hours after the US market closes.

There are plenty of papers focusing on the spillover effects between developed countries or between developed and developing countries. Eun and Shim (1989), Hamao et al. (1990), and Barclay et al. (1990) find that there are information and volatility spillover effects among developed countries' stock markets. Engle et al. (1990) suggest that information revealed that one country's foreign exchange market's opening will affect the return volatility of the next market to open. There are several papers regarding the spillover effects among China and other countries. For example, Johansson and Ljungwall (2009) examine the spillover effects between China mainland, Hong Kong and Taiwan by applying the GARCH model. But those 3 markets are restrained to a small region so that the high degree of correlation among those 3 markets will make the results less general. Li (2007) adopts a multivariate GARCH model, and finds there are no spillover effects between China and the US. The data he uses is from January 2000 to August 2005, which does not include the structural reform in China happened at the end of 2005. Hence, his conclusion may be restricted to the fact that his data period fails to cover the post-2005 period. Almost all the papers above calculate the stock close-to-close return. However, Hamao et al. (1990) examines the spillover effects among New York, Tokyo and London stock markets. In this paper, the authors divide the return data into close-to-close, open-to-close and close-to-open return in order to test the spillover effects from one country to another in a more specific way. In our paper, we follow the Hamao's method to divide the stock return into 3 categories in examining the spillover effects among China, Korea and America stock markets.

The rest of the paper is organized as follows. Section 2 discusses the data. Section 3 introduces the method. Section 4 gives the empirical results. Section 5 is the conclusion.

2. Data

We examine the daily stock return data from January 4, 2000 to December 30, 2010, with the total of 2472 observations. The data used is from FnGuide. We use daily prices from the market indices to compute several different types of daily return rates (close-to-close returns, close-to-open returns, and open-to-close returns) in 3 countries: China, Korea and America. For Chinese stock market, we adopt the SSE composite index. For Korean stock market, we adopt the KOSPI composite index. For the American stock market, we adopt the S&P's 500 composite index. These indices are all market value averaged and are the representative stock market indices of China, Korea and America.

The Shanghai stock market opens at 20:30 Eastern Standard Time (EST) and closes at 2:00 EST the next day with a lunch break between 22:30 EST and 24:00 EST. The Korean stock market opens at 19:00 EST and closes at 1:00 EST. The New York stock market opens at 9:30 EST and closes at 16:00 EST. Therefore, trading activities at these markets are not concurrent. The non-synchronous trading gives us a chance to find whether spillovers effects exist across different time zones. Figure 1 gives a more intuitive description.

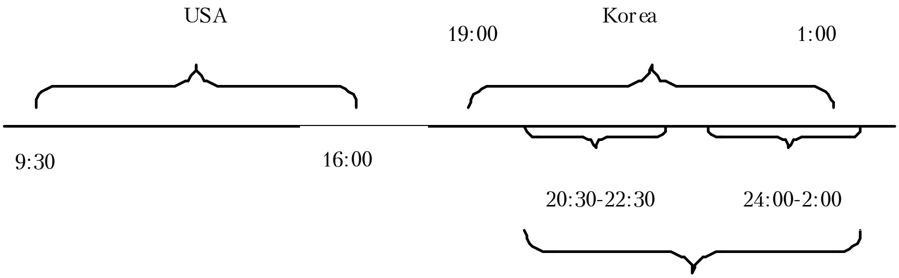

Figure 1. **The opening and closing hour (EST) of China, Korea and America stock markets**

The parameter stability condition of the model is very important for forecasting. Stock and Watson (1996) performed an experiment to assess the prevalence of instability in macroeconomic time series and found substantial instability in a significant fraction of univariate and bivariate autoregressive models. So we try to detect the unknown single structural breakdate by the method developed by Quandt (1960). This method is based on the Chow test statistics and the statistics is the maximum of the individual Chow F-statistics[4],

$$QLT_T = \max_{\tau \in \{\tau_{min}, \dots \tau_{max}\}} F_T(\tau) \quad (1)$$

For SSE stock returns series, the maximum F-statistics – 10.77545 (0.000022) is on November 28, 2005. This means the SSE stock return series has a mean structural break, and the break date is November 28, 2005. We define November 28, 2005 as the cut-off date and divide the overall sample data into 2 subperiods: the pre-break period (January 4, 2000 – November 27, 2005) and the post-break period (November 28, 2005 – December 30, 2010).

There are at least two potential explanations for the break at the China stock market. Firstly, the non-tradable shares reform in 2005 has an important impact on the Chinese stock market. Before 2005, there is a special equity structure of the listed companies in China, i.e. "binary equity structure". Some of the stock shares at Chinese stock market such as state-owned stock and corporate stock were classified as non-tradable shares and the others are tradable public stock shares. Non-tradable shares (i.e. non-circulation stock) cannot be traded at the secondary market (Wu, Wang, 2005). On May 8, 2005, China Securities Regulation Commission issued "Notice on the pilot reform of non-tradable shares of listed corporations", which started a series of non-tradable shares reform. Secondly, Chinese currency was revaluated to 8.11 per USD on July 21, 2005. It was pegged to USD at 8.28 RMB during the previous decade.

Table 1 gives the descriptive statistics of the SSE index, KOSPI index and S&P's 500 index. The descriptive statistics is based on 2 different sample periods: the pre-break period sample and the post-break period sample. For all the two different sample periods, the J-B statistics shows that those two time series of return rate are not

[4] Chow F-statistics is $F_T(\tau)=(T-2k)[SSR_{1:T}-(SSR_{1:\tau}+SSR_{\tau+1:T})/(SSR_{1:\tau}+SSR_{\tau+1:T})$. T is the total number of observations; and k is the number of parameters in the equation.

normal distributed at the 1% significance level, and the Ljung-Box statistics shows that the data is not independently distributed at the 1% significance level.

Table 1. **Descriptive statistics of SSE index, KOSPI index and S&P's 500 index**

	2000.1.4 – 2005.11.27			2005.11.28 – 2010.12.30		
	CN	KR	US	CN	KR	US
Mean	-0.00008	0.00002	-0.00003	0.00034	0.00018	-0.00002
Min	-0.02842	-0.05526	-0.02608	-0.04020	-0.04852	-0.04140
Max	0.04083	0.04710	0.02420	0.03924	0.04901	0.04759
Std. Dev.	0.00619	0.00876	0.00539	0.00900	0.00727	0.00696
Skewness	0.691	-0.376	0.181	-0.349	-0.651	-0.194
Kurtosis	8.407	6.952	5.302	5.367	9.975	11.727
J-B	1691.2*	878.7*	294.7*	296.6*	2452.1*	3717.3*
$Q_S(32)$	15.66*	12.07*	20.69*	20.84*	24.36*	40.49*

Notes: The J_B corresponds to the test statistics for the null hypothesis of normality in sample returns distribution. The Ljung-Box statistic, $Q_S(32)$, checks for the serial correlation of the squared returns up to the 32^{th} order. * indicates the rejection of the null hypothesis at 1% significance level.

3. Methodology

Due to the kurtosis, autocorrelations and the volatility clustering property of the time series of return rate of SSE index, KOSPI index and S&P's 500 index, we adopt GARCH family models developed by Bollerslev (1986) to analyze the data. Hansen and Lunde (2005) have compared a large number of volatility models and found no evidence that a GARCH (1, 1) is outperformed by more sophisticated models in their analysis of exchange rates, whereas the GARCH (1, 1) is inferior to those models that can accommodate a leverage effect in their analysis of IBM return.

3.1. Symmetric Spillover GARCH-M Model. We employ the univariate GARCH (1, 1)-M model established by Engle, Lilien and Robins (1987) to study these time series data just as Moon and Yu (2010) do in their paper. This GARCH (1, 1)-M model is regarded as our benchmark model. The symmetric GARCH model allows the conditional variance to be dependent upon previous own lags.

$$y_t = \alpha + \beta h_t + \varepsilon_t,\ where \cdot h_t = Var(\varepsilon_t | \Omega_{t-1}), \tag{2}$$

$$h_t = a + b\varepsilon_{t-1}^2 + ch_{t-1}, \tag{3}$$

where y_t is the daily return of the stock at time t, h_t is the conditional variance and ε_t is conditionally normal distributed. This kind of GARCH (1, 1)-M model is widely used to analyze financial time series.

In order to test the symmetric spillover between country i and country j, the mean and variance equations are:

$$r_{i,t} = \alpha + \beta h_{i,t} + \gamma r_{j,t-1} + \varepsilon_{i,t}, \tag{4}$$

$$h_{i,t} = a + bh_{i,t} + c\varepsilon_{i,t-1}^2 + d\varepsilon_{j,t-1}^2 \tag{5}$$

If the z-statistics of γ is significant, then there is information spillover effect from country j to country i. If the z-statistics of d is significant, then there is symmetric volatility spillover effect from country j to country i.

3.2. Asymmetric Spillover GARCH-M Model

In order to test the asymmetric spillover between country i and country j, the mean and variance equations are:

$$r_{i,t} = \alpha + \beta h_{i,t} + \gamma r_{j,t-1} + \varepsilon_{i,t}, \tag{6}$$

$$h_{i,t} = a + bh_{i,t} + c\varepsilon_{i,t-1}^2 + d\varepsilon_{j,t-1}^2 + eI_{t-1}\varepsilon_{j,t-1}^2 \quad (7)$$

If the z-statistics of γ is significant, then there is information spillover effect from country j to country i. If the z-statistics of both e and d are significant, then there is asymmetric volatility spillover effect from country j to country i.

We used the non-linear optimization techniques to get the maximum-likelihood estimates of both GARCH (1,1)-M model and GJR-GARCH (1,1)-M model[5], based on the Marquardt algorithm.

Table 2. **Estimation of GARCH (1, 1)-M model for symmetric spillovers from S&P500 returns and KOSPI returns to SSE composite returns**

	Pre-break			Post-break		
	$US_{c,t-1}$, $KR_{c,t}$> $CN_{c,t}$	$US_{c,t-1}$, $KR_{o,t}$> $CN_{o,t}$	$US_{c,t-1}$, $KR_{d,t}$> $CN_{d,t}$	$US_{c,t-1}$, $KR_{c,t}$> $CN_{c,t}$	$US_{c,t-1}$, $KR_{o,t}$> $CN_{o,t}$	$US_{c,t-1}$, $KR_{d,t}$> $CN_{d,t}$
α	-0.0013 (-1.97)*	-0.0002 (-0.40)	-0.0011 (-1.74)	0.0015 (1.63)	-0.0009 (-2.16)*	0.0003 (0.19)
â	7.5717 (2.14)*	16.0262 (2.10)*	7.6815 (1.74)	-1.7893 (-0.65)	2.5074 (0.41)	0.0742 (0.66)
γ	0.0367 (1.40)	0.0410 (1.02)	0.0487 (2.33)*	0.1246 (2.88)**	0.2476 (4.21)**	0.0182 (0.43)
δ	0.0273 (1.31)	-0.0026 (-0.07)	0.0467 (2.31)*	0.3078 (7.11)**	0.1389 (1.51)	0.3655 (7.95)**
a	0.0000 (2.62)**	0.0000 (4.51)**	0.0000 (2.49)*	0.0000 (2.27)*	0.0000 (4.10)**	0.0000 (2.67)**
b	0.8429 (23.06)**	0.6680 (8.75)**	0.8971 (30.68)**	0.9126 (43.63)**	0.6519 (6.33)**	0.9150 (45.96)**
c	0.1223 (3.76)**	0.2862 (2.30)**	0.0746 (3.39)**	0.0714 (3.84)**	0.3133 (2.02)*	0.0651 (3.67)**
d	-0.0003 (-0.92)	-0.0006 (-1.18)	0.0002 (1.03)	0.0002 (0.30)	0.0002 (0.51)	-0.0006 (-1.12)
e	0.0002 (0.97)	-0.0002 (-0.35)	0.0002 (0.88)	-0.0008 (-1.09)	-0.0007 (-0.80)	-0.0005 (-0.79)
Log-L	3787.82	4774.13	3916.09	3024.69	3940.66	3109.25
L-B(12)	8.69	12.39	13.32	16.50	11.12	17.19
$L\text{-}B^2(12)$	4.62	8.91	10.78	3.34	8.15	8.99

Notes: Values in parenthesis are z-statistics. * and ** indicate significance at the 5% and 1% levels, respectively. CN_c, KR_c and US_c denote close-to-close returns for SSECI, KOSPI, and S&P500, respectively. CN_o, KR_o and US_o denote close-to-open returns for SSECI, KOSPI, and S&P 500, respectively. CN_d, KR_d and US_d denote open-to-close returns for SSECI, KOSPI, and S&P 500, respectively.

4. Empirical results

Table 2 provides the results of the estimation of multivariate GARCH (1, 1)-M model for symmetric spillovers from S&P500 returns and KOSPI returns to SSE composite returns. Ljung-Box values of the first 12 normalized residuals or residuals squared are not significant at conventional significant levels except one (normalized residuals for SSE open-to-close return in total period), so the model is well specified.

In Table 2, we find significant information spillover effect from S&P 500 close-to-close return and KOSPI and SSE close-to-close return in post-break period [$\gamma = 0.1246(2.88)$, $\delta = 0.3078(7.11)$] from the mean equation. The return spillover from the US and Korea stock market to the China stock market has increased significantly after the post-break period. From the post-break period results, we find that

[5] Alternative GARCH models were estimated, but we find the GARCH (1, 1)-M model and GJR-GARCH (1, 1)-M model to provide the best fit in this study.

SSE opening prices are strongly impacted by the overnight S&P 500 stock returns based on the coefficient [γ = 0.2476(4.21)] and SSE closing prices are strongly impacted by KOSPI daytime returns based on the coefficient [δ = 0.3655(7.95)]. This different mean spillover effect on SSE opening price and closing price can be attributed to the time difference of market opening and closing between China (Korea) stock market and the US stock market. The coefficients on the *d* and *e* in variance equation are not significantly different from zero, indicating no volatility is transmitted to China stock market from the US and Korea stock markets.

Table 3. **Estimation of GARCH (1, 1)-M model for symmetric spillovers from SSE composite returns and KOSPI returns to S&P500 returns**

	Pre-break			Post-break		
	$CN_{c,t-1}$, $KR_{c,t-1}$> $US_{c,t}$	$CN_{c,t-1}$, $KR_{c,t-1}$> $US_{o,t}$	$CN_{c,t-1}$, $KR_{c,t-1}$> $US_{d,t}$	$CN_{c,t-1}$, $KR_{c,t-1}$> $US_{c,t}$	$CN_{c,t-1}$, $KR_{c,t-1}$> $US_{o,t}$	$CN_{c,t-1}$, $KR_{c,t-1}$> $US_{d,t}$
α	-0.0004 (-0.90)	0.0228 (3.44)**s	-0.0006 (-1.44)	0.0002 (0.70)	-0.0000 (-0.04)	0.0004 (1.04)
â	5.1127 (1.45)	1.0022 (3.44)**	7.3935 (1.70)*	0.8351 (0.33)	-3.9657 (-0.62)	0.9192 (0.34)
γ	-0.0184 (-0.93)	-0.0332 (-1.73)	-0.0210 (-1.05)	0.0494 (2.57)*	0.0114 (3.59)**	0.0423 (2.48)*
δ	0.0732 (4.87)**	0.0459 (5.03)**	0.0569 (3.90)**	0.0942 (4.26)**	0.0371 (2.06)*	0.0690 (3.39)**
a	0.0000 (6.00)**	0.0000 (15.7)**	0.0000 (4.18)**	0.0000 (2.01)*	0.0000 (3.85)**	0.0000 (17.64)**
b	0.8993 (68.03)**	0.4735 (2.95)**	0.9151 (63.08)**	0.8966 (40.50)**	0.5955 (5.98)**	0.8945 (53.68)**
c	0.0813 (5.40)**	0.0042 (4.62)**	0.0672 (4.60)**	0.0919 (4.49)**	0.1488 (2.41)*	0.0912 (4.91)**
d	-0.0000 (-0.30)	0.0003 (1.81)	-0.0000 (-0.34)	-0.0001 (-1.28)	0.0003 (2.50)*	-0.0002 (-2.47)*
e	-0.0005 (-4.06)**	-0.0002 (-3.91)**	-0.0003 (-2.79)**	-0.0002 (-0.85)	-0.0004 (-4.15)**	-0.0001 (-0.56)
Log-L	4047.60	5031.49	4174.67	3584.23	4543.01	3663.12
L-B(12)	16.11	15.15	15.35	25.53*	19.97	18.40
$L\text{-}B^2(12)$	4.99	9.95	6.99	26.12*	1.04	15.18

Notes: Values in parenthesis are z-statistics. * and ** indicate significance at the 5% and 1% levels, respectively.

The results of the estimation of multivariate GARCH (1,1)-M model for symmetric spillovers from SSE composite returns and KOSPI returns to S&P500 returns are presented in Table 3. From Table 3, we cannot find significant information spillover effect from SSE stock return to S&P 500 stock return based on the coefficient (γ) in pre-break period. But we find a significant information spillover effect from SSE stock return to S&P 500 stock return in post-break period. The coefficient (γ) is bigger compared to the period before break and also is more significant during the post-break period. And we find significant information spillover effect from KOSPI stock return to S&P 500 stock return in all two sample periods.

We find that the coefficients of the significant volatility spillover effect from China and Korea to the US are negative. But the impact of the overnight SSE returns to S&P 500 close-to-open returns is different from the impact of the overnight KOSPI returns to S&P 500 close-to-open returns. The unexpected rising volatilities in China would increase the US stock return volatilities based on the coefficients (*d = 0.0003, 0.0003*) in the variance equation in all two sample periods, but the unexpected rising volatilities in Korea would reduce the US stock return volatilities based on the coefficients(*e = -0.0002, -0.0004*) in the variance equation in all two sample periods.

Table 4. **Estimation of GARCH (1, 1)-M model for symmetric spillovers from S&P500 returns and SSE composite returns to KOSPI returns**

	Pre-break			Post-break		
	$US_{c,t-1}$, $CN_{c,t-1}$> $KR_{c,t}$	$US_{c,t-1}$, $CN_{c,t-1}$> $KR_{o,t}$	$US_{c,t-1}$, $CN_{c,t-1}$> $KR_{d,t}$	$US_{c,t-1}$, $CN_{c,t-1}$> $KR_{c,t}$	$US_{c,t-1}$, $CN_{c,t-1}$> $KR_{o,t}$	$US_{c,t-1}$, $CN_{c,t-1}$> $KR_{d,t}$
α	0.0019 (2.73)**	0.0008 (3.34)**	0.0014 (2.22)*	0.0008 (1.35)	0.0006 (1.81)	-0.0001 (-0.23)
â	-3.4125 (-1.41)	2.1859 (0.66)	-7.8034 (-2.41)*	0.4284 (0.13)	3.4227 (0.47)	1.4101 (0.36)
γ	0.6276 (13.69)**	0.8064 (34.01)**	-0.2091 (-6.01)**	0.4819 (14.41)**	0.6482 (32.03)**	-0.1116 (-3.75)**
δ	-0.0271 (-0.85)	-0.0025 (-0.21)	-0.0707 (-1.27)	-0.0397 (-2.22)*	-0.0120 (-1.24)	-0.0036 (-0.11)
a	0.0000 (3.82)**	0.0000 (1.05)	0.0000 (5.73)**	0.0000 (3.55)**	0.0000 (11.49)**	0.0000 (6.09)**
b	0.8971 (42.01)**	1.0001 (206.3)**	0.9132 (58.53)**	0.8779 (4.06)**	0.7326 (11.40)**	0.8532 (36.02)**
c	0.0842 (3.99)**	-0.0057 (-0.89)	0.0659 (4.07)**	0.0805 (4.06)**	0.1599 (2.61)**	0.0953 (4.36)**
d	-0.0019 (-1.92)	-0.0000 (-0.93)	-0.0011 (-2.98)**	-0.0016 (-4.39)**	-0.0001 (-0.35)	-0.0013 (-5.33)**
e	0.0006 (2.21)*	0.0000 (2.83)**	0.0008 (1.56)	0.0000 (0.80)	-0.0002 (-1.82)	0.0000 (0.30)
Log-L	3463.86	4452.87	3725.45	3469.96	4204.48	3703.27
L-B(12)	24.45*	22.74*	25.97*	20.29	29.45*	11.90
L-B^2(12)	10.46	6.28	17.36	5.34	1.01	10.52

Notes: Values in parenthesis are z-statistics. * and ** indicate significance at the 5% and 1% levels, respectively.

The results of the estimation of multivariate GARCH(1,1)-M model for symmetric spillovers from S&P500 returns and SSE composite returns to KOSPI returns are presented in Table 4. We find that the overnight returns of KOSPI index go in the same direction as the overnight returns of S&P 500, but KOSPI daytime returns go in the opposite direction to the overnight S&P 500 returns. It seems that KOSPI returns are strongly impacted by the overnight S&P 500 stock returns. Significant price reversals exist from close-to-open returns to open-to-close returns. This means that Korean investors tend to overreact to the overnight performance of the US stock market.

The results of the estimation of GJR-GARCH (1,1)-M model for asymmetric spillovers from S&P500 returns to SSE composite returns are presented in Table 5. From the mean equation in Table 5, we can find that there is significant information spillover effect from return of S&P 500 to return of SSE composite in the post-break period according to the z-statistics of γ. However, we do not find either symmetric or asymmetric volatility spillover effect from S&P500 returns to SSE composite returns according to the variance equation.

Table 5. **Estimation of GJR-GARCH (1, 1)-M model for asymmetric spillover from SSE composite returns and KOSPI returns to S&P500 returns**

	Total period		Pre-break		Post-break	
	$CN_{c,t-1}$> $US_{c,t}$	$KR_{c,t-1}$> $US_{c,t}$	$CN_{c,t-1}$> $US_{c,t}$	$KR_{c,t-1}$> $US_{c,t}$	$CN_{c,t-1}$> $US_{c,t}$	$KR_{c,t-1}$> $US_{c,t}$
α	-0.0000 (-0.62)	-0.0001 (-1.19)	-0.0002 (-1.54)	-0.0003 (-1.92)*	-0.0000 (-0.01)	0.0000 (0.05)
â	0.9679 (0.35)	2.2182 (0.72)	6.5208 (0.98)	11.9240 (1.52)	-0.3271 (-0.14)	-0.8939 (-0.40)
γ	0.0380 (2.51)*	0.0862 (6.82)**	-0.0099 (-0.53)	0.0784 (5.33)**	0.0574 (3.16)**	0.1015 (4.18)**
δ	0.0000 (3.18)**	0.0000 (2.07)*	0.0000 (1.38)	0.0000 (1.53)	0.0000 (3.23)**	0.0000 (2.90)**
a	0.9335 (110.3)**	0.9325 (115.9)**	0.9417 (88.23)**	0.9239 (65.95)**	0.9610 (105.5)**	0.9699 (113.2)**
b	-0.0237 (--2.35)*	-0.0205 (1.91)	-0.0262 (-2.02)*	-0.0102 (-0.70)	-0.0572 (-5.59)**	-0.0642 (-5.34)**
c	-0.0000 (-0.91)	-0.0000 (-1.90)	0.0000 (2.66)**	-0.0001 (-2.62)**	-0.0000 (-3.42)**	-0.0000 (-0.70)
d	0.1617 (8.80)**	0.1548 (7.91)**	0.1523 (6.41)**	0.1415 (5.07)**	0.1723 (8.83)**	0.1719 (8.54)**
Log-L	9734.27	9753.00	5161.51	5174.73	4580.46	4581.33
L-B(12)	16.58	30.17**	8.27	17.05	15.28	21.30*
$L\text{-}B^2(12)$	14.86	13.73	4.71	6.84	21.72*	20.33*

Notes: Values in parenthesis are z-statistics. * and ** indicate significance at the 5% and 1% levels, respectively.

From the mean equation in Table 5, we find a significant information spillover effect from SSE composite returns to S&P500 returns in the post-break period and a significant information spillover effect from KOSPI returns to S&P500 returns in all 3 periods. From the variance equation, we find an asymmetric volatility spillover effect from SSE composite returns and KOSPI returns to S&P500 returns in all 3 periods. As is the same with Korea stock market, US stock market responds strongly to bad news. Good news in China and Korea reduce the volatility of the US stock market, but bad news in China and Korea increase the volatility of the US stock market based on the negative coefficient *d* and positive coefficient *e* in variance equation. From the results in mean and variance equation, we argue that the China's stock market has more information influence on the US stock market.

5. Conclusions

Using the GARCH and GJR-GARCH models, we find a significant information spillover effect from S&P 500 close-to-close return and KOSPI close-to-close return to SSE close-to-close return in the post-break period. The return spillover from America and Korea stock market to China stock market has increased significantly after the break. From the post-break period results, we find that SSE opening prices are strongly impacted by the overnight S&P 500 stock returns and SSE closing prices are strongly impacted by KOSPI daytime return. This different mean spillover effect in SSE opening price and closing price can be attributed to the time difference of market opening and closing between the China (Korea) stock market and the US stock market. We find a significant information spillover effect from SSE stock return to S&P 500 stock return in post-break period. And we find a significant information spillover effect from KOSPI stock return to S&P 500 stock return in all 3 sample periods.

We find that KOSPI returns are strongly impacted by the overnight S&P 500 stock returns. But this effect from S&P500 returns to KOSPI returns in the post-break period is relatively smaller compared to the effect in the pre-break period. Moreover, we find that American bad news have stronger effect on Korean stock market than good news.

We find a significant information spillover effect from SSE composite returns to S&P500 returns in the post-break period and a significant information spillover effect from KOSPI returns to S&P500 returns in all 3 periods. And we find asymmetric volatility spillover effect from SSE composite returns and KOSPI returns to S&P500 returns in all 3 periods.

For China and America, the results show that in the post-break period, significant mean spillover effects exist both from the US to China and from China to the US. And there are symmetry and asymmetry volatility spillover effects from China to the US in all periods. However, there is no asymmetry volatility spillover effect from the US to China. There is only a symmetry volatility spillover effect from the US to China. In terms of China and Korea, there is a significant mean spillover effect from China to Korea in all 3 periods and significant mean spillover effect from Korea to China only in the post-break period. There is an asymmetry volatility spillover effect from China to Korea in all 3 periods. In terms of the US and Korea, there are significant mean and asymmetry volatility spillover effects both from Korea to the US and from the US to Korea in all 3 periods.

According to our findings, we can see that there are mean and volatility spillover effects in the stock markets of countries which locate in different time zones. Hence, it is necessary for investors to pay attention to other countries' stock markets rather than just focusing on their own country's stock market. And by possessing the global perspective in investing, stock holders can probably increase their return rate to some degree.

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