GARCH and TGARCH Approach to Information Linkages

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Abstract

In this study, we examined the flow of information and knowledge between the stock market of the United States (US) and emerging Asian stock markets for a period from January 2000 – December 2017. The sample included four emerging markets of India, Indonesia, Philippines, South Korea, and one developed market of the US. Our study identified the structural breaks for all the markets and then explored the asymmetric volatility spillover between the US and all Asian markets by using an extended TGARCH model. The findings of the study reflected that shocks and information transmission from the US stock market were significant from 2007 – 2010, which was the period of the global sub-prime financial crisis, which confirms the notion that during the financial crisis, the degree of dependence between the stock markets increased. Besides this, volatility persistence was also observed from the stock market of the US to all the sample stock markets for all structural break periods, and this persistency was highest from 2015 – 2017. Further, the extent and durability of the reactions to volatility coming from the US stock market were not uniform across all Asian stock markets. The integration of emerging markets of Asia with the developed market of the US has important implications for regulators and investors.

Keywords : **volatility, volatility spillover, unit root test, GARCH, TGARCH**

JEL Classification : C58, C49, F65, F63

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Globalization, economic regulations, financial innovations, regionalization, and speedy reforms are facilitating the integration of securities markets across the globe. As a result, the interdependence between the financial markets is ever increasing. The interdependence of markets leads to information transmission and dissemination across stock markets which, in turn, brings volatility and return spillovers in those markets. Stock market information and its transmission have been examined by many researchers in different stock markets across the globe (Jawadi & Arouri, 2008 ; Patel, 2017 ; Shah & Deo, 2016). These studies have revealed that apart from globalization, economic regulations, financial innovations, regional economic integration, and speedy reforms, financial and economic crises are also important factors that influence information transmission and stock market linkages. During the last two decades, researchers have examined and scrutinized the influence of various pecuniary crises, especially global crises (Ali & Afzal, 2012 ; Rousseau & Wachtel, 2011). It has further been observed that the world's largest economic crisis, which emerged after

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mid-2007 having its genesis in the USA, had a significant, immense, and continuous impact on the network of Asian stock markets (Aswani, 2017 ; Fidrmuc & Korhonen, 2010 ; Reinhart & Rogoff, 2009 ; Wang, 2014). Stock markets of Asia responded immediately to the financial crisis of 2008 as stock returns were critically affected. Many researchers have examined the impact of the global financial crisis on the volatility of stock returns by comparing pre-crisis and post-crisis periods (Lim, Brooks, & Kim, 2008 ; Singh & Kaur, 2015). The study of the interdependence of stock markets provides important information, which is useful in policy formulation and deciphering the influence of overseas factors along with the country-specific factors on the economic growth of a country. Besides this, return and volatility behavior and its diffusion have important implications in portfolio construction. Portfolio efficiency can be maximized by analyzing market integration and improving international diversification. In this backdrop, our study intends to identify the return volatility spillover along with information transmission between the US stock market and emerging Asian stock markets of India, the Philippines, South Korea, and Indonesia. The US stock market is represented by the Dow Jones Industrial Average ; the Indian market is represented by Sensex ; the South Korean market is represented by the Korea Composite Stock Price Index (KOSPI) ; the Philippine stock market is represented by the Philippine Stock Exchange Composite Index (PSEI) ; and the Indonesia stock market is represented by the Jakarta Composite Index (JKSE). GARCH (1, 1) model is used to measure the effect of shock and volatility persistence. To quantify leverage outcome and to evaluate information diffusion between the chosen securities markets, the TGARCH model is used.

Studies in the past on these issues have majorly concentrated on US markets and other developed markets of Asia, Europe, and the UK. Few studies are available for developing stock markets of Asia and the US. This study fills the important research gap and contributes to the literature of assorted fusion of Asian nations and the US and will help market participants construct better portfolio strategies and formulate an effective regulatory framework.

Review of Literature

The literature on information transmission and market assimilation is assorted and plentiful in terms of volatility, return, and cross border spillovers across developed, developing, and emerging stock markets (Alotaibi & Mishra, 2015 ; Amudha & Muthukamu, 2018 ; Boucekkine & Huang, 2016 ; Dikshita & Singh, 2019 ; Mukherjee, 2011). The literature clearly states that economic boom and depression in financial markets are influenced by information transmission and both good and bad news significantly, which influence stock markets worldwide. Most of the initial studies have clustered around the US, Japan, and other developed nations. Studies in the context of emerging economies, especially in Asia, are still not much in number. This leaves room to cover this area, especially how volatility spills from the US to India and other emerging Asian economies affect the stock markets.

A dive into the literature revealed the co-movements in stock markets of the United States, Japan, UK, Canada, Germany, and other developed economies, and volatility spillovers emerged from the US stock market to other markets (Aloui & Hkiri, 2014 ; Horvath & Poldauf, 2012). A deeper look into the literature also informed unidirectional price volatility spillovers in stock markets of Tokyo, London, and New York (Hamao, Masulis, & Ng, 1990). The volatility transmission was further observed to be asymmetric in the stock markets of Denmark, Norway, Sweden, and Finland (Booth, Martikaine & Tse, 1997). Brooks and Henry (2000), in their study in the context of the US, Japan, and Australia, reported that size and sign of return innovations were important factors in determining the degree of spillovers in volatility. Their study further confirmed that volatility transmission was nonlinear, which can be clearly explained by the multivariate GARCH model. Brailsford (1996) in his study in the context of Australia and New Zealand reported that globalization deepened spillover and network effects. The results of his study also hinted at the presence of feedback effects in both the markets.

Crisis and shocks in an economy influence stock markets internally and also travel to other markets. Many studies have examined the impact of the economic crisis on information spillovers across the border (Adamu, 2011 ; Aloui, Aïssa, & Nguyen, 2011; Diebold & Yilmaz, 2009 ; Fidrmuc & Korhonen, 2010). The literature further claimed that volatility spillovers between emerging and mature markets have increased due to the financial crisis (Das, Kannadhasan, Tiwari, & Al - Yahyaee, 2018 ; Zhang, Li, & Yu, 2013). The momentum of information transmission, diffusion mechanism of uncertainty, and aversion of risk in the securities trading market were stated as important reasons which make these crises global (Èerný & Koblas, 2008 ; Yang, Yang, & Zhou, 2012).

Economic crises have occurred in many countries over different eras. The global financial crisis of 2007–2009, marked as the world's largest crisis, originated from the US and was a byproduct of several economic crises such as banking crisis, Asian financial crisis, Russian financial crisis, Turkish economic crisis, and many more. US crisis had a distressing impact on developed, developing, and growing world of commerce. US stock markets are considered the most influential enroot for the volatility of other stock markets (Hammoudeh, Yuan, & McAleer, 2009 ; Li & Giles, 2015 ; Majdoub & Mansour, 2014). Aloui et al. (2011) in their study examined the interdependence between BRIC and US stock markets and reported that stock return volatility changed significantly due to the global economic crisis. However, in another study conducted for Australia, Singapore, UK, and US stock markets, it was reported that the financial crisis of US did not cause any significant effect on the stock market returns, but it increased the volatility across stock markets of Australia, Singapore, UK, and US (Athukoralalage, Valadkhani, & O'Brien, 2010).

In the Asian context, few mentionable studies are : Chow (2017) ; Jebran and Iqbal (2016) ; Joshi (2011) ; Rajan (2011) ; Khanna and Kumar (2019) ; Natarajan, Singh, and Priya (2014) ; Mukherjee and Mishra (2010) ; Singh, Kumar, and Pandey (2010) ; Singhania and Anchalia (2013). Volatility spillovers have also been examined among the US and Asian stock markets (Kumar & Mukhopadhyay, 2007 ; Thao, Daly, & Ellis, 2013). Development of information and its transmission fueled integration of developed financial markets and developing and emerging markets (Ehrmann, Fratzscher, & Rigobon, 2011 ; Gros & Alcidi, 2010 ; Lehkonen, 2015). Linkages and alliances among East Asian stock markets increased significantly since 1990 and the intensity of return and volatility spillovers have also changed significantly for Asian stock markets since then (Kumar & Khanna, 2018 ; Yilmaz, 2010). The literature related to the global transmission of crisis paint a prominent picture of significant differences in the degree of integration and volatility of stock returns due to the financial crisis.

Thus, the literature on this topic confirms that volatility behavior and its diffusion have been explored worldwide by different researchers. However, in the Asian context, it has not yet been thoroughly explored. Besides this, there are very few studies that have explored volatility spillovers from the US stock market to emerging Asian markets for different break periods identified with the help of structural break techniques. This study will be a contribution to the literature on volatility transmission and dynamic correlations considering the structural breaks between US and Asian stock markets namely, South Korea, Philippines, Indonesia, and India.

Research Gaps

The literature review shows that capital markets in different countries are not bereft of developments in other markets. The movements in one country are intricately linked with activities taking place in other regions or countries. This interdependence exercises an important role on the performance of capital markets.

The relationship between capital markets, the effect of new knowledge, and the study of their interdependence by the means of observing the time-varying correlations are being done since the 1970s, and literature on this topic has also got enriched since then. Nevertheless, there are still some important gaps that we have identified by rigorously reviewing the available literature on this topic. Most of the studies analyzed only a small number of

capital markets together (mainly concerning the US, UK, and Japan). Mapping transmission of uncertainty on a global scale, especially Asia is missing. Our study aims to examine the transmission of volatility and complex correlations, considering the systemic breaks between the US and emerging Asian stock markets. Further, spillovers of uncertainty and their propagation are based on both the time and the economic scenario underlying it. Therefore, the study must be dynamic and should consider the changes in the relationship between stock markets periodically because the course of causality can be altered. The need for such a study was felt. Our study bridges this gap by identifying structural breaks between the selected Asian stock markets. Finally, research examining spillovers and volatility transmission involving emerging economies, such as India, South Korea, Philippines, and Indonesia is scarce. Examining how emerging economies like India are engaging and contributing to the global transmission of uncertainty and contagion will be truly fascinating.

Research Organization

Objectives of the Study

(i) To discover and ascertain the volatility spillover between the US and four emerging Asian stock markets of India, South Korea, Philippines, and Indonesia according to structural breaks.

(ii) To investigate the asymmetric nature of volatility spillover between the US and emerging Asian stock markets.

Data

Daily closing values of the benchmark indices of the leading stock exchanges of all these markets have been used for analyzing their interdependence. Table 1 shows the stock market indices of countries selected for the study. The period of the data such collected ranges from January 4, 2000 – December 28, 2017. The period of our study, that is, from 2000 – 2017 is very comprehensive. During this period, many crucial economic crises took place. The broad period enables us to access the volatility spillover separately for crisis periods and periods before and after it. The data for the study were collected from the website of Yahoo Finance.

Table 1. Stock Markets Indices : January 4, 2000 – December 28, 2017

Country	Stock Market Index
India	Sensex
Indonesia	Jakarta Composite Index (JCI)
Philippines	Philippine Stock Exchange Index (PSEI)
South Korea	Korea Composite Stock Price Index (KOSPI)
United States of America	Dow Jones Industrial Average (DJIA)

Source : www.yahoofinance.com

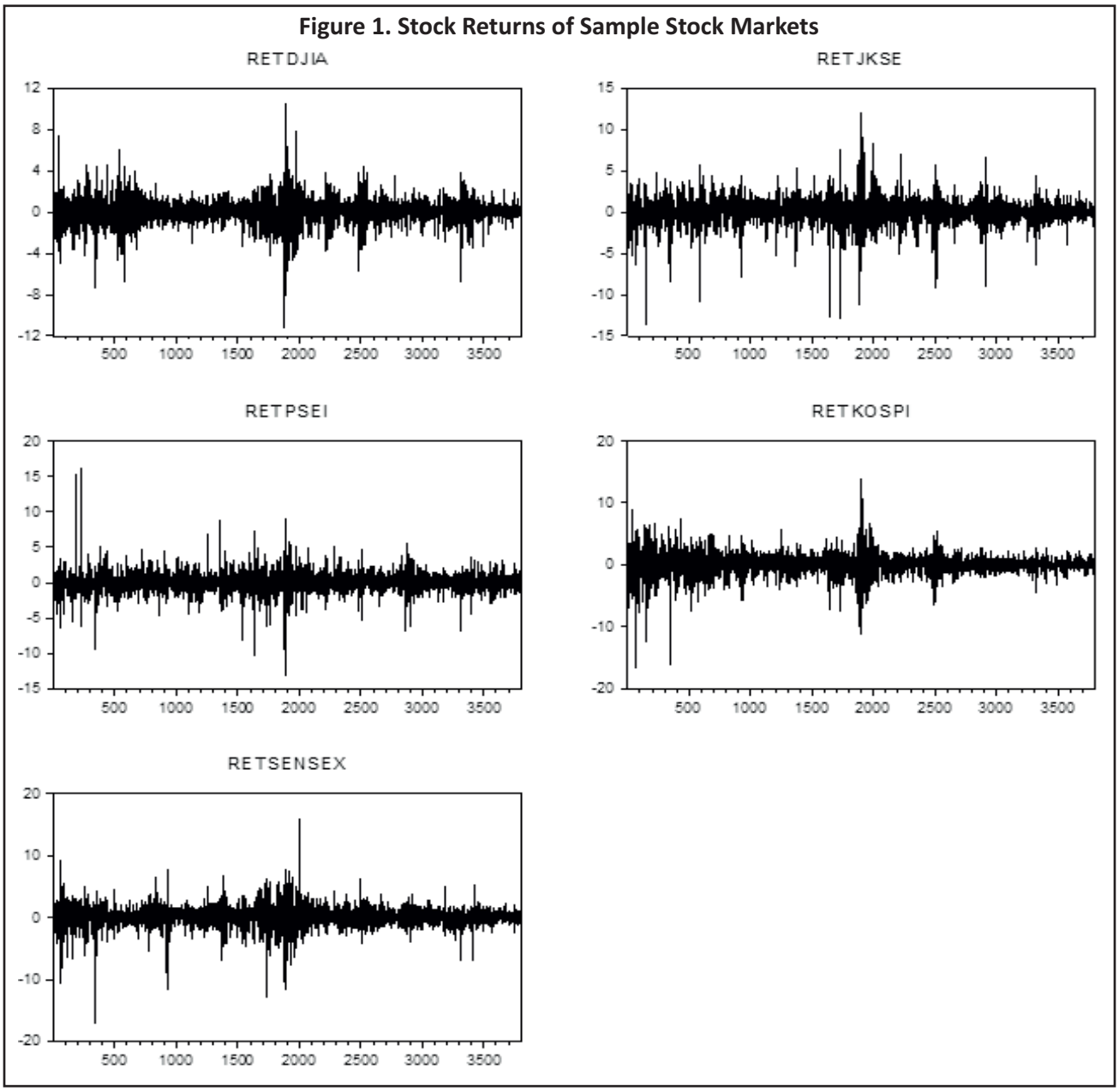
The time-series data comprising of the daily closing values of the benchmark indices is usually a random walk that is not fit for applying advanced econometric techniques. Therefore, from these daily closing values, we have computed the daily continuously compounded return for each series by using the following equation :

$$R_t = \ln p_t - \ln p_{t-1} \qquad (1)$$

where, R_t is the daily compounded return, p_t is the daily closing price of a benchmark index of exchange at time t.

Accordingly, five return variables named RET_{DJIA} (US), RET_{SENSEX} (India), RET_{JKSE} (Indonesia), RET_{KOSPI} (South Korea), and RET_{PSEI} (Philippines) have been created. Line graphs of all these variables are shown in Figure 1. From these graphs, we observe that each return series tends to come back to its average value, which indicates the stationarity of the return series. However, a further confirmation of the stationarity of the time series shall be made after applying the mathematical unit root test on them. Besides this, all return series represent volatility clustering, which means periods of high volatility are followed by further volatile periods and periods of low volatility are followed by more number of less volatile periods. Any time-series data which demonstrates volatility clustering

Figure 1. Stock Returns of Sample Stock Markets



can be appropriately modeled by using the GARCH family models as the results of the ordinary least square regression method are not considered reliable on this type of time series data.

Descriptive Statistics

Descriptive statistics of the five return variables are given in Table 2. From Table 2, it may be observed that the average daily returns are positive for all the five markets for the full study period. The average daily return is highest in Indonesia (0.057903) followed by India (0.047888) ; whereas, for the same period, average returns are least in stock markets of US (0.021449) and South Korea is second from below with return of 0.022271. Highest volatility (1.679779) has been observed in the stock market of South Korea and lowest volatility (1.234281) has been reported in the US stock market, which means that the South Korean stock market is the most volatile and the US stock market is the most stable market during the period of the study. The coefficient of skewness is positive for the Philippine stock market only and all other market returns are negatively skewed. Kurtosis value is greater than 3 for all the markets, which makes the stock markets leptokurtic. The non-normal nature of all the return series is further confirmed by the value of the Jarque – Bera test statistic for all of them. Non-linear models such as GARCH family models are more suitable for this type of data (Joshi, 2011). For examining the stationarity of the time series, the Augmented Dicky – Fuller (ADF) test for unit root has been applied. ADF test has a null hypothesis of the presence of unit root, which means series is not stationary. The *p*-value of the ADF statistic is less than 0.01 for all the return series. Therefore, the null hypothesis of unit root is rejected and all return series are stationary. Advanced econometric models such as GARCH etc. thus can be applied to them.

Further, structural breaks in time series have been identified with the help of least square with breakpoint technique. The data has also been examined for the presence of ARCH effect. For ascertaining the ARCH effect, the ARCH-LM model is used. The specification of this test is as follows:

Table 2. Descriptive Statistics

	RET_{DJIA}	RET_{JKSE}	RET_{PSEI}	RET_{KOSPI}	RET_{SENSEX}
Mean	0.021449	0.057903	0.036262	0.022271	0.047888
Median	0.051210	0.116055	0.028992	0.071910	0.087214
Maximum	10.50835	12.08728	16.17760	13.86347	15.98998
Minimum	–11.26980	–13.60253	–13.08869	–16.77875	–17.18396
Std. Dev.	1.234281	1.508318	1.437652	1.679779	1.658701
Skewness	–0.256500	–0.981691	0.055236	–0.743460	–0.649324
Kurtosis	11.97021	14.31253	17.22677	13.32653	14.12118
Jarque-Bera	12775.18	20861.81	32031.91	17225.23	19839.33
Probability	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	81.46480	219.9140	137.7240	84.58386	181.8769
Sum Sq. Dev.	5784.537	8638.262	7847.806	10713.84	10446.64
Observations	3798	3798	3798	3798	3798
ADF-Statistic and *p*-value	–66.4658 (0.0000)	–57.1746 (0.0000)	–37.6679 (0.0000)	–61.2479 (0.0000)	–59.0024 (0.0000)
ARCH-LM Test Statistics and *p*-value	307.3556 (0.0000)	109.428 (0.0000)	29.1197 (0.0000)	44.3356 (0.0000)	90.7378 (0.0000)

$$y_t = \alpha x_t + \mu_t \quad (2)$$

Here, u_t is the Gaussian white noise. The null hypothesis of this test states that the series does not have any ARCH effect. By rejecting the null hypothesis, we conclude that the series has an ARCH effect. If ARCH outcome is noticed, the future value of residuals can be projected by historical values of it, which will make the ordinary least square regression spurious. It will necessitate the use of non-linear GARCH family models.

The presence of the ARCH effect is confirmed for each return series as the *p*-value of observed *R*-squared is significant for all return variables at a 1% significance level.

Structural Breaks in the Price Series

An unexpected shift in a time series known as structural breaks has been identified using the least-squares method with breakpoints. The identification of structural breaks is important to prevent forecasting errors. For this purpose, we have identified structural breaks for each pair of Asian stock markets and the US stock market (see Table 3).

Table 3. Date Wise and Observation Wise Structural Breaks between the Asian Markets and the US

S. No.	Stock Markets	Structural Breaks Period - Date wise	Structural Breaks Periods - Observation wise
1	India and US	January 4, 2000 –February 24, 2005	(1 – 1099)
		February 25, 2005 – October 8, 2007	(1100 – 1668)
		October 10, 2007 – June 18, 2010	(1669 – 2237)
		June 21, 2010 – May 9, 2014	(2238 – 3050)
		May 12, 2014 – December 28, 2017	(3051 – 3799)
2	South Korea and US	January 4, 2000 – February 21, 2003	(1 – 655)
		February 24, 2003 – September 16, 2005	(656 – 1224)
		September 20, 2005 –January 28, 2009	(1225 – 1941)
		January 29, 2009 –March 9, 2012	(1942 – 2602)
		March 12, 2012 –March 16, 2015	(2603 – 3218)
		March 17, 2015 –December 28, 2017	(3219 – 3799)
3	Philippines and US	January 4, 2000 – July 21, 2004	(1 – 965)
		July 22, 2004 –September 26, 2008	(966 – 1876)
		October 6, 2008 –November 6, 2012	(1877 – 2745)
		November 7, 2012 –December 28, 2017	(2746 – 3799)
4	Indonesia and US	January 4, 2000 – October 6, 2004	(1 – 1016)
		October 7, 2004 –October 6, 2008	(1017 – 1877)
		October 7, 2008 –June 5, 2013	(1878 – 2862)
		June 7, 2013 – December 28, 2017	(2863 – 3799)

Empirical Methodology

For quantifying and enumerating the information associations and volatility spillovers for different break periods as per structural breaks between the chosen Asian stock markets and the US stock market, GARCH (1,1) and TGARCH models have been applied. Conventional GARCH family models do not clarify the leverage effect and

asymmetry of the error term distribution. The leverage effect means that losses have a more significant influence on future volatilities in comparison to profits, and asymmetry implies that the distribution of losses has a heavier tail vis-à-vis distribution of profits. Therefore, to understand why bad news causes more volatility, we have applied the TGARCH (1, 1) models. For applying these advanced econometric techniques, stationarity of data is mandatory along with the presence of ARCH effect. Both these conditions have been verified and confirmed for each return series with the help of appropriate tests.

GARCH (1, 1) and TGARCH Models

The mean equation and conditional variance equation of GARCH model used in our study are specified below.
Mean equation :

$$RET_{ASM} = \mu + \phi * RET_{DJIA,t-1} + e_t \quad (3)$$

$$h_t = \omega + \alpha * e^2_{t-1}(-1) + \beta * h_{t-1}, e_t \sim N(0, h_t) \quad (4)$$

Here, RET_{ASM} represents the daily return indices of Asian stock markets, RET_{DJIA} represents the daily return value of *DJIA*, e_t^2 stands for residual squares on day t, h_t is the conditional variance. Effect of shocks or noise from one stock market to another stock market is measured by the α, also called arch coefficient and volatility persistence, also known as the GARCH coefficient, can be examined by the β. The important condition for the model is that $\alpha, \beta \geq 0$ and sum $\alpha + \beta$ should be less than 1.

The variance equation for the asymmetric threshold GARCH (TGARCH) model proposed by Zakoian (1994) and GJR GARCH model developed by Glosten, Jagannathan, and Runkle (1993) is specified below :

$$h_t = \omega + \alpha * e^2_{t-1}(-1) + \delta * D * e^2_{t-1}(-1) + \beta * h_{t-1} \quad (5)$$

D is a dummy variable. $D_t = \begin{cases} 1 & e_{t-1} < 0 \\ 0 & e_{t-1} > 0 \end{cases}$

if the value of δ in equation 5 is positive and significant, then volatility spillover is said to be asymmetric, which means the impact of negative news is greater than positive news on stock markets.

Data Analysis and Results

India – US

The results of information transmission from the US to the Indian stock market for all the break periods are shown in Table 4. The values of ARCH (α) and GARCH coefficient (β) are significant for all the sub-periods. It confirms that volatility from US stock market enters the Indian stock market persistently. Hence, there is a clear indication of diffusion of information that affects the Indian stock market and this phenomenon is uniform for all the break periods. Effect of a shock coming from the US stock market is maximum (0.1210) during Break Period 3, which is also the period of the global financial crisis ; volatility persistence is maximum (0.9511) during Break Period 5. The empirical findings reveal that fluctuations in the US stock market have an important effect on the variations in the Indian stock market also for the period of the global financial crisis as the transmission of uncertainty from the US to the Indian capital market got magnified. The results of the TGARCH model reflect that the value of δ is

Table 4. GARCH Estimation – India and the US

Coefficients	Whole Period	Break Period 1	Break Period 2	Break Period 3	Break Period 4	Break Period 5
μ	0.0944	0.1315	0.1940	0.1006	0.0549	0.0551
	(0.0000)	(0.0014)	(0.0003)	(0.2284)	(0.1551)	(0.1269)
ϕ	0.2157	0.1207	0.5213	0.3538	0.2235	0.1981
	(0.0000)	(0.0019)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
			Variance Equation			
ω	0.0280	0.1413	0.1111	0.0665	0.0665	0.0159
	(0.0000)	(0.0001)	(0.0021)	(0.0223)	(0.0223)	(0.0063)
α	0.0919	0.1196	0.1149	0.1210	0.0282	0.0318
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0168)	(0.0000)
β	0.9035	0.8458	0.8274	0.8488	0.9253	0.9511
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
$\alpha + \beta$	0.9954	0.9654	0.9423	0.9698	0.9535	0.9829
δ	0.1165	0.1970	0.2220	0.2862	0.1104	0.0911
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0006)	(0.0000)
Log Likelihood	–6613.364	–2092.519	–954.4712	–1260.430	–1241.161	–1014.437

positive and statistically significant for all break periods, which shows asymmetric volatility spillovers from the US to the Indian stock market. However, the impact of negative news on the Indian stock market from the US stock market is maximum (0.2862) during Break Period 3, which runs parallel to the period of global financial crisis and is minimum (0.0911) during Break Period 5.

South Korea – US

The results of GARCH models between US and South Korean stock markets are presented in Table 5. The results clearly show that shocks (see the value of ARCH coefficient α) coming from the US stock market to the Korean stock market are significant for all the break periods. The value of the GARCH coefficient is also statistically significant, which confirms that volatility coming from US stock markets is persistent and this phenomenon has been observed for all the break periods. The sum of ARCH and GARCH coefficient is less than one, which indicates that our model is a good fit. The effect of a shock coming from the US stock market is highest (0.1545) during Break Period 4 and volatility persistence is maximum (0.9247) during Break Period 5. We consider long-term co-integration between the US market and Korean stock market, and after the crisis time, the degree of co-integration has increased. The asymmetric nature of volatility transmission is also confirmed from the TGARCH test, which means negative news coming from the US market is more impactful and creates more volatility in the stock market of South Korea than good news. The impact of negative news from the US stock market is maximum (0.1887) during Break Period 4 (from January 29, 2009 – March 9, 2012) and minimum (0.0833) during Break Period 5 (from March 12, 2012 – March 16, 2015). Thus, the empirical findings from this analysis indicate that volatility interrelates the US and South Korean stock markets. The global financial crisis has propagated the proliferation of uncertainty. The extent and intensity of the impetus of uncertainty varies across structural breaks.

Table 5. Break Wise GARCH Estimation – South Korea and the US

Coefficients	Whole Period	Break Period 1	Break Period 2	Break Period 3	Break Period 4	Break Period 5	Break Period 6
μ	0.03400	–0.0266	0.1489	0.0650	0.0959	–0.0169	0.0217
	(0.0183)	(0.7867)	(0.0043)	(0.1758)	(0.0217)	(0.5879)	(0.5005)
ϕ	0.3850	0.4690	0.5057	0.4912	0.4129	0.3715	0.2389
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
				Variance Equation			
ω	0.0166	0.7104	0.0518	0.0335	0.0527	0.0191	0.0702
	(0.0000)	(0.0123)	(0.0001)	(0.0177)	(0.0000)	(0.1033)	(0.0103)
α	0.0987	0.1419	0.0734	0.1025	0.1545	0.0431	0.0862
	(0.0000)	(0.0007)	(0.0001)	(0.0000)	(0.0001)	(0.0073)	(0.0002)
β	0.8981	0.7605	0.8969	0.8919	0.8221	0.9247	0.7957
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
$\alpha + \beta$	0.9968	0.9024	0.9703	0.9944	0.9766	0.9678	0.8819
δ	0.0926	0.1144	0.1302	0.1866	0.1887	0.0833	0.1278
	(0.0000)	(0.0007)	(0.0006)	(0.0000)	(0.0011)	(0.0001)	(0.0000)
Log-Likelihood	–6277.31	–1517.04	–960.42	–1302.57	–1069.31	–707.554	–657.875

Philippines and US

The results of the GARCH model are not different for the Philippine stock market (see Table 6). The noise of shocks coming from the US stock market to the Philippine stock market is significant for all the break periods

Table 6. Break Wise GARCH Estimation – Philippines and the US

Coefficients	Whole Period	Break Period 1	Break Period 2	Break Period 3	Break Period 4
μ	0.0657	–0.0180	0.0532	0.0950	0.0595
	(0.0007)	(0.7273)	(0.2846)	(0.0063)	(0.0539)
ϕ	0.3780	0.1977	0.7141	0.3685	0.3323
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
			Variance Equation		
ω	0.0704	0.4956	1.6174	0.0647	0.0519
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
α	0.0844	0.0935	0.1197	0.1357	0.0897
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
β	0.8835	0.7048	0.0377	0.8216	0.8664
	(0.0000)	(0.0000)	(0.8212)	(0.0000)	(0.0000)
$\alpha + \beta$	0.9679	0.7983	0.1574	0.9573	0.9561
δ	0.0969	0.0813	0.2001	0.0828	0.1599
	(0.0000)	(0.0000)	(0.0001)	(0.0000)	(0.0000)
Log-Likelihood	–6318.589	–1757.198	–1578.237	–1348.705	–1506.527

identified. The persistence of volatility is also confirmed as the value of the GARCH coefficient is significant and the sum of ARCH and GARCH coefficients is less than one. The impact of shocks is maximum for the Break Period 3 (0.1357) and volatility persistence is highest (0.8664) during Break Period 5. The nature of information transmission is also asymmetric for all the break periods (see the value of δ). The impact of negative news is maximum (0.2001) during Break Period 2 (from October 6, 2008 – November 6, 2012) and is minimum (0.0813) during Break Period 1 (from July 22, 2004 – September 26, 2008).

Indonesia and the US

The results of the GARCH model for examining the volatility transmission from the US stock market to the Indonesian stock market too are on similar lines with other Asian markets (see Table 7). The shocks from the US to Indonesia are significant and bring volatility in this market. The volatility coming to Indonesia from the US is persistent. The results are the same for all the break periods. The effect of the shocks coming from the US stock market is maximum (0.2221) during Break Period 2 and volatility persistence is maximum (0.9220) during Break Period 4. From the results of the TGARCH model, it is also confirmed that the impact of positive and negative news coming from the US stock market is not the same on the Indonesian stock market, and negative news has more impact than positive news.

The results of our study are on similar lines for all Asian markets, which can be understood by the following pointers :

- The US is a major trading partner for all the discussed emerging markets in Asia.
- The currencies of these countries are pegged to the US dollar.
- Ever since the financial crisis of 2008, the pegging of the exchange rate has become much stronger.

Table 7. Break Wise GARCH Estimation – Indonesia and the US

Coefficients	Whole Period	Break Period 1	Break Period 2	Break Period 3	Break Period 4
μ	0.0848	0.0864	0.1686	0.1055	0.0341
	(0.0000)	(0.0864)	(0.0001)	(0.0020)	(0.2411)
ϕ	0.2848	0.1319	0.4467	0.3693	0.2480
	(0.0000)	(0.0004)	(0.0000)	(0.0000)	(0.0000)
			Variance Equation		
ω	0.0439	0.2442	0.1176	0.0390	0.0163
	(0.0000)	(0.0000)	(0.0000)	(0.0001)	(0.0000)
α	0.1502	0.1162	0.2221	0.1139	0.0588
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
β	0.8450	0.7976	0.7670	0.8658	0.9220
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
α + β	0.9952	0.9138	0.9891	0.9797	0.9808
δ	0.0921	0.1147	0.8403	0.1143	0.0653
	(0.0000)	(0.000)(	0.0000)	(0.0000)	(0.0006)
Log-Likelihood	–6288.247	–1875.791	–1505.756	–1602.321	–1249.573

- All these countries have become more liberalized and have initiated economic reforms.

Discussion and Conclusions

This study examines the volatility spillovers in returns, volatility persistence, and asymmetric volatility spillovers from the US stock market to Asian stock markets of India, South Korea, Philippines, and Indonesia using the daily data from January 2000 – December 2017. For the robustness of our results, the study period has been divided into several sub-periods based on formal structural break tests. The study identifies the spillovers in returns and conditional volatility for the four Asian markets. The results of our study reveal that structural breaks are present in the time-series data. Therefore, the nature of the relationship must be studied separately for the different break point periods. The results state that shocks coming from the US stock market have a significant effect on all four markets. The information coming from the US stock market to these emerging Asian stock markets is meaningful for all break periods as well. In all systemic splits, volatility persistence is observed from the US stock market to all sample stock markets, and its persistence increases. The nature of information transmission is observed to be asymmetric and bad news from the US market has more impact on the volatility in underlying markets than good news. Our findings further indicate that financial crises originating from the US have a negative effect on emerging-market performance. The results confirm the notion that long-term stability, volatility persistence, and transmission of volatility are correlated with market growth and liberalization in emerging markets.

The main reasons which can be claimed for explaining the interrelationship between developing and developed markets are deregulation of the financial markets, liberalization of economies, the escalating influence of multinational companies, macroeconomic policy coordination, innovation, etc. The argument given here is quite convincing as since the start of globalization, the cross-market movement has become an important determinant of stock market return in developing nations and there is greater 'psychological contagion' between markets over this period. The rise of information technology too has led to the rapid transmission of information from one market to another. The results of our study are similar to the studies conducted in the recent past (Adamu, 2011 ; Aloui et al., 2011 ; Arshad, Rizvi, & Haroon, 2019 ; Chow, 2017 ; Diebold & Yilmaz, 2009 ; Fidrmuc & Korhonen, 2010 ; Kang, Ko, & Yoon, 2017). In harmony with these studies, our paper contributes to the notion that financial linkages between stock markets have become much stronger and their study is helpful in magnifying returns from the stock market.

Research Implications

The findings from this paper have numerous economic and financial consequences. First, it is of interest to regulators in developing countries because it offers some answers about risk management and stabilization of stock markets. Second, to help them make investment decisions, it tells international or domestic investors about the stability of the financial markets in terms of volatility transmission and contagion danger.

In addition to regulators and investors, it will provide researchers and policymakers with insights into how best to maximize the potential benefits of financial integration, such as successful capital use, trade, and aggregate economic development, while at the same time identifying appropriate policy responses aimed at seeking financial stability, mitigating the resulting economic instability that market interdependence reveals. Understanding the nature and extent of international financial market linkages will enable policymakers to informatively design policy proposals aimed at mitigating the destabilizing effects and adverse shocks that may result from increasing financial globalization to the domestic economy.

Limitations of the Study and Scope for Further Research

This study is confined to four developing countries in Asia and the period from 2000 – 2017 (only 17 years) is considered due to time constraints. The times of the numerous financial crises are neglected. More number of countries from the North, South, West, and East Asian regions can be included in the future and more reliable results could be obtained. Another major constraint lies with the GARCH and TGARCH models. The model we have used in our analysis is currently too restrictive.

All constraints mentioned in the limitations can serve as an opportunity and scope for further research in this field. For example, one may analyze the spillover trend by considering those markets which are not currently included in our study. Additionally, the pattern shown by spillover data can be defined for a different pair of countries. Adequate modeling of spillover data using suitable theoretical distributions will yield useful inferences in understanding the existence of spillovers. This will help us to develop predictive models that can be used for different research and practical purposes.

Authors' Contribution

Dr. Ashish Kumar conceived the idea and developed qualitative and quantitative design to undertake the empirical study. Swati Khanna extracted research papers with high repute, filtered these based on keywords, and generated concepts and codes relevant to the study design. Dr. Ashish Kumar verified the analytical methods and supervised the study. The numerical computations were done by Swati Khanna using EVIEWS. Swati Khanna and Dr. Ashish Kumar wrote the manuscript in consultation with each other.

Conflict of Interest

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest, or non-financial interest in the subject matter, or materials discussed in this manuscript.

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