"Does volatility traverse between emerging and frontier stock markets of Asia?"

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BUSINESS PERSPECTIVES

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DOES VOLATILITY TRAVERSE BETWEEN EMERGING AND FRONTIER STOCK MARKETS OF ASIA?

Abstract

Given Asian market recognition at the forefront of the investment domain, the research examines volatility spillover and asymmetric transmission between emerging and frontier stock markets of Asia. Stock returns of two frontier and nine emerging markets, during the data period spanning from August 2000 to March 2020, were analyzed using multivariate asymmetric GARCH-BEKK model around the global financial crisis (GFC). The study results suggest that the structure of cross-markets shocks and volatility spillover between emerging markets are higher during post-GFC. Therefore, this diminishes the possibility of portfolio diversification and investment opportunities to the investors in most of the Asian emerging markets. In the case of Asian frontier markets, most of the volatility generates due to its past shocks and volatility traverse from Asian emerging markets are considerably less. Hence, asset allocations prospects exist in the Asian frontier stock markets. Nevertheless, safe investment strategies need to design to reap diversification benefits from these markets, particularly during financial turmoil and market distress in the future.

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INTRODUCTION

The Asian stock markets across the world are preferred to be an attractive destination place for global investors to channelize their investment and grab the international portfolio diversification benefits. The Asia-Pacific region assembles around 80% of the total investment funds (Thomas, Kashiramka, & Yadav, 2017). The enormous economic growth and high potentiality of generating better returns than other region's markets amplified its worldwide appreciation in global investors' hearts.

However, due to the dramatic changes in Information and Communication Technology (ICT), reforms, and development in the stock exchanges and with the wave of liberalization, the inter-linkages between stock markets strengthened over the years. As a result, any events, crises, and other structural imbalances in one economy emanate rapidly in other economies. Due to such strong integration and linkages, various information transmission channels enhanced the volatility across the markets. Volatility spillover is a contagion effect that indicates the spread of one market disorder in another market, thereby bringing a movement in the stock prices, capital flows, and exchange rates (Dornbusch, Park, & Claessens, 2000). Therefore, understanding volatility transmission between stock markets provides implications to the portfolio investors for appropriate asset allocation strategies and the policy authority to frame informed decisions, par-

ticularly during economic instability. Given this backdrop, this research examines the volatility spillover and asymmetric transmission between Asian emerging and frontier stock markets. Given this, the entire outline of the research addresses the following questions:

a) Whether Asian emerging and frontier stock markets behaviors are different towards volatility spillover during pre- and post-global financial crisis?

b) Whether markets are prospective for portfolio diversification and investment opportunities after the global financial crisis?

1. LITERATURE REVIEW

One of the imperative issues in the financial market that has been a long controversy is cross-markets volatility spillover. As volatility spillover is the function of market integration and financial events, the investors worldwide have an incredible focus on this growing issue to form appropriate financial decisions. Therefore, across a globe, there is a stylized fact that voluminous strength of studies devoted their attention to examining cross-border volatility spillover.

In the Asian region, the studies that delve their attention to assessing volatility spillover between markets are marked as follows. By taking the sample variables as developed markets of the world and other emerging markets, Wei, Liu, Yang, and Chaung (1995), Miyakoshi (2003), Li and Giles (2015), Yu and Lei (2016) reported that the USA and, to some extent, Japan is the dominating leading markets in the Asian region. Further, over the years, with the increased importance of emerging markets globally, extensive research focused on volatility linkages and spillover between Asian developed and emerging markets. Rahim, N. Ahmad, and I. Ahmad (2009) noticed the unidirectional volatility transmission between Southeast Asian market returns. Worthington and Higgs (2004) considered three developed and six emerging stock markets of Asia to examine volatility transmission between markets. Using the MGARCH BEKK model, the evidence of positive mean and volatility spillover was reported in the study. Lee (2009), Jebran and Iqbal (2016), Abbas, Khan, and Ali Shah (2013), Mukherjee and Mishra (2010), Singhania and Anchalia (2013), Islam (2014) also reported interdependence and volatility spillover among some of the

Asian stock markets. They claimed that the European debt crisis, the Asian crisis, and the global financial crisis also heightened the spillover impact between some of the Asian markets. On the other hand, Chakrabarti (2011), Joshi (2011), using the multivariate GARCH BEKK model, noticed the low magnitude of volatility linkages and asymmetric volatility spillover between Asian stock markets. Therefore, they suggested that there is breathing space to avail mean risk-adjusted returns and diversification benefits in these markets. Jebran, Chen, Ullah, and Mirza (2017), B.-H. Kim, H. Kim, and Lee (2015), Kumar, MoonHaque, and Sharma (2018) examined a few Asian emerging markets and reported bidirectional volatility transmission. They suggested that these volatility linkages formed between the markets have a significant implication for the investor.

With an emerging growth of the frontier market and continuous initiatives for liberalizing the markets for foreign activities, the researchers have also thrown a light towards frontier stock markets integration and volatility spillover. Berger, Pukthuanthong, and Yang (2011) exhibited a lower level of frontier market integration with other developed and emerging markets, thereby leaving the scope for portfolio diversification. According to Baumohl and Lyocsa (2014), asymmetrical volatility transmission is not identical both in emerging and frontier stock markets. Chen, Chen, and Lee (2014) noticed a significant impact of GFC on the relationship between the frontier and leading stock markets. Seth and Singhania (2019), one of the recent studies in the context of volatility in frontier markets, used multivariate GARCH-BEKK and DCC-GARCH models. They narrated that frontier markets are not integrated in the long

and short run; therefore, investors can draw significant portfolio diversification benefits by including these markets.

Looking at the strand of past researched work, it is a noteworthy observation that so far less attention has been received into the volatility status between the Asian emerging and frontier stock markets. The researcher also did not address the change in behaviors of volatility spillover between markets around the global financial crisis. In the recent era at the forefront of the world sphere, these markets are recognized as an investment destination hub due to its prominence growth. Taking this into a review, the present research focuses on examining volatility spillover and asymmetric transmission between emerging and frontier stock markets of Asia using a multivariate GARCH model.

2. METHOD

The Asian emerging and frontier stock market equity indices daily data from 1st August 2000 to 31st March 2020 were used in the study (Table 1). Since the stock markets are sensitive and dynamic, the daily frequency data were used to capture immediate volatility interactions. Further, the whole data set is divided into two sub-periods, pre-global financial crisis (pre-GFC) from 1st August 2000 to 29th August 2008 and post-global financial crisis (post-GFC) from 4th April 2009 to 29th March 2020, to refine the volatility spillover impact between the selected markets. The homogenous set of data observations across sample periods has been taken by making an appropriate adjustment because of a national or public holiday or any other day when the markets' stock exchanges remained closed. The equity indices data are expressed in USD value (i.e., USD/domestic exchange rate), as it is used as a standard currency by international market participants while interpreting the result.

Further, the return of the index series has been calculated using the following equation:

$$SR_t = Ln\left(SP_t / SP_{t-1}\right) \cdot 100, \qquad (1)$$

where SR is daily stock returns in percentage, SP_t is stock prices at day t, SP_{t-1} is stock prices at day $t-1$, and Ln denotes natural logarithm form.

Table 1. Classification of stock markets

No.	Countries/markets	Stock indices
Asian emerging stock markets		
1	China	SHCOM
2	India	NIFTY FIFTY
3	Indonesia	JCI
4	South Korea	KOSPI
5	Malaysia	KLCI
6	Pakistan	KSE-100
7	Philippines	PSEI
8	Taiwan	TWI
9	Thailand	SET
Asian frontier stock markets		
10	Sri Lanka	CSEALL
11	Vietnam	VNI

Note: Classification is as per MSCI 2019 report.

The primary requirement to analyze financial time series data is checking for the stationarity property to avoid the pseudo results. Therefore, the authors began the analysis by testing the stock markets data series' stationarity property, using the most prominent Augmented Dickey-Fuller (ADF) test. Another pre-requisite to apply GARCH family models is volatility clustering or ARCH effect. This has been identified using the ARCH LM test (Engle, 1982). Additionally, autocorrelation in residuals has been tested using Ljung-Box Q^2 statistics up to 12 lags (Ljung & Box, 1978). After running these basic tests, a multivariate GARCH (MV-GARCH) model was utilized to assess the shock, volatility, and asymmetric transmission between stock markets.

The multivariate GARCH model was initially constructed based on the univariate ARCH model of Engle (1982) and the GARCH model (Bollerslev, 1986). The ARCH and GARCH econometric models are widely recognized due to its application of time-varying variances in a single variable, but they do not incorporate the variances' iterations. This has further extended into MV-GARCH model. In fact, in a research background, this model received outstanding attention to examining volatility contagion effects between asset classes, spillover and portfolio diversification, and Value at Risk (VaR). Therefore, in the present study, the asymmetric BEKK model in an MV-GARCH model was used to compute volatility spillover and asymmetric transmission between Asian selected

stock markets. Thus, MV-GARCH-BEKK model is represented as follows:

$$H_t = C' \cdot C + A' \left(\varepsilon_{t-1} \cdot \varepsilon'_{t-1} \right) \cdot A + B' H_{t-1} B, \quad (2)$$

where

$$C = \begin{bmatrix} c_{11} & \cdots & c_{111} \\ \vdots & \ddots & \vdots \\ c_{111} & \cdots & c_{1111} \end{bmatrix},$$

$$A = \begin{bmatrix} a_{11} & \cdots & a_{111} \\ \vdots & \ddots & \vdots \\ a_{111} & \cdots & a_{1111} \end{bmatrix},$$

$$B = \begin{bmatrix} b_{11} & \cdots & b_{111} \\ \vdots & \ddots & \vdots \\ b_{111} & \cdots & b_{1111} \end{bmatrix},$$

C is a parameter matrix of constant with 11 x 11 elements, A and B are the coefficient matrices that measure ARCH and GARCH effects with 11 x 11 symmetric elements. Diagonal elements in matrices A and B are the estimates of past shocks and volatility impact, whereas off-diagonal elements capture the cross-product shock and volatility spillover in the short and long run.

To assess the asymmetric effect (i.e., the response of markets towards negative news), Kroner and Ng (1998) further expanded the GARCH-BEKK model. This can be formulated as follows:

$$H_t = C' \cdot C + A' \cdot \left(\varepsilon_{t-1} \cdot \varepsilon'_{t-1} \right) \cdot A + \\ + B' \cdot H_{t-1} \cdot B + D' \cdot \left(\varepsilon_{t-1} \cdot \varepsilon'_{t-1} \right) \cdot D, \quad (3)$$

where

$$D = \begin{bmatrix} d_{11} & \cdots & d_{111} \\ \vdots & \ddots & \vdots \\ d_{111} & \cdots & d_{1111} \end{bmatrix}.$$

Matrix D measures whether unexpected falls in returns generate higher or lower volatility in the markets (i.e., due to negative news). Ultimately, to check the accuracy of the model, the authors used Ljung-Box Q^2 statistics.

3. RESULTS AND DISCUSSION

3.1. Descriptive statistics

The statistical result of stock returns in Tables 2 and 3 presents the preliminary analysis of the data, which consists of returns distribution, variation, normality, heteroscedasticity, and data stationarity. Amongst emerging markets, Indonesia provided the highest positive daily returns of 0.0695% to the investors during pre-GFC, and Thailand offered 0.0307% returns during post-GFC. Similarly, the Vietnam frontier market presented the highest positive returns during pre-GFC and Sri Lanka during post-GFC. The Korean market is embedded with more risk during pre-GFC and India during post-GFC from the standard deviation value. The leptokurtic and asymmetry in return distribution were noted across sample periods with kurtosis and skewness values. This has also confirmed through the Jarque-Bera test as revealed non-normality in data series. The ADF test statistics in Tables 2 and 3 are significant at 5%, which states that the return series are stationary at log level. Further, Ljung-Box Q^2 statistics at squared residuals up to 12 lags curbed serial correlation, and the ARCH LM test evidenced the presence of heteroscedasticity effect in the residuals. Given this necessity, the multivariate asymmetric GARCH-BEKK model was employed to assess the volatility spillover between the markets.

3.2. Shocks and volatility spillover between stock markets (pre-global financial crisis)

The asymmetric MV-GARCH-BEKK model is employed to identify own and cross-product volatility transmission amongst/between regional emerging and frontier stock markets. The analytical result of this model for the pre-GFC has enumerated in Table 4. The highlighted diagonal elements of matrix A are significant across markets (except $a_{8,8}$, i.e., Taiwan) with a high magnitude of coefficient value. This has noted the impact of past shocks on the current market volatility. Unlike emerging markets, the past innovation emanating in Asian frontier markets was observed to be higher of 0.7147 for $a_{10,10}$ (Sri Lanka) and 0.8983 for $a_{11,11}$ (Vietnam). In the same matrix, the evidence from off-diagonal elements showed that none

Table 2. Descriptive statistics of the stock returns during pre-global financial crisis

Markets	Mean	SD	Skewness	Kurtosis	Jarque-Bera	ARCH-LM test	LB² (12)	ADF
China	0.0170	1.5889	−0.1271	8.0493	2244**	30.04**	259.51**	−46.209**
India	0.0578	1.6094	−0.6847	8.1581	2501**	351.96**	719.01**	−42.478**
Indonesia	0.0695	1.6934	−0.7244	−0.7244	4459**	31.13**	136.11**	−40.909**
Korea	0.0347	1.7954	−0.4739	6.3727	1078**	13.17**	237.39**	−44.466**
Malaysia	0.0202	0.9465	−1.1949	15.7774	14835**	19.19**	135.03**	−39.541**
Pakistan	0.0671	1.5382	−0.2821	5.5634	605**	151.83**	979.11**	−41.557**
Philippines	0.0293	1.5043	2.1039	35.4022	93727**	25.10**	41.26**	−40.116**
Taiwan	−0.0067	1.5939	−0.2397	5.6524	638**	41.37**	493.76**	−43.522**
Thailand	0.0486	1.4189	−0.6172	12.8885	8718**	179.82**	196.67**	−29.719**
Sri Lanka	0.0585	1.3589	0.0584	35.9481	95306**	46.28**	179.97**	−33.194**
Vietnam	0.0716	1.6093	−0.3014	6.9495	1401**	136.24**	2725.90**	−15.970**

Notes: ** indicates that *p*-values are significant at 5% level. Jarque-Bera test is for normality. ARCH-LM test statistics are for heteroscedasticity. LB² (12) is Ljung-Box Q² statistics of squared residuals at 12 lags for autocorrelation. ADF test statistics signify stationarity in data series.

Table 3. Descriptive statistics of the stock returns during post-global financial crisis

Markets	Mean	SD	Skewness	Kurtosis	Jarque-Bera	ARCH-LM	LB²(12)	ADF
China	0.0012	1.3955	−1.0161	9.3453	5259**	86.99**	696.72**	−51.825**
India	0.0156	1.4007	0.1340	23.6025	50290**	13.90**	255.31**	−52.304**
Indonesia	0.0174	1.3327	−0.4520	9.9912	5886**	107.13**	1459.90**	−49.449**
Korea	0.0093	1.3198	−0.3529	8.0841	3121**	418.94**	2052.30**	−51.433**
Malaysia	0.0032	0.8613	−0.1651	8.9729	4239**	228.16**	1295.50**	−48.053**
Pakistan	0.0245	1.0977	−0.5782	8.0902	3228**	115.26**	1020.30**	−48.009**
The Philippines	0.0299	1.2174	−1.2031	15.7758	20021**	12.62**	1171.30**	−50.047**
Taiwan	0.0182	1.0627	−0.5137	7.7974	2851**	168.84**	653.27**	−51.290**
Thailand	0.0307	1.1641	−0.9614	13.9531	14649**	53.65**	1152.70**	−52.177**
Sri Lanka	0.0164	0.7969	−0.0127	16.4408	21400**	37.17**	371.75**	−25.327**
Vietnam	0.0138	1.2213	−0.6073	6.5145	1638**	134.13**	1007.10**	−46.156**

Notes: ** indicates that *p*-values are significant at 5% significance level. Jarque-Bera test is for normality. ARCH-LM test statistics are for heteroscedasticity. LB² (12) is Ljung-Box Q² statistics of squared residuals at 12 lags for autocorrelation. ADF test statistics signify stationarity in data series.

of the Asian emerging stock markets innovative shocks are strong enough to explain the current volatility of frontier markets. Only the smaller size of less than 8% other markets shock spillover in the frontier markets. However, on the flip side, there exists a remarkable shock transmission from Asian frontier markets to emerging stock markets such as ($a_{10,2}$), ($a_{10,3}$), ($a_{10,5}$), ($a_{10,7}$), ($a_{10,9}$), ($a_{11,4}$), and ($a_{11,7}$). Given this, it can be inferred that past information is the main factor in explaining the current volatility of frontier markets, but the same is not true in the case of emerging markets. For instance, the off-diagonal elements from the context of the emerging markets in matrix A reported that, on average, bi-directional shock spillover exists between the markets (7 pairs are significant). In particular, the coefficient of Malaysia ($a_{5,9}$) and Thailand ($a_{9,5}$) is equal to 0.2856 and 0.0323. Put

differently, 1% innovative shocks in each of the markets transmit 28.56% and 3.23% volatility in Thailand and the Malaysian market in the short run. Moreover, Thailand is the most exposed market in the emerging category, as it receives a 40% positive shock and a 28% negative shock effect from other Asian markets. This finding is also in support of Yu and Lei (2016). When it comes to the sender of shock, emerging markets such as Malaysia, Taiwan, and Thailand substantially influence other Asian markets. Overall, in the context of emerging markets, the authors have observed that China receives and emits less cross shock effects, indicating the sign of segmentation (Yu & Lei, 2016).

The coefficients of matrix B further quantified the volatility persistence or spillover between the mar-

kets in the long run. The diagonal elements measure the effect of its past volatility on the current market's conditional variance. The higher volatility persistence due to its past volatility noted ($b_{8,8}$ is equal to 0.9897) for the Taiwanese market and ($b_{11,11}$ is equal to 0.8983) for the Vietnamese market. The lowest own lagged volatility persistence highlighted in the Philippines market ($b_{7,7}$ is equal to 0.5287). From off-diagonal elements of matrix B, there is evidence of bi-directional and unilateral volatility spillover between most Asian emerging stock markets. In aggregate, the authors have observed bidirectional linkages between Indonesia and India, Malaysia, the Philippines, and Thailand; between Thailand and India, Korea, Malaysia, and the Philippines; between Korea and Malaysia, the Philippines, and Taiwan; and between Malaysia and the Philippines. However, the higher contribution accounts from Malaysia, Thailand, and Korea ($b_{i,j}$) drive most of the volatility in regional markets, particularly in the Philippines and Indonesia. On the other hand, some evidence of unidirectional and bilateral volatility transmission was also noted between Asian emerging and frontier stock markets but not highly remarkable.

Overall, Table 4 shows that the volatility traverse in the current market is significantly higher from unexpected news shock channels than through volatility spillover, specifically in Asian emerging stock markets during pre-GFC.

3.3. Asymmetric response of stock markets (pre-global financial crisis)

The result illustrated in Table 5 throws light on the asymmetric response or transmission due to negative market news. All diagonal elements are significantly higher (except $d_{1,1}$) compared to cross-market transmission, which signifies the greater market response due to its bad news. Moreover, the cross-market asymmetric response between emerging markets also manifested in the findings, and remarkable observation is in the case of $d_{8,4}$ and $d_{7,3}$. Indonesia and South Korea are the most affected markets of the emerging economies, which receives a total of (+58% to +59%), (–11% to –16%) of asymmetry, respectively, due to falling market conditions across the Asian region. Nevertheless, it is less in the case of the frontier

market (Sri Lanka) and a little remarkable for that of Vietnam. In aggregate, measuring the contribution of asymmetry, Thailand and the Philippines ($d_{i,j}$) are the core players asserting the Asian region's asymmetric effect.

Overall findings during pre-GFC suggested that emerging markets (except China) more exposed to shock, volatility and asymmetric transmission of other markets. On the other hand, frontier markets are more responding to past shocks and transmission.

3.4. Shocks and volatility spillover between stock markets (post-global financial crisis)

To identify the changes in the extent of linkages, the authors further analyzed the selected markets during post-GFC. Table 6 shows the coefficient of diagonal parameters in matrices A and B marked to be statistically significant during the post-GFC across selected emerging and frontier stock markets. Therefore, it characterizes the increase in the level of current market volatility due to its past shocks and volatility. The highest shock and volatility persistence are for $a_{2,2}$ (India) and $b_{9,9}$ (Thailand), while the lowest noted for $a_{4,4}$ (Korea), and $a_{8,8}$ (Taiwan). Comparatively, the magnitude of volatility persistence is higher than the shock effect.

In matrix A, 35 out of 110 off-diagonal parameters were noted significant during the pre-GFC period but amplified it by 81 significant parameters after GFC. Similarly, the off-diagonal elements in matrix B (87 out of 110) coefficients showed volatility spillover during post-GFC, which is more than 52 significant parameters found during pre-GFC. A large magnitude of unilateral and feedback volatility transmission between emerging markets (except China) was observed during post-GFC. The considerable highlight for China is that its current market volatility is more driven by its past shock and volatility (Hung, 2019). Even after the robust economy in the Asian belt, it was found less impacted by the volatility of other regional markets. For other emerging economies, it has noted that already affected markets during pre-GFC continue to trigger higher shock and volatility spillover effect after GFC, suggesting that market linkages

Table 4. Shocks and volatility spillover between stock markets during pre-global financial crisis

Markets	China ($i = 1$)	India ($i = 2$)	Indonesia ($i = 3$)	Korea ($i = 4$)	Malaysia ($i = 5$)	Pakistan ($i = 6$)	The Philippines ($i = 7$)	Taiwan ($i = 8$)	Thailand ($i = 9$)	Sri Lanka ($i = 10$)	Vietnam ($i = 11$)
c_{i1}	0.0990 (0.0000)***	–	–	–	–	–	–	–	–	–	–
c_{i2}	−0.0655 (0.0011)***	0.2140 (0.0000)***	–	–	–	–	–	–	–	–	–
c_{i3}	−0.2088 (0.0000)***	0.1531 (0.0000)***	0.4423 (0.0000)***	–	–	–	–	–	–	–	–
c_{i4}	−0.1160 (0.0000)***	0.0269 (0.2279)	0.1191 (0.0000)***	0.0729 (0.0001)***	–	–	–	–	–	–	–
c_{i5}	0.0909 (0.0000)***	−0.0120 (0.4339)	0.1832 (0.0000)***	−0.1609 (0.0000)***	0.1889 (0.0000)***	–	–	–	–	–	–
c_{i6}	0.0925 (0.0000)***	−0.0697 (0.0040)***	0.0150 (0.5315)	0.0616 (0.0053)***	−0.0589 (0.0419)**	0.1577 (0.0000)***	–	–	–	–	–
c_{i7}	−0.2327 (0.0000)***	0.0796 (0.0013)***	−0.1884 (0.0000)***	−0.0420 (0.1116)	0.0136 (0.5430)	0.1554 (0.0000)***	0.5466 (0.0000)***	–	–	–	–
c_{i8}	−0.0576 (0.0000)***	0.0510 (0.0011)***	0.0844 (0.0000)***	−0.0046 (0.8011)	0.0509 (0.0017)***	0.0286 (0.2076)	0.0017 (0.9367)	−0.0009 (0.9433)	–	–	–
c_{i9}	0.1251 (0.0000)***	0.0616 (0.0055)***	0.7133 (0.0000)***	−0.3866 (0.0000)***	0.4079 (0.0000)***	0.0150 (0.5316)	0.3294 (0.0000)***	−0.0005 (0.9777)	0.1211 (0.0000)***	–	–
c_{i10}	0.0257 (0.3462)	0.0365 (0.1755)	0.0321 (0.1911)	−0.2310 (0.0000)***	−0.2128 (0.0000)***	0.0453 (0.1181)	−0.0694 (0.0064)***	0.0527 (0.0455)**	0.0562 (0.0066)***	0.3266 (0.0000)***	–
c_{i11}	−0.0647 (0.0005)***	−0.0495 (0.0196)**	−0.0421 (0.0355)**	0.0100 (0.6312)	−0.0404 (0.0920)*	0.0447 (0.0635)*	−0.0191 (0.4445)	−0.0070 (0.7087)	−0.0631 (0.0032)***	−0.0012 (0.9656)	−0.0086 (0.6622)
μ	0.0118 (0.7259)	0.1298 (0.0000)***	0.1370 (0.0000)***	0.1174 (0.0000)***	0.0396 (0.0218)**	0.1291 (0.0002)***	0.0655 (0.0068)***	0.0387 (0.1817)	0.0610 (0.0229)**	0.0510 (0.0513)*	0.0005 (0.9884)
a_{i1}	0.1304 (0.0000)***	−0.0050 (0.7581)	0.0033 (0.8233)	−0.00001 (0.9997)	−0.0023 (0.9261)	0.0274 (0.1394)	−0.0006 (0.9683)	0.0071 (0.5712)	0.0061 (0.6804)	−0.0271 (0.1364)	−0.0031 (0.8495)
a_{i2}	−0.0019 (0.9109)	0.2524 (0.0000)***	−0.0143 (0.2617)	−0.0033 (0.8027)	0.0151 (0.3716)	0.0134 (0.4383)	−0.0077 (0.6735)	0.0249 (0.0625)*	0.0351 (0.0014)***	−0.0247 (0.0525)*	−0.0053 (0.7403)
a_{i3}	0.0281 (0.1573)	0.0429 (0.0003)***	0.2545 (0.0000)***	−0.0262 (0.0735)*	−0.0546 (0.0121)**	0.0118 (0.5646)	−0.0361 (0.0024)***	−0.0212 (0.2041)	0.1002 (0.0000)***	−0.0530 (0.0067)***	0.0139 (0.3447)
a_{i4}	0.0078 (0.6464)	0.0452 (0.0005)***	0.0119 (0.3251)	0.0812 (0.0000)***	0.0022 (0.9024)	−0.0029 (0.8605)	−0.0210 (0.0897)*	0.0353 (0.0019)***	0.0207 (0.0251)**	0.0044 (0.6534)	0.0286 (0.0585)*
a_{i5}	0.0117 (0.2919)	−0.0076 (0.2973)	−0.0311 (0.0001)***	−0.0072 (0.3603)	0.2984 (0.0000)***	0.0032 (0.7786)	−0.0387 (0.0000)***	0.0783 (0.0000)***	0.0323 (0.0000)***	−0.0323 (0.0038)***	−0.0065 (0.3487)
a_{i6}	−0.0061 (0.7557)	−0.0229 (0.1729)	0.0164 (0.3425)	0.0334 (0.0515)*	0.0398 (0.1902)	0.2125 (0.0000)***	−0.0253 (0.2719)	−0.0076 (0.6866)	0.0429 (0.0222)**	0.0211 (0.1470)	0.0165 (0.4536)

Table 4 (cont.). Shocks and volatility spillover between stock markets during pre-global financial crisis

Markets	China (i = 1)	India (i = 2)	Indonesia (i = 3)	Korea (i = 4)	Malaysia (i = 5)	Pakistan (i = 6)	The Philippines (i = 7)	Taiwan (i = 8)	Thailand (i = 9)	Sri Lanka (i = 10)	Vietnam (i = 11)
a_{i7}	0.0236 (0.1567)	0.0097 (0.3908)	−0.0916 (0.0000)***	0.0015 (0.9284)	−0.0857 (0.0000)***	0.0263 (0.1087)	0.1901 (0.0000)***	0.0149 (0.0161)**	−0.0151 (0.1493)	−0.0445 (0.0113)**	0.0651 (0.0000)***
a_{i8}	0.0083 (0.4655)	0.0228 (0.0528)*	0.0133 (0.2471)	0.0945 (0.0000)***	0.0608 (0.0005)***	0.0076 (0.5676)	−0.0122 (0.3395)	−0.0131 (0.1901)	0.0099 (0.3922)	−0.0240 (0.1360)	0.0140 (0.2669)
a_{i9}	0.0056 (0.7397)	−0.0848 (0.0000)***	−0.0125 (0.3478)	−0.0182 (0.1113)	0.2856 (0.0000)***	−0.0023 (0.8820)	−0.0446 (0.0017)***	0.1040 (0.0000)***	0.2213 (0.0000)***	−0.1107 (0.0000)***	−0.0024 (0.8561)
a_{i10}	−0.0020 (0.9181)	0.0095 (0.4893)	−0.0008 (0.9682)	−0.0233 (0.0001)***	−0.0211 (0.4049)	−0.0113 (0.5653)	0.0035 (0.8495)	0.0079 (0.6781)	−0.0020 (0.9141)	0.6350 (0.0000)***	−0.0032 (0.8636)
a_{i11}	−0.0096 (0.6159)	0.0027 (0.8718)	−0.0098 (0.5433)	−0.0178 (0.3021)	−0.0271 (0.3127)	0.0030 (0.8671)	0.0196 (0.2012)	0.0236 (0.1722)	−0.0154 (0.1990)	0.0042 (0.8443)	0.3697 (0.0000)***
b_{i1}	0.9859 (0.0000)***	0.0073 (0.2189)	−0.0092 (0.3051)	0.0013 (0.7633)	0.0086 (0.5178)	−0.0157 (0.0264)**	0.0039 (0.7428)	0.0026 (0.3277)	−0.0080 (0.4731)	0.0134 (0.1638)	−0.0018 (0.6907)
b_{i2}	0.0093 (0.0741)*	0.9634 (0.0000)***	−0.0215 (0.0252)**	0.0211 (0.0015)***	−0.0035 (0.8217)	−0.0037 (0.6758)	−0.0238 (0.0692)*	−0.0020 (0.6504)	−0.0706 (0.0000)***	0.0135 (0.2501)	−0.0036 (0.5984)
b_{i3}	0.0271 (0.0044)***	0.0632 (0.0000)***	0.8791 (0.0000)***	0.0065 (0.4607)	0.1638 (0.0000)***	0.0176 (0.1467)	−0.2620 (0.0000)***	0.0277 (0.0036)***	−0.1287 (0.0000)***	0.0096 (0.5251)	−0.0008 (0.9303)
b_{i4}	0.0049 (0.2848)	0.0060 (0.3750)	−0.0062 (0.4748)	0.9749 (0.0000)***	0.1101 (0.0000)***	0.0115 (0.1075)	−0.1343 (0.0000)***	−0.0179 (0.0026)***	0.0287 (0.0336)**	−0.0116 (0.2036)	−0.0139 (0.0185)**
b_{i5}	0.0055 (0.1914)	0.0149 (0.0078)***	0.0398 (0.0000)***	0.0524 (0.0000)***	0.8063 (0.0000)***	−0.0182 (0.0015)***	0.0639 (0.0000)***	0.0038 (0.4101)	−0.1963 (0.0000)***	0.0100 (0.2289)	0.0071 (0.1844)
b_{i6}	0.0060 (0.2633)	0.0262 (0.0021)***	−0.0395 (0.0010)***	0.0246 (0.0010)***	−0.0147 (0.4721)	0.9268 (0.0000)***	0.0179 (0.2530)	0.0058 (0.2335)	−0.0974 (0.0000)***	−0.0161 (0.2100)	−0.0043 (0.5399)
b_{i7}	−0.0058 (0.5883)	−0.0158 (0.1758)	0.1619 (0.0000)***	−0.0607 (0.0000)***	0.2502 (0.0000)***	0.0212 (0.1057)	0.5265 (0.0000)***	0.0074 (0.4962)	0.2555 (0.0000)***	0.0371 (0.0293)**	−0.0301 (0.0094)***
b_{i8}	0.0049 (0.0881)*	0.0102 (0.0340)**	−0.0116 (0.1234)	0.0193 (0.0007)***	0.0067 (0.5488)	0.0032 (0.5177)	−0.0584 (0.0000)***	0.9897 (0.0000)***	−0.0433 (0.0000)***	0.0106 (0.2447)	−0.0071 (0.0923)*
b_{i9}	0.0234 (0.0074)***	0.0870 (0.0000)***	0.0386 (0.0006)***	0.1295 (0.0000)***	−0.2493 (0.0000)***	−0.0088 (0.4104)	−0.0419 (0.0031)***	0.0142 (0.1102)	0.5287 (0.0000)***	0.0274 (0.0128)**	0.0276 (0.0010)***
b_{i10}	−0.0035 (0.6109)	−0.0104 (0.3124)	0.0167 (0.2039)	0.0010 (0.9173)	0.0319 (0.1598)	0.0083 (0.3948)	−0.0297 (0.0508)*	0.0106 (0.1638)	0.0328 (0.0146)**	0.7147 (0.0000)***	−0.0048 (0.5809)
b_{i11}	−0.0033 (0.4261)	0.0049 (0.4731)	−0.0041 (0.6743)	−0.0261 (0.0000)***	0.0465 (0.0066)***	−0.0053 (0.3994)	−0.0082 (0.5126)	0.0025 (0.5219)	0.0639 (0.0000)***	−0.0107 (0.3752)	0.8983 (0.0000)***

Notes: *, **, *** indicate that *p*-values are significant at 1%, 5%, and 10%. Variable order: 1 (China), 2 (India), 3 (Indonesia), 4 (Korea), 5 (Malaysia), 6 (Pakistan), 7 (the Philippines), 8 (Taiwan), 9 (Thailand), 10 (Sri Lanka), and 11 (Vietnam). The parameters in matrix C are constant, A and B matrices parameters represent the ARCH and GARCH effects.

Table 5. Asymmetric transmission during pre-global financial crisis

Markets	China (i = 1)	India (i = 2)	Indonesia (i = 3)	Korea (i = 4)	Malaysia (i = 5)	Pakistan (i = 6)	Philippines (i = 7)	Taiwan (i = 8)	Thailand (i = 9)	Sri Lanka (i = 10)	Vietnam (i = 11)
d_{i1}	0.0551 (0.1143)	−0.0035 (0.8931)	−0.0055 (0.7975)	0.0293 (0.1332)	−0.0308 (0.4274)	0.0124 (0.6920)	0.0077 (0.7412)	−0.0050 (0.8372)	0.0475 (0.1031)	−0.0024 (0.8909)	−0.0109 (0.6723)
d_{i2}	−0.0334 (0.3154)	−0.0924 (0.0028)***	0.0173 (0.5573)	−0.0623 (0.0416)**	0.1785 (0.0005)***	0.0109 (0.7666)	0.0429 (0.2713)	0.0882 (0.0137)**	−0.0896 (0.0326)**	0.0456 (0.1691)	0.0404 (0.2239)
d_{i3}	0.0201 (0.6837)	0.1205 (0.0003)***	−0.3043 (0.0000)***	0.0073 (0.8453)	0.0442 (0.4787)	−0.0330 (0.4762)	0.2391 (0.0000)***	0.1226 (0.0049)***	−0.0687 (0.1599)	0.0380 (0.3899)	−0.0028 (0.9272)
d_{i4}	−0.0138 (0.6522)	0.0396 (0.0830)*	−0.1420 (0.0000)***	−0.1980 (0.0000)***	0.0344 (0.3509)	0.0181 (0.5330)	0.1341 (0.0000)***	0.2879 (0.0000)***	0.0056 (0.8038)	0.0270 (0.3386)	0.0362 (0.1564)
d_{i5}	−0.0055 (0.8232)	−0.0285 (0.1246)	0.0892 (0.0000)***	−0.0942 (0.0000)***	0.1272 (0.0000)***	−0.0080 (0.7449)	−0.0046 (0.7522)	0.0073 (0.7462)	−0.0974 (0.0001)***	0.0187 (0.4572)	0.0222 (0.2470)
d_{i6}	−0.0291 (0.4513)	−0.0056 (0.8704)	−0.0168 (0.6201)	−0.0322 (0.3618)	0.0695 (0.2276)	0.2484 (0.0000)***	−0.0113 (0.8094)	−0.0546 (0.1760)	−0.0087 (0.8581)	0.0558 (0.0834)*	−0.0137 (0.6705)
d_{i7}	−0.0897 (0.0537)*	−0.0531 (0.1261)	−0.1282 (0.0011)***	−0.1082 (0.0005)***	0.0179 (0.6583)	0.0556 (0.0715)*	0.6230 (0.0000)***	0.1266 (0.0029***)	−0.0067 (0.8957)	0.0929 (0.0413)**	0.0013 (0.9703)
d_{i8}	0.0094 (0.6576)	0.0199 (0.4015)	−0.0274 (0.2254)	−0.1492 (0.0000)***	−0.0147 (0.6428)	−0.0129 (0.5478)	0.0910 (0.0007)***	0.1013 (0.0002)***	−0.0105 (0.6072)	0.0163 (0.4401)	0.0484 (0.0181)**
d_{i9}	−0.1117 (0.0024)***	−0.0238 (0.4154)	0.0709 (0.0267)**	−0.1413 (0.0000)***	0.1063 (0.0420)**	−0.0770 (0.0237)**	0.1613 (0.0000)***	0.0580 (0.1249)	−0.2015 (0.0000)***	0.0995 (0.0039)***	−0.0519 (0.0345)**
d_{i10}	−0.0001 (0.9976)	−0.0117 (0.7444)	−0.0106 (0.7705)	0.0301 (0.0069)***	−0.0548 (0.3756)	−0.0059 (0.8614)	−0.0296 (0.3805)	0.0002 (0.9960)	0.0050 (0.8961)	0.2670 (0.0000)***	0.0323 (0.2515)
d_{i11}	−0.1878 (0.0000)***	0.0622 (0.0527)*	−0.0739 (0.0120)**	−0.0032 (0.9070)	0.1077 (0.0177)**	0.0418 (0.1057)	−0.0256 (0.4116)	−0.0596 (0.0748)*	0.1303 (0.0019)***	0.0209 (0.4680)	0.4040 (0.0000)***
LB Q² (12)	4.84	9.94	16.28	12.17	9.13	18.98	4.92	12.78	11.78	5.67	16.65
LB Q² (24)	10.83	21.42	33.32	17.43	25.96	22.56	8.98	30.67	29.99	7.92	29.38
ARCH LM	0.11	0.10	1.69	4.42	0.22	0.10	0.79	4.76	6.04	0.02	0.12

Notes: *, **, *** indicate that *p*-values are significant at 1%, 5%, and 10%. Parameters of matrix D connote the asymmetric effect. LB Q² (12) and LB Q² (24) is Ljung-Box Q² statistics on squared residuals for detecting serial correlation at 12 and 24 lags, which signified the appropriateness of the model.

have accelerated over time. For instance, spillover effect in the emerging stock markets such as Pakistan, India, and Korea ($a_{i,j}$ and $b_{i,j}$) was lower in the pre-GFC, but it escalated during post-GFC. Besides, along with the major role of Thailand, during post-GFC, other emerging economies' influence was also exhibited in the study. For instance, Thailand alone inserts a higher negative 20% shock spillover in the Indian market ($a_{9,2}$). The higher positive volatility spillover contribution of 48% and 26% from Taiwanese ($b_{8,3}$) and Malaysian ($b_{5,3}$) markets also accounted for the growing Indonesian economy. Thus, this is a clear-cut indication that the structure of cross-markets shocks and volatility spillover dramatically changed due to the global financial crisis.

Although there is a gradual increase of shock and volatility spillover in Asian frontier markets during post-GFC, it is not highly remarkable compared to Asian emerging markets. It ascertained that frontier markets emit more volatility transmission in other regional markets than reverse effect due to the low degree of openness of markets for foreign activities.

3.5. Asymmetric response of stock markets (post-global financial crisis)

Table 7 revealed the asymmetric behavior of the markets during post-GFC. Except for India ($d_{2,2}$) and Sri Lanka ($d_{10,10}$), all emerging markets and frontier markets are entrenched towards asymmetric response due to its negative news. The off-diagonal elements result in matrix D, suggesting that bi-directional cross-markets asymmetric response enlarged more in Asian emerging markets during post-GFC than pre-GFC. India responds for 59% positive and 56% negative asymmetric behavior from Asian emerging markets. Moreover, in this total, major contribution moves from other emerging markets such as Indonesia and Korea. On the other hand, cross-border, asymmetric transmission due to negative news noise noticed very less in Asian frontier markets during both sample periods than emerging markets.

For the past three decades, particularly after liberalization reforms, Asian emerging markets have maintained a significant economic rational amongst them in terms of trade, a supply of capital, allowing foreign activities to operate in domestic markets and other bilateral activities. For instance, Korea, Malaysia, and Thailand are considered the significant-top trading partners for most markets. Therefore, these are some of the parameters that significantly contribute to economic linkages. As a result, this has enhanced the volatility traverse between the markets over time. The repercussion of the GFC that has jolted most global markets could be another reason for dynamic change in volatility spillover between markets, particularly after the crisis. In terms of Asian frontier markets, the less exposure to volatility shocks of other regional markets could be due to the shelter of extensive regulations for foreign activities.

CONCLUSION

The analysis results suggest a drastic change in volatility traverse between Asian emerging and frontier stock markets around the GFC. Although cross-market shocks and volatility spillover between emerging markets were less apparent during pre-GFC, certainly, it has been intensified during post-GFC. Therefore, to absorb risk-adjusted returns and diversification benefits, investors need to design an appropriate strategy that will suit volatile market conditions. In the case of Asian frontier markets, a remarkable observation that its past shocks drive most of the volatility during pre-GFC. However, over the years after GFC, other regional markets' volatility gradually started emanating in these markets but not highly remarkable. Thus, there is a need for safe investment strategies while allocating the asset for portfolio diversification from the Asian frontier markets, particularly during financial turmoil and market distress. Since these markets are nascent and march towards growth, they form a high economic rationale with other advanced and emerging markets. As a result, they tend to expose to external shocks, particularly to the financial crises in the future.

Table 6. Shocks and volatility spillover between stock markets during post-global financial crisis

Markets	China ($i = 1$)	India ($i = 2$)	Indonesia ($i = 3$)	Korea ($i = 4$)	Malaysia ($i = 5$)	Pakistan ($i = 6$)	The Philippines ($i = 7$)	Taiwan ($i = 8$)	Thailand ($i = 9$)	Sri Lanka ($i = 10$)	Vietnam ($i = 11$)
c_{i1}	0.0955 (0.0000)***	–	–	–	–	–	–	–	–	–	–
c_{i2}	0.2705 (0.0000)***	0.5097 (0.0000)***	–	–	–	–	–	–	–	–	–
c_{i3}	−0.1179 (0.0000)***	−0.2482 (0.0000)***	0.2647 (0.0000)***	–	–	–	–	–	–	–	–
c_{i4}	0.0155 (0.1899)	0.2066 (0.0000)***	−0.0130 (0.2203)	0.2107 (0.0000)***	–	–	–	–	–	–	–
c_{i5}	0.0631 (0.0000)***	−0.0637 (0.0000)***	−0.0792 (0.0000)***	0.0133 (0.0824)*	0.0984 (0.0000)***	–	–	–	–	–	–
c_{i6}	−0.0297 (0.0457)**	−0.0249 (0.0921)*	−0.1776 (0.0000)***	−0.1214 (0.0000)***	−0.0738 (0.0000)***	0.2108 (0.0000)***	–	–	–	–	–
c_{i7}	0.0192 (0.1570)	−0.1196 (0.0000)***	0.5008 (0.0000)***	−0.1396 (0.0000)***	0.0266 (0.0484)**	−0.1467 (0.0000)***	0.3534 (0.0000)***	–	–	–	–
c_{i8}	0.3199 (0.0000)***	−0.0595 (0.0004)***	−0.1401 (0.0000)***	−0.2937 (0.0000)***	0.1063 (0.0000)***	0.0162 (0.1890)	−0.0716 (0.0000)***	0.0469 (0.0000)***	–	–	–
c_{i9}	0.0750 (0.0000)***	0.0223 (0.0259)**	−0.0766 (0.0000)***	0.0272 (0.0107)**	−0.0085 (0.4016)	−0.0054 (0.6183)	−0.0507 (0.0000)***	0.0116 (0.3449)	0.0049 (0.4875)	–	–
c_{i10}	−0.0048 (0.5660)	0.0331 (0.0000)***	0.0083 (0.3862)	−0.0264 (0.0005)***	−0.0379 (0.0000)***	0.0289 (0.0010)***	−0.0087 (0.3588)	−0.0172 (0.0383)**	−0.0033 (0.7116)	0.0066 (0.2196)	–
c_{i11}	0.1382 (0.0000)***	−0.0267 (0.0347)**	0.0147 (0.2560)	0.0194 (0.1478)	−0.0234 (0.0289)**	0.0643 (0.0000)***	−0.0419 (0.0024)***	−0.0252 (0.00375)***	−0.0084 (0.5599)	0.0274 (0.0125)**	−0.0046 (0.6579)
μ	−0.0085 (0.7216)	0.0154 (0.4314)	0.0305 (0.0812)*	0.0045 (0.7808)	0.0160 (0.1674)	0.0726 (0.0003)***	0.0450 (0.0111)**	0.0149 (0.2687)	0.0553 (0.0008)***	0.0029 (0.8284)	0.0457 (0.0284)**
a_{i1}	0.1531 (0.0000)***	0.0065 (0.6032)	0.0370 (0.0066)***	0.0092 (0.4929)	−0.1166 (0.0000)***	−0.0063 (0.6213)	0.0290 (0.0368)**	−0.0176 (0.3031)	−0.0134 (0.3531)	−0.0296 (0.1191)	0.0238 (0.0815)*
a_{i2}	0.0413 (0.0033)***	0.3661 (0.0000)***	−0.0675 (0.0000)***	−0.1226 (0.0000)***	−0.0505 (0.0000)***	0.0422 (0.0014)***	0.0262 (0.0019)***	−0.0013 (0.9269)	−0.1977 (0.0000)***	0.0172 (0.0372)**	−0.0231 (0.0084)***
a_{i3}	0.0489 (0.0001)***	−0.0488 (0.0000)***	0.1527 (0.0000)***	0.0203 (0.0287)**	0.0550 (0.0004)***	−0.0263 (0.0134)**	−0.0902 (0.0000)***	0.1052 (0.0000)***	−0.1240 (0.0000)***	−0.1439 (0.0000)***	0.0179 (0.1082)
a_{i4}	0.0170 (0.0954)*	0.1354 (0.0000)***	0.0178 (0.0401)**	−0.0447 (0.0000)***	0.0543 (0.0000)***	−0.0263 (0.0041)***	−0.0245 (0.0141)**	0.0374 (0.0005)***	−0.0799 (0.0000)***	−0.0866 (0.0000)***	0.0733 (0.0000)***
a_{i5}	0.0220 (0.0013)***	0.0618 (0.0000)***	0.0370 (0.0000)***	−0.0296 (0.0000)***	0.1710 (0.0000)***	0.0075 (0.1799)	−0.0261 (0.0000)***	−0.0241 (0.0045)***	0.0072 (0.1977)	−0.0475 (0.0002)***	−0.0198 (0.0093)***
a_{i6}	0.0212 (0.1171)	−0.0214 (0.3920)	0.0151 (0.1644)	0.0453 (0.0000)***	−0.0662 (0.0000)***	0.1017 (0.0000)***	−0.0034 (0.7710)	0.0131 (0.3351)	0.0239 (0.0492)**	0.0392 (0.0446)**	−0.0243 (0.0785)*

Table 6 (cont.). Shocks and volatility spillover between stock markets during post-global financial crisis

Markets	China (i = 1)	India (i = 2)	Indonesia (i = 3)	Korea (i = 4)	Malaysia (i = 5)	Pakistan (i = 6)	The Philippines (i = 7)	Taiwan (i = 8)	Thailand (i = 9)	Sri Lanka (i = 10)	Vietnam (i = 11)
a_{i7}	0.0312 (0.0195)**	0.0851 (0.0000)***	0.0332 (0.0008)***	0.0520 (0.0000)***	−0.0968 (0.0000)***	−0.0418 (0.0000)***	0.1706 (0.0000)***	−0.0516 (0.0000)***	−0.0629 (0.0000)***	−0.0162 (0.3995)	0.0374 (0.0000)***
a_{i8}	0.0281 (0.0011)***	0.0298 (0.0004)***	0.0715 (0.0000)***	0.1269 (0.0000)***	−0.0592 (0.0000)***	0.0112 (0.3311)	−0.0441 (0.0000)***	−0.0922 (0.0000)***	−0.0449 (0.0000)***	−0.0064 (0.6855)	−0.0399 (0.0001)***
a_{i9}	0.0128 (0.1938)	0.0485 (0.0000)***	0.0453 (0.0000)***	−0.0291 (0.0000)***	−0.0339 (0.0026)***	0.0146 (0.0360)**	0.0488 (0.0000)***	−0.0744 (0.0000)***	0.2048 (0.0000)***	−0.0749 (0.0000)***	0.0011 (0.9083)
a_{i10}	−0.0024 (0.7317)	0.0347 (0.0000)***	−0.0244 (0.0003)***	0.0051 (0.2873)	−0.0148 (0.0395)**	0.0011 (0.8477)	−0.0067 (0.2318)	0.0319 (0.0000)***	−0.0053 (0.3425)	0.2639 (0.0000)***	−0.0233 (0.0013)***
a_{i11}	0.0537 (0.0000)***	0.0125 (0.1577)	0.0202 (0.0615)*	0.0023 (0.8058)	−0.0304 (0.0564)*	0.0036 (0.7514)	0.0189 (0.0916)*	−0.0669 (0.0000)***	0.0013 (0.9012)	0.0238 (0.0815)*	0.1988 (0.0000)***
b_{i1}	0.9839 (0.0000)***	−0.0250 (0.0000)***	0.0184 (0.0504)*	0.0139 (0.0556)*	0.0328 (0.0010)***	0.0091 (0.1218)	−0.0010 (0.9204)	−0.0347 (0.0004)***	−0.0040 (0.6584)	0.0151 (0.0136)**	−0.0074 (0.0888)*
b_{i2}	0.0059 (0.2861)	0.6131 (0.0000)***	0.1059 (0.0000)***	−0.2362 (0.0000)***	0.2409 (0.0000)***	0.0056 (0.6625)	0.2220 (0.0000)***	0.1422 (0.0000)***	0.0475 (0.0000)***	−0.0085 (0.0902)*	−0.0224 (0.0015)***
b_{i3}	−0.0022 (0.0002)***	0.0994 (0.0000)***	0.5929 (0.0000)***	−0.2902 (0.0000)***	0.2619 (0.0000)***	0.0811 (0.0000)***	−0.0570 (0.0000)***	0.4779 (0.0000)***	0.1735 (0.0000)***	0.0528 (0.0000)***	−0.0136 (0.0908)*
b_{i4}	−0.0114 (0.0054)***	−0.1165 (0.0000)***	0.1457 (0.0000)***	0.7702 (0.0000)***	0.0270 (0.0084)***	0.0407 (0.0000)***	0.0574 (0.0000)***	0.2603 (0.0000)***	−0.0757 (0.0000)***	0.0411 (0.0000)***	−0.0210 (0.0002)***
b_{i5}	0.0021 (0.4923)	−0.0511 (0.0000)***	−0.0373 (0.0000)***	0.0694 (0.0000)***	0.9499 (0.0000)***	−0.0088 (0.0664)*	0.0364 (0.0000)***	−0.0983 (0.0000)***	0.0461 (0.0000)***	0.0111 (0.0198)**	−0.0052 (0.1395)
b_{i6}	0.0019 (0.6240)	−0.0396 (0.0000)***	0.0383 (0.0007)***	0.0213 (0.0141)**	−0.0313 (0.0048)***	0.8825 (0.0000)***	0.2179 (0.0000)***	−0.1563 (0.0000)***	−0.0229 (0.0035)***	−0.0263 (0.0019)***	0.0019 (0.7519)
b_{i7}	0.0022 (0.6905)	0.0070 (0.2124)	−0.2860 (0.0000)***	0.1916 (0.0000)***	0.2111 (0.0000)***	0.0680 (0.0000)***	0.5524 (0.0000)***	−0.0133 (0.2280)	0.2284 (0.0000)***	0.0249 (0.0245)**	−0.0153 (0.0353)**
b_{i8}	0.0186 (0.0000)***	−0.1251 (0.0000)***	−0.0931 (0.0000)***	0.1696 (0.0000)***	0.0034 (0.7778)	−0.0458 (0.0000)***	0.1679 (0.0000)***	0.6267 (0.0000)***	0.1502 (0.0000)***	0.0069 (0.4072)	0.0038 (0.5399)
b_{i9}	0.0004 (0.8906)	0.0049 (0.2978)	0.1285 (0.0000)***	0.1778 (0.0000)***	−0.1104 (0.0000)***	−0.0313 (0.0000)***	0.0143 (0.1487)	−0.2495 (0.0000)***	0.8864 (0.0000)***	0.0224 (0.0013)***	−0.0066 (0.1364)
b_{i10}	0.0027 (0.0924)*	−0.0482 (0.0000)***	−0.0045 (0.4079)	−0.0268 (0.0000)***	0..0442 (0.0000)***	−0.0101 (0.0103)**	0.0253 (0.0000)***	0.0119 (0.0340)**	0.0157 (0.0024)***	0.9526 (0.0000)***	−0.0026 (0.3487)
b_{i11}	−0.0059 (0.0510)*	0.0172 (0.0197)**	−0.0319 (0.0000)***	0.0498 (0.0000)***	0.0190 (0.0542)*	0.0021 (0.7560)	0.0215 (0.0503)*	−0.0695 (0.0000)***	0.0162 (0.0211)**	−0.0046 (0.5057)	0.9535 (0.0000)***

Notes: *, **, *** indicate that *p*-values are significant at 1%, 5% and 10%. Variable order: 1 (China), 2 (India), 3 (Indonesia), 4 (Korea), 5 (Malaysia), 6 (Pakistan), 7 (the Philippines), 8 (Taiwan), 9 (Thailand), 10 (Sri Lanka), and 11 (Vietnam). The parameters in Matrix C are constant, A and B matrices parameters represent the ARCH and GARCH effects.

Table 7. Asymmetric transmission during post-global financial crisis

Markets	China ($i = 1$)	India ($i = 2$)	Indonesia ($i = 3$)	Korea ($i = 4$)	Malaysia ($i = 5$)	Pakistan ($i = 6$)	Philippines ($i = 7$)	Taiwan ($i = 8$)	Thailand ($i = 9$)	Sri Lanka ($i = 10$)	Vietnam ($i = 11$)
d_{i1}	0.0556 (0.0011)***	−0.0024 (0.9065)	0.0128 (0.6153)	0.0156 (0.5183)	−0.0888 (0.0184)**	−0.0365 (0.0450)**	−0.0023 (0.9207)	0.0087 (0.7854)	−0.0085 (0.7130)	0.0268 (0.3426)	0.0161 (0.4443)
d_{i2}	−0.0954 (0.0000)***	−0.0260 (0.2615)	0.2976 (0.0000)***	−0.1671 (0.0000)***	0.0675 (0.1668)	−0.1519 (0.0000)***	0.1020 (0.0005)***	0.1222 (0.0021)***	−0.1434 (0.0000)***	0.3202 (0.0000)***	0.0047 (0.8720)
d_{i3}	0.0034 (0.8574)	0.0759 (0.0000)***	−0.1755 (0.0000)***	−0.2568 (0.0000)***	−0.1310 (0.0005)***	0.0222 (0.1876)	0.3396 (0.0000)***	0.1189 (0.0000)***	0.0786 (0.0000)***	−0.2097 (0.0000)***	0.1060 (0.0000)***
d_{i4}	0.0559 (0.0000)***	0.0249 (0.1281)	0.0977 (0.0000)***	−0.0919 (0.0000)***	−0.1274 (0.0000)***	−0.0727 (0.0000)***	0.0209 (0.2894)	0.1106 (0.0000)***	−0.0476 (0.0218)**	−0.0403 (0.1910)	−0.0377 (0.0701)*
d_{i5}	0.0114 (0.3409)	−0.0132 (0.1386)	0.0253 (0.0152)**	−0.1088 (0.0000)***	−0.1449 (0.0000)***	−0.0154 (0.0710)*	0.0669 (0.0000)***	0.0666 (0.0007)***	0.0282 (0.0075)***	−0.0426 (0.0466)**	0.0252 (0.0846)*
d_{i6}	−0.0509 (0.0003)***	−0.0712 (0.0000)***	0.0461 (0.0167)**	0.0050 (0.8220)	0.0542 (0.1446)	0.2769 (0.0000)***	−0.1314 (0.0000)***	−0.0299 (0.3009)	0.0788 (0.0010)***	0.0561 (0.1602)	−0.0582 (0.0126)**
d_{i7}	0.0023 (0.8668)	0.1214 (0.0000)***	−0.1240 (0.0000)***	−0.1359 (0.0000)***	−0.0134 (0.6677)	0.0718 (0.0000)***	0.3098 (0.0000)***	−0.0179 (0.5166)	−0.1708 (0.0000)***	−0.3684 (0.0000)***	0.1623 (0.0000)***
d_{i8}	−0.0688 (0.0000)***	−0.1371 (0.0000)***	−0.0130 (0.5326)	−0.0995 (0.0000)***	0.1183 (0.0004)***	−0.0590 (0.0008)***	0.0327 (0.1310)	0.0736 (0.0153)**	0.0406 (0.0590)*	0.0938 (0.0022)***	−0.0402 (0.0586)*
d_{i9}	−0.0212 (0.1982)	0.0186 (0.1554)	0.1523 (0.0000)***	0.0869 (0.0000)***	−0.0736 (0.0004)***	−0.0206 (0.0673)*	−0.0097 (0.0000)***	0.0081 (0.6863)	−0.1784 (0.0000)***	−0.0151 (0.6337)	0.0379 (0.0303)**
d_{i10}	−0.0227 (0.0245)**	0.1087 (0.0000)***	0.0040 (0.7379)	−0.0333 (0.0243)**	0.0472 (0.0044)***	−0.0086 (0.2751)	−0.0310 (0.0006)***	−0.0120 (0.4887)	0.0108 (0.2932)	0.0412 (0.1229)	0.0231 (0.0878)*
d_{i11}	−0.0567 (0.0005)***	0.0393 (0.0413)**	0.0362 (0.1009)	−0.1069 (0.0000)***	0.0496 (0.1540)	−0.0472 (0.0023)***	0.0222 (0.2956)	−0.0119 (0.7079)	−0.0155 (0.4594)	−0.1220 (0.0003)***	0.2254 (0.0000)***
LB Q² (12)	16.12	9.02	16.41	18.54	7.92	10.60	4.78	2.64	13.39	3.99	11.40
LB Q² (24)	26.99	11.07	26.40	30.98	11.18	22.32	10.47	10.82	18.37	9.95	18.50
ARCH LM	0.13	0.82	1.24	1.99	0.14	0.02	0.25	0.02	1.39	0.32	1.60

Notes: *, **, *** indicate that *p*-values are significant at 1%, 5%, and 10%. Parameters of matrix D connote the asymmetric effect. LB Q² (12) and LB Q² (24) is Ljung-Box Q² statistics on squared residuals for detecting serial correlation at 12 and 24 lags, which signified the appropriateness of the model.

AUTHOR CONTRIBUTIONS

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