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Volatility Spillovers Across Stock Index Futures in Asian Markets: Evidence from Range Volatility Estimators.

Abstract:

This paper investigates the channels of volatility transmission across stock index futures in 6 major developed and emerging markets in Asia. We analyse whether the popular volatility spillovers tests are susceptible to the choice of range volatility estimators. Our results demonstrate strong linkages between markets within the Asian region, indicating that the signal receiving markets are sensitive to both negative and positive volatility shocks, which reveals the asymmetric nature of volatility transmission channels. We find that some markets play a destabilizing role while other countries - contrary to popular belief - have a stabilizing effect on other markets in Asia.

1. Introduction

The increasing role of Asian financial markets in the world economy has recently attracted much attention to the problem of transmission of volatility shocks within the Asian region and beyond (e.g., Sin, 2013; He et al., 2015; Rughoo and You, 2015). The existing literature has been increasingly focusing on this issue after the Asian financial crisis of 1997 (e.g., Caporale et al., 2006; Yilmaz, 2010). Parallel to that the introduction of the stock index futures in Asian markets stimulated a debate about the intensity, speed and directions of international information transmission across futures markets (see e.g., Li, 2015). Since the early papers by Cox (1976) and Harris (1989) the empirical evidence tends to show that futures trading improves the channels of information transmission because the news are conveyed by futures markets faster than by underlying spot markets. Therefore, the question how the signals are transmitted across the futures markets and what is the dynamics of cross-markets information flows is highly relevant. Due to the fact that stock index futures are relatively new instruments in Asia, the analysis of directions and intensity of transmission of volatility shocks across futures markets is particularly interesting using this new Asian data[1]. Thus, this paper aims to address the question: who are the net-contributors and net-recipients of volatility shocks within the Asian markets? We deal with this issue by exploring the direction and asymmetric nature of volatility transmission across emerging and developed Asian markets employing stock index futures data.

This paper is distinctly different from previous studies in two major ways. First, whilst most of the existing papers employed stock indices data in their analysis of volatility transmission across Asian markets, we argue that using stock index futures data provides more practically relevant results. Stock indices cannot be traded by investors as financial instruments, therefore from the point of view of the construction, testing and execution of actual trading strategies, the analysis of volatility transmission is much more realistic using the futures data (see, e.g., Yarovaya et al., 2016). Second, the existing literature on volatility spillovers often fails to provide consistent results. One of the underlying problems is that volatility spillovers tests are sensitive to the choice of volatility estimators (e.g., Shu and Zhang, 2005). The advantages of the range volatility estimators have been widely discussed in the previous literature (see, e.g., Garman and Klass, 1980; Parkinson, 1980; Rogers and Satchell, 1991, Yang and Zhang, 2000; among others) and the emphasis in the earlier studies has been on their sensitivity analysis. In this paper we do not aim, however, to compare the accuracy of range volatility estimators, which has been already done before in previous studies, but our purpose is to demonstrate how the results of volatility spillovers analysis may depend on the choice of volatility estimators.

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[1] The first stock index futures contracts traded in China was IFBK10 (04/16/10-05/21/10), in Hong Kong it was HIJ92 (04/01/92-04/29/92), in Taiwan it was FTU98 (07/21/98-09/17/98), in Singapore it was QZV98 (09/07/98-10/30/98), in South Korea it was KMM96 (05/03/96-06/13/96) and in Japan it was NKZ88 (09/05/88-12/08/88).

2. Data and Methodology

2.1. Database

We use the data about the weekly volatility of stock index futures of 6 major Asian markets. The selection of countries includes both developed markets, i.e. Hong Kong, Singapore and Japan, and emerging markets, i.e. China, South Korea and Taiwan. Since in China the stock index futures have been introduced only in the year 2010, our sample period starts in September 2010 and extends until September 2015, so it includes 260 weekly frequency observations for each country.[2] The daily opening, closing, high and low prices for futures contracts with the closest expiration dates were collected from Bloomberg database.

2.2. Estimation of Volatility

The classical measures of assets price variance are based on close-to-close prices from n-period historical datasets. In this paper, we provide the evidence from range estimators, i.e. Parkinson (1980), Garman and Klass (1980), Rogers and Satchell (1991), denoted respectively as P, GK and RS, which are described below following the notation from Shu and Zhang (2006) and Yang and Zhang (2000) by equations (1) – (3):

$$\sigma_P^2 = \frac{1}{4ln2}(h-l)^2 \tag{1}$$

$$\sigma_{GK}^2 = 0.511(h-l)^2 - 0.019[c(h+l) - 2hl] - 0.383c^2 \tag{2}$$

$$\sigma_{RS}^2 = h(h-c) + l(l-c) \tag{3}$$

where: c, o, h and l are the normalized closing, opening, high and low prices, respectively. The weekly volatilities are estimated for all 6 futures markets in our sample.

2.3. Methodology

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[2] Due to the fact that trading volume on contracts with expiration dates from May till August is comparatively low, the first futures contract used to generate continuous futures series for China is IFBU10 starting in September 2010.

First, we use Diebold and Yilmaz (2012) methodology which provides the measure for volatility spillovers based on forecast error variance decompositions from a vector autoregressive (VAR) model.[3] Total volatility spillover index captures the intensity of volatility spillovers across the selected markets, while net volatility spillover indices are used to identify net-contributors and net-recipients of volatility shocks.

Second, our procedure employs Gauss code written by Hatemi-J (2012) to run asymmetric causality test. The cumulative sums of positive and negative shocks of each underlying variables can be defined as follows:

$$\theta_{1t}^{+} = \sum_{i=1}^{t} \Delta\theta_{1i}^{+},\quad \theta_{1t}^{-} = \sum_{i=1}^{t} \Delta\theta_{1i}^{-},\quad \theta_{2t}^{+} = \sum_{i=1}^{t} \Delta\theta_{2i}^{+},\quad \theta_{2t}^{-} = \sum_{i=1}^{t} \Delta\theta_{2i}^{-}, \tag{4}$$

where positive and negative shocks are defined as: $\theta_{1t}^{+} = \max(\Delta\theta_{1i},0)$, $\theta_{2t}^{+} = \max(\Delta\theta_{2i},0)$, $\theta_{1t}^{-} = \min(\Delta\theta_{1i},0)$ and $\theta_{2t}^{-} = \min(\Delta\theta_{2i},0)$.

Third, we further investigate asymmetric response to volatility shocks using a variant of the DCC-GARCH model originally introduced by Engle (2002). We apply its modification, i.e. asymmetric generalized dynamic conditional correlation (AG-DCC) model, developed further by Cappiello et al. (2006):

$$Q_t = (\bar{P} - A'\bar{P}A - B'\bar{P}B - G'\bar{N}G) + A'\varepsilon_{t-1}\varepsilon_{t-1}'A + G'n_{t-1}n_{t-1}'G + B'Q_{t-1}B, \tag{5}$$

where: A, B and G are $k \times k$ parameter matrices, $n_t = I[\varepsilon_t < 0]^{\circ}\varepsilon_t$ (where $I[\cdot]$ is $k \times 1$ indicator function that takes on value 1 if the argument is true and 0 otherwise, while "°" indicates the Hadamard product) and $\bar{N} = E[n_t n_t']$. Q_t is positive definite for all possible realizations if the intercept $\bar{P} - A'\bar{P}A - B'\bar{P}B - G'\bar{N}G$ is positive semi-definite and the initial covariance matrix Q_0 is positive definite.

3. Empirical Results and Discussion

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[3] For more details regarding the description of this methodology please see Diebold and Yilmaz (2012).

3.1. Volatility Spillover Index

Table 1 presents volatility spillovers results. It shows that the value of total volatility spillover index, relying on the Diebold and Yilmaz (2012) framework, depends on the choice of volatility estimators. Particularly, Parkinson method underestimates the intensity of spillovers across markets in comparison to Garman-Klass and Rogers-Satchell. However, the general picture regarding net-contributors and net-recipients of volatility shocks in Asia is consistent using all three range volatility estimators. Our results show that Hong Kong, South Korea and Taiwan are net-contributors, while Japan, Singapore and China are net-recipients.

[Table 1 around here]

Figure 1 plots total volatility spillovers indices and it indicates that the pattern of spillovers is not significantly different for all three volatility estimators.

[Figure 1 around here]

However, Diebold and Yilmaz (2012) framework does not allow to separate transmission of positive and negative shocks across markets, therefore in the next sections we further investigate the pattern of asymmetric responses.

3.2. Asymmetric Causality Test Results

Table 2 summarises the pairwise results of asymmetric causality test across stock index futures of all 6 analysed markets in the Asian region. The test was conducted on 180 pairs of markets and the evidence of causality was found for only 13 pairs (i.e. 7%) at the 10% significance level.

[Table 2 around here]

The results of asymmetric causality test for Parkinson volatility estimator detect four pairs of causal relationships, providing the evidence of two channels of intra-region volatility transmission. The first channel indicates that volatility transmits from Singapore to Japan and then from Japan to China. The second channel shows that volatility transmits from South Korea to Hong Kong and then from Hong Kong to Taiwan. In case of both those channels, the results of asymmetric causality test mean that a negative volatility shock in one market causes a negative shock in the volatility in another market. Hence, for example, i.e. a decline in volatility on the Singaporean market caused a decline in volatility in Japan first and afterwards this effect spread to China.

The conveyance of negative volatility shocks from Japan to China is also evident in case of the Garman-Klass volatility estimator. Besides, the results for Garman-Klass indicate that Taiwan is susceptible to negative volatility shocks transmitted from Hong Kong. In contrast to Parkinson volatility estimator's results, the findings for Garman-Klass volatility estimator reveal the transmission of positive volatility shock across markets, which provides evidence that South Korea is a recipient of volatility from Singapore, China and Taiwan. The same results are obtained for Rogers-Satchell volatility estimator, which means that volatility is transmitted from China and Taiwan to South Korea. The results for Rogers-Satchell range volatility estimator also indicate that volatility transmits from China to South Korea and also from Hong Kong to South Korea. In the opposite direction, the negative volatility shocks are conveyed from South Korea to Taiwan, which documents the existence of bi-directional causality between these two markets. The summary of the above findings is presented in Table 3.

[Table 3 around here]

Using three different range volatility estimators we found significant difference among the results. For example, according to Garman-Klass results South Korea is a recipient of volatility, however, the findings for Parkinson and Rogers-Satchell volatility estimators also show that South Korea is the source of negative volatility shocks for Hong Kong and Taiwan, respectively. Another important difference regards the type of volatility shocks, i.e. positive or negative ones. The results of asymmetric causality test for Parkinson volatility estimator identified conveyance of only the negative volatility shocks, while for Garman-Klass and Rogers-Satchell volatility estimators there is evident transmission of both types of shocks.

The asymmetry in volatility spillovers means that volatility transmission mechanisms can lead to both destabilizing and stabilizing effects on other markets. While volatility spillovers are commonly perceived as predominantly a destabilizing force, our results based on the asymmetric test show that decrease in volatility in one market can cause a decrease in volatility in another market. Thus, the transmission of negative volatility shocks can play a stabilizing role for stock markets and we detected such effect using the stock index futures data from Asia.

Overall, Table 3 shows some interesting patterns when the results are analyzed also from the point of view of developed and emerging markets as groups of countries. First, there is no clear dominance of either of these two types of markets in terms of their role as volatility contributors. There are 7 cases with developed markets and 6 cases with emerging markets in Table 3, where these countries are identified as contributors. Second, the emerging markets are, however, substantially more sensitive to volatility shocks as recipients. There are only 2 cases where the developed markets act as recipients and 12 cases where emerging markets are the recipients of volatility. Most notably, South Korea appears as the recipient 6 out of all 12 cases in Table 3. Third, when results are broken down between positive and negative impacts of volatility, Table 3 reveals that the developed markets act as contributors of stabilizing effects in 5 cases versus only 2 cases when emerging markets play such role (see “-“ signs in Table 3). The emerging markets, however, are more likely to induce volatility in other markets than the developed markets, as it is evidenced by only 2 such cases for developed markets versus 4 cases for emerging markets (see “+“ signs in Table 3). Therefore, we can conclude that there is a dominance of evidence of stabilizing influence of developed markets and evidence of destabilizing effect of emerging markets on other countries in our sample.

3.3. AG-DCC Model Results

Table 4 summarises results of the AG-DCC model of Cappiello et al. (2006) for Japan, Hong Kong, Singapore, China, South Korea and Taiwan. Most parameters are statistically significant, indicating that the data is fitted with the AG-DCC model well and that the shocks to correlation are typically highly persistent. Most notably, the estimate of the asymmetric term (g_1) for most futures markets is significant at the 5% level using Parkinson range estimator, thereby providing evidence of an asymmetric response in correlations. In other words, the conditional correlation among the stock markets exhibits higher dependency when it is driven by negative shocks. This result supports the evidence of the presence of asymmetric responses to negative shocks reported by Kenourgios et al. (2011) and it is also consistent with the asymmetric causality test that we used in the previous section. When we apply Garman-Klass range estimator, we also find evidence of an asymmetric response in correlations (only except for China). For Rogers-Satchell range estimator there is evidence for Japan, Hong Kong and Taiwan of an asymmetric response in correlations.

[Table 4 around here]

Subsequently, we converted the series of “Q” matrices to 5 pairwise time-varying correlations series[4]. In Figure 1, we plot the dynamic conditional correlations (DCCs) between each pair of stock index futures returns via China. The fluctuation around the time path of DCC series is evident over the entire sample period for all pairs, suggesting that the assumption of constant conditional correlations (CCC) models is not appropriate.

[Figure 2 around here]

Panel A in Figure 2 shows that the dynamic correlation between China and Japan is lowest and most stable throughout the sample when using the Parkinson range estimator.

4. Concluding remarks

We use stock index futures data to analyse volatility transmission across emerging and developed markets in Asia. Based on our findings for all three range volatility estimators, i.e. Parkinson, Garman-Klass, Rogers-Satchell, we conclude that while the results relying on generalized vector autoregressive framework provide consistent picture regardless of the choice of the range volatility estimator, i.e. Hong Kong, South Korea and Taiwan are net-contributors while Japan, Singapore and China are net-recipients, the results of asymmetric causality test depend on the choice of volatility estimator. Thus, for Parkinson volatility estimator the identified conveyance of volatility is limited to negative shocks only, while for Garman-Klass and Rogers-Satchell volatility estimators the transmission of both types of shocks is evident. Further application of AG-DCC model supports the asymmetric response in correlation across markets. Our findings provide evidence about the stabilizing role of the transmission of negative volatility shocks across countries within the Asian region.

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[4] The relevant RATS codes are available from: https://estima.com/forum/viewtopic.php?f=8&t=792.

This study also shows that the results of empirical tests are susceptible to the choice of volatility estimators, which supports other findings about the ambiguity of the existing evidence on the directions of volatility spillovers in the previous literature. Therefore, we suggest that the research on volatility transmission should include different range volatility estimators, which can help avoid possible biases in the results.

References:

Caporale, G.M., Pittis, N. and Spagnolo, N. (2006). Volatility transmission and financial crises. Journal of Economics and Finance, 30(3), 376-390.

Cappiello, L., Engle, R.H. and Sheppard, K. (2006). Asymmetric dynamics in the correlations of global equity and bond returns. Journal of Financial Econometrics, 4(4), 537–572.

Cox, C.C. (1976). Futures trading and market information. Journal of Political Economy, 84(6), 1215-1237.

Diebold, F. X., and Yilmaz, K. (2012). Better to give than to receive: Predictive directional measurement of volatility spillovers. International Journal of Forecasting, 28(1), 57-66.

Engle, R.F. (2002). Dynamic conditional correlation. Journal of Business and Economic Statistics, 20(3), 339-350.

Garman, M.B., and Klass, M.J. (1980). On the estimation of price volatility from historical data. Journal of Business, 53(1), 67–78.

Harris, L. (1989). S&P 500 cash stock price volatilities. Journal of Finance, 44(5), 1155-1175.

Hatemi-J, A. (2012). Asymmetric causality tests with an application. Empirical Economics, 43(1), 447-456.

He, H., Chen, S., Yao, S. and Ou, J. (2015). Stock market interdependence between China and the world: A multi-factor R-squared approach. Finance Research Letters, 13, 125–129.

Kenourgios, D., Samitas, A. and Paltalidis, N. (2011). Financial crises and stock market contagion in a multivariate time-varying asymmetric framework. Journal of International Financial Markets, Institutions and Money, 21(1), 92-106.

Li, S. (2015). Volatility spillovers in the CSI300 futures and spot markets in China: Empirical study based on discrete wavelet transform and VAR-BEKK-bivariate GARCH model. Procedia Computer Science, 55, 380 – 387.

Parkinson, M. (1980). The extreme value method for estimating the variance of the rate of return. Journal of Business, 53(1), 61–65.

Rogers, L. C. G. and Satchell, S.E. (1991). Estimating variance from high, low, and closing prices. Annals of Applied Probability, 1(4), 504–512.

Rughoo, A. and You, K. (2015). Asian financial integration: Global or regional? Evidence from money and bond markets. International Review of Financial Analysis (forthcoming), http://dx.doi.org/10.1016/j.irfa.2015.03.007

Shu, J. and Zhang, J.E. (2006). Testing range estimators of historical volatility. Journal of Futures Markets, 26(3), 297.

Sin, C.Y. (2013). Using CARRX models to study factors affecting the volatilities of Asian equity markets. North American Journal of Economics and Finance, 26(c), 552– 564.

Yang, D. and Zhang, Q. (2000). Drift-independent volatility estimation based on high, low, open, and close prices, Journal of Business, 73(3), 477–491.

Yarovaya, L., Brzeszczynski, J. and Lau, C.K.M. (2016). Intra- and inter-regional return and volatility spillovers across emerging and developed markets: Evidence from stock indices and stock index futures, International Review of Financial Analysis, 43, 96-114.

Yilmaz, K. (2010). Return and volatility spillovers among the East Asian equity markets. Journal of Asian Economics, 21(3), 304–313.

Table 1. Volatility spillovers across markets.

Parkinson		JPN	HKG	SGP	CHN	KOR	TWN	From Others*	Net	Conclusion
Japan	JPN	64.86	7.54	6.79	2.77	8.54	9.50	35.14	-16.47	net-recipient
Hong Kong	HKG	4.84	44.55	12.07	10.51	15.91	12.12	55.45	10.26	net-contributor
Singapore	SGP	4.91	14.70	45.03	3.28	17.25	14.83	54.97	-6.31	net-recipient
China	CHN	0.69	13.91	3.55	72.83	3.77	5.26	27.17	-3.42	net-recipient
South Korea	KOR	3.41	16.32	14.01	2.45	44.65	19.16	55.35	9.13	net-contributor
Taiwan	TWN	4.82	13.25	12.23	4.74	19.01	45.94	54.06	6.82	net-contributor
**Contribution to others		18.67	65.71	48.66	23.75	64.48	60.88	282.14		
***Contribution including own		83.53	110.26	93.69	96.58	109.13	106.82	47.0%		
Garman-Klass		JPN	HKG	SGP	CHN	KOR	TWN	From Others*	Net	Conclusion
Japan	JPN	60.47	7.93	6.70	3.27	9.05	12.57	39.53	-17.38	net-recipient
Hong Kong	HKG	5.16	41.56	10.31	14.17	15.46	13.34	58.44	8.73	net-contributor
Singapore	SGP	4.68	13.03	47.38	3.64	17.03	14.24	52.62	-6.50	net-recipient
China	CHN	1.68	18.24	4.48	60.83	6.04	8.74	39.17	-7.38	net-recipient
South Korea	KOR	3.67	14.57	12.92	3.68	48.66	16.50	51.34	15.99	net-contributor
Taiwan	TWN	6.97	13.41	11.70	7.03	19.73	41.15	58.85	6.53	net-contributor
**Contribution to others		22.16	67.17	46.12	31.79	67.33	65.38	299.95		
***Contribution including own		82.62	108.73	93.50	92.62	115.99	106.53	50.0%		
Rogers-Satchell		JPN	HKG	SGP	CHN	KOR	TWN	From Others*	Net	Conclusion
Japan	JPN	59.08	8.51	5.83	3.68	8.67	14.23	40.92	-14.23	net-recipient
Hong Kong	HKG	5.81	41.55	8.26	16.92	14.00	13.45	58.45	7.87	net-contributor
Singapore	SGP	4.77	11.31	55.00	3.32	13.35	12.24	45.00	-6.57	net-recipient
China	CHN	3.00	20.27	4.32	56.09	7.35	8.98	43.91	-8.16	net-recipient
South Korea	KOR	4.45	12.89	10.15	4.16	53.23	15.13	46.77	16.46	net-contributor
Taiwan	TWN	8.65	13.34	9.87	7.68	19.86	40.60	59.40	4.63	net-contributor
**Contribution to others		26.68	66.32	38.43	35.76	63.23	64.03	294.45		
***Contribution including own		85.77	107.87	93.43	91.84	116.46	104.63	49.1%		

Notes: * From Others - directional spillover indices measure spillovers from all markets j to market i; ** Contribution to others - directional spillover indices measure spillovers from market i to all markets j; *** Contribution including own - directional spillover indices measure spillovers from market i to all markets j including contribution from own innovations of market i; Other columns contain net pairwise (i,j)-th spillovers indices.

Table 2. The asymmetric causality test results using the bootstrap simulation technique (September 2010 – September 2015).

	Parkinson				Garman-Klass				Rogers-Satchell			
Null Hypothesis	Test value	Bootstrap CV at 1%	Bootstrap CV at 5%	Bootstrap CV at 10%	Test value	Bootstrap CV at 1%	Bootstrap CV at 5%	Bootstrap CV at 10%	Test value	Bootstrap CV at 1%	Bootstrap CV at 5%	Bootstrap CV at 10%
Japan (+) ≠> Hong Kong (+)	0.098	12.641	4.162	2.424	0.091	17.808	4.85	2.409	0.223	18.445	3.619	2.268
Japan (-) ≠> Hong Kong (-)	0.013	12.393	4.376	2.781	0.401	13.886	4.388	2.628	0.471	10.273	3.055	1.942
Hong Kong (+) ≠> Japan (+)	0.301	8.896	3.434	2.292	0.398	10.758	3.733	2.352	0.151	13.827	3.433	2.087
Hong Kong (-) ≠> Japan (-)	0.098	7.333	3.271	2.182	0.248	8.738	6.142	4.678	0.202	13.256	3.471	2.04
Japan (+) ≠> Singapore (+)	0.054	13.004	4.195	2.294	0.317	12.939	3.768	1.927	0.212	12.585	2.845	1.721
Japan (-) ≠> Singapore (-)	0.793	9.853	3.796	2.314	0.112	16.029	3.282	1.976	0.001	23.058	3.174	1.623
Singapore (+) ≠> Japan (+)	0.149	14.838	3.715	2.248	0.045	15.036	3.747	2.28	0.072	17.789	3.533	1.788
Singapore (-) ≠> Japan (-)	**3.279****	9.61	3.268	1.937	0.034	11.743	2.78	1.836	1.12	26.002	4.385	1.928
Japan (+) ≠> China (+)	0.593	9.43	3.835	2.615	2.079	14.205	3.547	2.391	0.977	14.242	3.898	2.135
Japan (-) ≠> China (-)	**3.274***	9.599	3.791	2.597	**2.567***	11.298	4.109	2.42	1.053	10.838	3.391	2.161
China (+) ≠> Japan (+)	0.481	10.614	3.808	2.721	0.73	10.152	4.04	2.367	0.191	12.862	3.262	2.084
China (-) ≠> Japan (-)	0.552	8.61	3.469	2.364	0.278	9.134	3.52	2.304	0.024	10.706	3.492	2.241
Japan (+) ≠> South Korea (+)	0.881	7.952	3.726	2.415	2.623	8.753	4.146	2.719	2.193	11.65	3.767	2.475
Japan (-) ≠> South Korea (-)	0.001	7.549	3.444	2.363	0.445	6.886	3.762	2.258	0.656	8.967	3.148	2.204
South Korea (+) ≠> Japan (+)	0.148	9.866	3.798	2.355	0.471	11.996	3.783	2.176	0.377	7.721	3.555	2.468
South Korea (-) ≠> Japan (-)	1.18	9.987	5.952	4.703	0.407	10.024	4.329	2.607	0.288	15.818	3.757	2.514
Japan (+) ≠> Taiwan (+)	0.395	9.065	3.52	2.284	0.431	10.14	3.825	2.253	0.037	10.459	3.504	2.154
Japan (-) ≠> Taiwan (-)	0.158	12.385	3.944	2.44	0.095	16.174	4.057	2.286	0.017	8.473	3.432	1.954
Taiwan (+) ≠> Japan (+)	0.135	16.854	4.5	2.726	0.003	21.127	4.501	2.326	0.256	12.772	3.727	2.059
Taiwan (-) ≠> Japan (-)	0.105	9.566	3.848	2.381	0.083	9.318	3.578	2.226	0.117	18.841	3.406	1.941
Hong Kong (+) ≠> Singapore (+)	0.257	12.385	3.944	2.44	1.041	9.788	3.532	2.392	1.304	18.278	3.923	2.282
Hong Kong (-) ≠> Singapore (-)	1.752	13.932	3.744	2.513	0.459	12.409	3.457	2.067	0.22	9.94	3.575	1.916
Singapore (+) ≠> Hong Kong (+)	0.047	9.041	3.929	2.449	0.081	10.597	4.027	2.459	0.096	12.653	3.979	2.258
Singapore (-) ≠> Hong Kong (-)	1.464	8.202	3.643	2.311	0.024	7.447	3.406	2.291	0.013	21.825	3.349	1.919
Hong Kong (+) ≠> China (+)	0.833	11.343	5.813	4.633	0.002	7.656	3.445	2.268	0.004	11.951	3.403	2.274
Hong Kong (-) ≠> China (-)	0.545	11.776	6.814	4.89	0.495	13.796	4.689	2.811	2.137	17.027	6.747	4.465
China (+) ≠> Hong Kong (+)	0.698	12.637	7.188	5.279	0.067	10.403	4.42	2.984	0.025	13.053	4.036	2.514
China (-) ≠> Hong Kong (-)	0.206	11.869	6.393	4.739	0.44	14.052	4.163	2.529	1.378	18.321	7.071	4.432
Hong Kong (+) ≠> South Korea (+)	0.217	14.039	6.612	4.552	1.28	7.789	3.561	2.47	**4.811****	7.61	3.919	2.697
Hong Kong (-) ≠> South Korea (-)	1.248	10.828	5.995	4.395	0.674	9.493	5.85	4.295	0.5	12.655	5.538	3.968
South Korea (+) ≠> Hong Kong (+)	0.209	11.887	6.19	4.603	0.092	9.798	4.567	2.713	0.031	8.614	3.895	2.688
South Korea (-) ≠> Hong Kong (-)	**27.766*****	14.015	9.991	7.91	0.844	10.661	5.784	4.34	3.196	12.301	6.038	4.519
Hong Kong (+) ≠> Taiwan (+)	2.314	13.698	7.373	4.751	0.867	8.611	3.353	2.23	0.276	11.38	3.604	2.31
Hong Kong (-) ≠> Taiwan (-)	**4.697***	10.978	6.234	4.599	**4.973*****	15.336	6.765	4.392	0.084	11.371	3.342	2.257
Taiwan (+) ≠> Hong Kong (+)	3.016	15.911	6.479	4.698	0.103	14.257	4.48	2.649	0.146	18.018	3.771	2.247
Taiwan (-) ≠> Hong Kong (-)	3.884	11.265	7.193	5.013	1.06	13.628	6.168	4.522	0.383	8.881	3.249	2.277

Table 2. (Continued).

Singapore (+) ≠> China (+)	0.402	9.199	4.214	2.631	0.29	8.822	3.946	2.375	0.004	11.543	3.921	2.371
Singapore (-) ≠> China (-)	0.167	7.949	3.442	2.337	0.004	7.172	3.505	2.224	0.001	16.169	3.736	2.252
China (+) ≠> Singapore (+)	0.037	8.51	4.121	2.927	0.032	10.908	4.183	2.625	0.054	16.818	4.147	2.294
China (-) ≠> Singapore (-)	0.021	9.875	3.855	2.491	0.267	12.509	3.62	2.213	0.113	13.072	3.479	1.886
Singapore (+) ≠> South Korea (+)	1.694	8.695	4.062	2.386	**3.628***	10.553	4.665	2.574	2.18	11.647	4.337	2.442
Singapore (-) ≠> South Korea (-)	0.331	7.182	3.571	2.568	0.058	10.02	4.287	2.413	1.162	12.749	3.243	2.201
South Korea (+) ≠> Singapore (+)	0.42	8.213	3.817	2.645	0.202	8.051	4.047	2.682	0.201	9.485	3.95	2.312
South Korea (-) ≠> Singapore (-)	0.384	9.422	3.787	2.141	0.405	8.262	3.689	2.509	0.415	8.635	3.765	2.365
Singapore (+) ≠> Taiwan (+)	0.501	10.653	3.716	2.336	0.094	12.872	3.871	2.531	0.081	11.197	3.502	2.03
Singapore (-) ≠> Taiwan (-)	0.757	9.824	4.572	2.692	0.034	11.743	2.78	1.836	0.468	23.13	4.559	2.385
Taiwan (+) ≠> Singapore (+)	0.463	10.302	3.989	2.355	0.002	10.242	3.594	2.327	0.159	17.743	3.45	1.972
Taiwan (-) ≠> Singapore (-)	0.508	10.229	3.401	2.349	0.041	15.176	3.41	2.178	0.185	14.876	2.946	1.862
China (+) ≠> South Korea (+)	1.373	8.986	3.926	2.543	**6.742****	9.95	3.955	2.667	**16.576*****	12.821	6.029	4.37
China (-) ≠> South Korea (-)	0.331	7.182	3.571	2.568	0.659	7.442	3.556	2.389	1.166	13.292	5.888	4.309
South Korea (+) ≠> China (+)	0.237	7.633	4.155	2.647	0.394	9.374	3.696	2.581	0.191	10.824	6.222	4.546
South Korea (-) ≠> China (-)	0.15	6.638	3.633	2.497	0.42	7.434	3.743	2.705	1.49	14.124	6.517	4.452
China (+) ≠> Taiwan (+)	0.138	10.903	6.805	4.801	1.34	11.37	4.076	2.607	1.325	14.406	3.385	2.218
China (-) ≠> Taiwan (-)	1.055	10.564	6.293	4.493	1.369	15.039	6.297	4.258	0.009	10.222	3.382	2.116
Taiwan (+) ≠> China (+)	3.654	12.171	6.459	4.55	1.646	10.653	4.065	2.499	0.031	17.621	3.954	2.247
Taiwan (-) ≠> China (-)	1.389	11.63	6.482	4.513	1.465	14.492	5.798	4.201	0.369	13.533	3.39	2.149
South Korea (+) ≠> Taiwan (+)	2.481	10.82	6.203	4.385	0.692	11.191	6.396	4.459	0.314	9.914	6.44	4.535
South Korea (-) ≠> Taiwan (-)	3.883	10.655	6.686	4.829	4.876	15.568	6.895	4.952	**16.241*****	15.722	7.369	4.868
Taiwan (+) ≠> South Korea (+)	4.329	13.005	6.607	4.803	**21.506*****	13.063	6.959	4.664	**44.332*****	14.95	6.521	4.801
Taiwan (-) ≠> South Korea (-)	0.122	10.781	6.154	4.655	0.497	12.6	5.866	4.393	0.509	16.106	7.446	4.882

Notes: The critical values for the asymmetric causality test are calculated using a bootstrap algorithm with leverage correction.* The rejection of the Null Hypothesis of no causality at the 10% significance level. **The rejection of the Null Hypothesis of no causality at the 5% significance level; *** The rejection of the Null Hypothesis of no causality at the 1% significance level. The symbol A ≠> B means that A does not cause B which is the null hypothesis.

Table 3. Summary for contributors and recipients, asymmetric test.

Parkinson:	pair 1	pair 2	pair 3	pair 4	pair 5
Contributors	Singapore	Japan	South Korea	Hong Kong	
Recipients	Japan	China	Hong Kong	Taiwan	
Type of shock	-	-	-	-	
Garman-Klass:					
Contributors	Japan	Hong Kong	Singapore	China	Taiwan
Recipients	China	Taiwan	South Korea	South Korea	South Korea
Type of shock	-	-	+	+	+
Rogers-Satchell:					
Contributors	Hong Kong	China	Taiwan	South Korea	
Recipients	South Korea	South Korea	South Korea	Taiwan	
Type of shock	+	+	+	-	

Notes: Positive shock indicates that the increase in volatility of contributor market causes the increase in volatility of recipient market. Negative shock means that the decline in volatility of contributor market causes the decline in volatility of recipient market.

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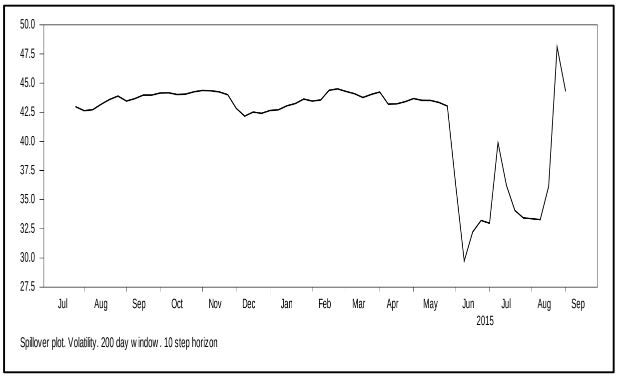
Table 4. Results of asymmetric dynamic conditional correlation analysis.

Stock market	**a_i^2**	**g_i^2**	**b_i^2**	**a_i^2**	**g_i^2**	**b_i^2**	**a_i^2**	**g_i^2**	**b_i^2**
	Parkinson			Garman-Klass			Rogers-Satchell		
Japan	0.0564	-0.3684***	0.9987***	0.755***	0.8489***	0.3294*	0.6021***	0.5059***	0.7469***
Hong Kong	0.3185***	0.1874**	0.9043***	0.3166***	0.2983***	0.9044***	0.1866***	0.3418***	0.9541***
Singapore	0.5741***	-0.3319**	0.7179***	0.4537***	-0.2091***	0.8418***	0.3073***	0.1077	0.8911***
China	0.2583***	0.2938*	0.7685***	0.2928***	0.1625	0.7937***	0.3032***	-0.1761	0.7631***
Korea	0.381***	-0.4477**	0.5961***	0.4569***	-0.3175***	0.6514***	0.3882***	-0.0332	0.7222***
Taiwan	0.3849***	-0.5734**	0.2722**	0.2965***	-0.253***	0.7556***	0.2856***	-0.1109***	0.7104***

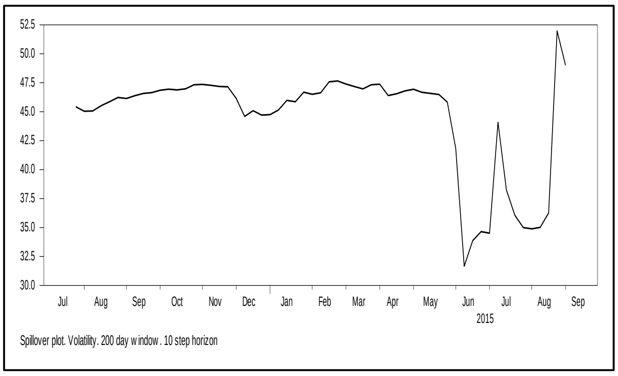
Notes: This table reports parameter estimates for the asymmetric DCC GARCH models. *Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level.

Figure 1. Spillover plots.

Panel A: Parkinson



Panel B: Garman-Klass



Panel C: Rogers-Satchell

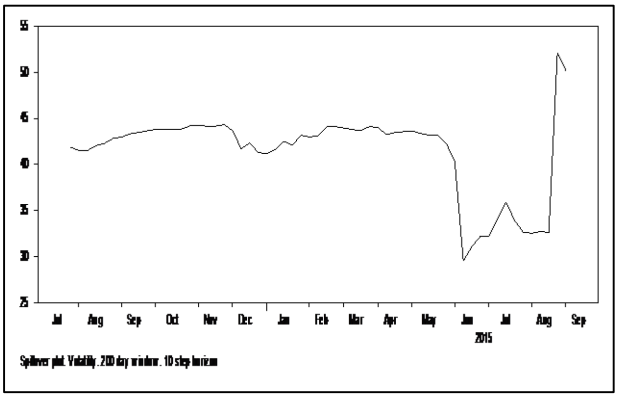
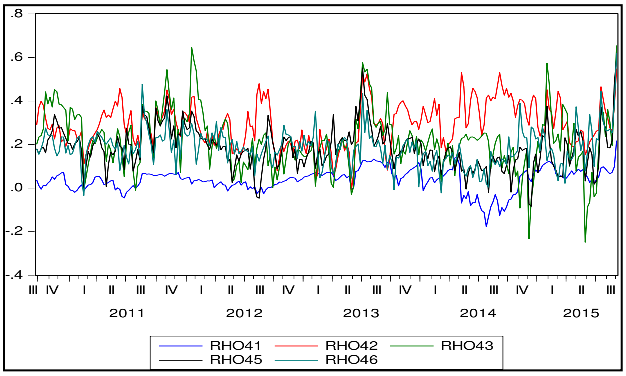
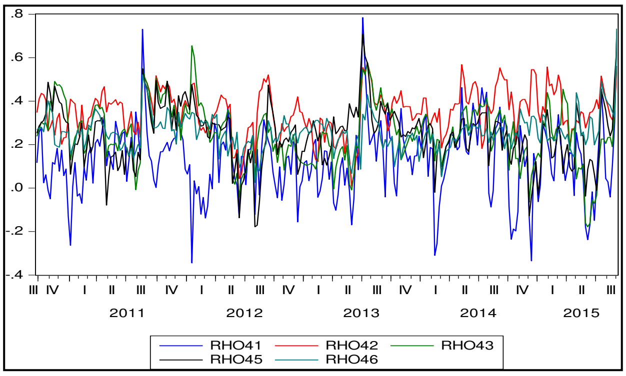


Figure 2. Dynamic correlations between China and other stock markets (AG-DCC).

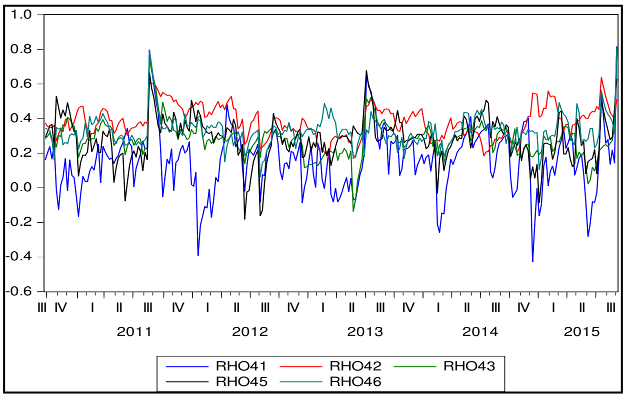
Panel A: Parkinson



Panel B: Garman-Klass



Panel C: Rogers-Satchell



Note: RHO41: China-Japan; RHO42: China-Hong Kong; RHO43: China-Singapore; RHO45: China-South Korea; RHO46: China-Taiwan.