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An Empirical Analysis of Volatility Spillovers in SAARC Stock Markets Using Multivariate GARCH Models

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Abstract

Examining the persistence of volatility transmission over an extended timeframe, regardless of specific events, reveals significant importance, as it uncovers the inherent fundamental and structural drivers that give rise to volatility. However, previous research in South Asia is minimal and has primarily concentrated on periods of specific events or crises. Thus, it is crucial to understand South Asian equity markets' long-term interconnections beyond specific events that have not been addressed previously. To estimate the volatility transmission source, direction, and intensity among the select South Asian (India, Sri Lanka, Bangladesh, and Pakistan) equity markets, this study employed four-dimensional Multivariate GARCH models (BEKK, Simple Diagonal VECH, Dynamic Conditional Correlation and Constant Conditional Correlation) for examining the long-term interconnectedness, utilising daily data from January 2013 to March 2023. The findings reveal a relatively low degree of volatility transmission and more influence of spillovers within the same market than spillovers across different markets, indicating minimal inter-market connectedness in South Asian countries. As a result, this research contributes to a deeper understanding of market behaviour and volatility in South Asian equity markets, highlighting the favourable conditions for portfolio managers and foreign institutional and domestic investors to formulate diversification strategies.

Keywords*:* Stock Market Integration, Volatility Spillover, Interconnectedness, Multivariate GARCH, South Asia.
JEL Classifications: C13, C32, F21, G15

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1. Introduction

The notion of integration of stock markets emanates from the theory known as the law of one price (LOOP), which refers to the equity markets in various countries moving in tandem and exhibiting identical risk-adjusted returns (Patel et al., 2022; Sharma & Seth, 2012). If the markets are highly integrated, it benefits the investors during the bullish market condition only and, in contrast, hampers them while markets are bearish. Thus, when the markets are bearish, integration would only result in negative returns, and any degree of diversification would not result in positive returns for the investors. Therefore, Markowitz (1952) proved that diversification can lower the exposure to unsystematic or specific risks by combining investments that do not have a high positive correlation of returns. Hence, achieving the desired results of reducing the risk is possible when returns from the assets in a portfolio are negatively correlated. A corollary to this logic is that if the markets are highly integrated, shocks occurring in one market spread to others, leading to the least possibility of diversifying the systemic risk (Cheng, 2000).

In this millenium, the stock markets throughout the globe have witnessed more integration owing to the easing of restrictions on cross-border investments, advancements in technology, and a notable surge in the number of overseas investors participating in the national market, and hence this made equity markets more volatile (Baele et al., 2004; Carrieri et al., 2007; Goetzmann et al., 2005; Mishra et al., 2022; Panda & Nanda, 2018; Saiti et al., 2014; Yu & Hassan, 2008). However, globalisation boosts economic growth, but the market becomes more vulnerable to the occurrence of economic turmoil. Before the global financial crisis, investors perceived globalisation as an opportunity for capital mobility and trade liberalisation. On the other hand, the financial crisis in 1997 – 1998 and 2007 - 2008 has thrown a long shadow over the growth of stock markets (Collins & Biekpe, 2003; Click & Plummer, 2005; Saiti et al., 2014; Mensi et al., 2016). Thus, the increased interconnectedness between the economies has paved the way for volatility spillover (Levine & Schmukler, 2007), which has pushed a question on the impact of global economic liberalisation to the forefront (Jebran et al., 2017). With the advent of globalisation, market integration has intensified volatility transmission, posing a persistent challenge for effective portfolio diversification and impacting foreign institutional investors, portfolio managers, and domestic investors.

Further, international investors increasingly seek opportunities in emerging markets, and among, those South Asia stands out as a fast-growing region (Kumar & Dhankar, 2017). This creates a need to focus on the South Asian economies, where all the countries in the region formed an association for regional cooperation and named it the “South Asian Association for Regional Cooperation" (SAARC), which promotes cooperation and integration with an aim to accelerate their economic growth. The member countries of SAARC are Bangladesh, Afghanistan, India, Bhutan, Pakistan, Maldives, Nepal, and Sri Lanka, and they have worked on initiatives to encourage economic integration on a regional scale through the "South Asian Free Trade Area (SAFTA)". In addition to this, the creation of SAARCFINANCE, the Federation of the Exchanges of the SAARC, and a common regulatory forum, namely the "South Asian Securities Regulators' Forum (SASRF)", were also initiated to develop the integration of the markets of the member countries (Sehgal et al., 2018). Further, over the last twenty years, SAARC economies and their stock markets have witnessed substantial growth with the vibrant markets in Sri Lanka, Bangladesh, India, and Pakistan. For instance, India's market capitalisation soared from $225.6 billion to $2.6 trillion, reflecting robust economic expansion. Bangladesh also saw an impressive growth with its increased market capitalisation. Similarly, Sri Lanka and Pakistan also experienced a notable development. These trends highlight South Asia's growing prominence in the global landscape. To provide a glimpse of these developments, Table 1 exhibits the essential data of these four markets.

Table 1: Key Indicators of Select SAARC Stock Markets Performance

Indicators	2000	2005	2010	2015	2020
Market capitalization of listed domestic companies (current US$ in Millions)					
Bangladesh	2192.18	3299.61	41616.87	65484.86	89773.66
India	225648.37	624739.19	1762461.86	1745169.24	2595462.35
Sri Lanka	1074.14	5719.99	19923.86	20804.11	15981.91
Pakistan	6624.60	45317.28	38007.18	32567.93	50278.51
Listed domestic companies, total					
Bangladesh	364	195	192	543	628
India	5853	4763	5034	5835	5215
Sri Lanka	239	239	241	294	283
Pakistan	723	639	625	-----	-----
Stocks traded, total value (% of GDP)					
Bangladesh	1.75	0.29	4.19	6.97	3.99
India	109.48	57.74	63.31	38.13	72.92
Sri Lanka	0.81	4.42	8.51	2.10	2.00
Pakistan	37.79	116.14	6.577	-----	-----

Source: Compiled by Authors https://data.worldbank.org/

Additionally, the regional economic integration of South Asia is significantly influenced by the intricate history of conflict and cooperation, which is characterised by cultural exchange and shared challenges. Despite political tensions between India and Pakistan, border disputes with Bangladesh, and water-sharing issues, there has been significant economic growth and cultural connection. As regional cooperation grows worldwide, investors and portfolio managers need to comprehend stock market integration and volatility spillovers in South Asia. This understanding helps to diversify and develop effective hedging strategies, ensuring economic stability and informed decision-making in South Asian markets. Analysing these spillovers exhibits distinctive characteristics such as volatility clustering, time-varying patterns, and infinite non-divergence properties. These factors shape volatility models (Panda & Nanda, 2018). There are several models for capturing the effect of volatility spillover, and among those, the "Autoregressive Conditional Heteroskedasticity (ARCH)" family model is the standard one. Later, GARCH models gained widespread use for examining the effects of volatility transmission and capturing the persistent nature of those impacts over time. However, the market integration and the cross-market effect are to be captured simultaneously in multiple markets using MGARCH models (multivariate GARCH). Earlier studies used MGARCH models to examine the spillover effect and their interconnectedness across the markets (Hung, 2020; Khan, 2023; Majdoub & Mansour, 2014; Mohammadi & Tan, 2015; Panda & Nanda, 2018; Wong, 2017) with coverage of markets of developed and fastly developing economies.

Thus, this study examines the presence of market integration and the transmission of volatility in the South Asian region and makes several significant contributions to the literature on market integration and volatility transmission, particularly within the South Asian region. Firstly, by concentrating on South Asian equity markets, the study bridges the gap in the literature, which often emphasises more on developed markets or other emerging regions. Secondly, the study specifically investigates the interdependencies and volatility spillovers under general market conditions in the recent period, which provides a clear understanding of market behaviour that can be contrasted with periods of turmoil or other exceptional conditions, which has been the focus of many researchers earlier. Thirdly, the study uses MGARCH-BEKK models, allowing for modelling volatility spillovers with the inclusion of lagged effects in conditional variances and covariances, providing a more nuanced and accurate representation of the underlying volatility dynamics and their spillover effects across South Asian markets, which has not been examined earlier. Further, this study employs diagonal VECH models, which capture both short-term dynamics and instantaneous effects while examining the long-term relationships between the countries. This dual focus offers a more holistic view of market interactions and their temporal characteristics. Lastly, applying DCC and CCC models enables the study to capture the time-varying nature of volatility spillover between the equity markets. This aspect sheds light on the evolution of interactions over time, providing valuable insights into how these relationships vary in the changing environment.

The subsequent sections of the paper comprise the following segments: Section two presents related literature about the volatility transmission in global as well as in South Asian contexts. The third section of the study focuses on the methodology employed to investigate volatility spillover. The fourth section presents the empirical analysis and discussion. The fifth section presents the conclusion, while the sixth section discusses the limitations and directions for future research.

2. Literature Review

2.1 Global Context

Market integration in the global context gained prominence during the 1970s through various studies conducted by Grubel (1968), Joy et al. (1976), and Panton et al. (1976). Following them, many studies have been conducted (Bekaert, 1995; Bracker & Koch, 1999; Campbell & Hamao, 1992; Engle, 2002; Grubel & Fadner, 1971; Lessard, 1973; Levy & Sarnat, 1970; Longin & Solnik, 1995; Solnik, 1974), and they collectively sharpened the focus on the research concept of equity market integration. In this sequence, Kearney & Lucey, (2004) describe two methods to evaluate market integration: direct measurement based on the law of one price and indirect measurement linked to liberalisation and deregulation effects. The pioneer studies on equity market integration laid a strong foundation for discussing global portfolio diversification. For instance, Grubel (1968) analysed the stock market interdependence using correlation analysis and found a greater interconnectedness between the US, UK, and West Germany. Similarly, Bertoneche (1979) proved the existence of a low correlation between each possible pair of equity markets among the US, UK, Italy, Germany, France, and the Netherlands, which was perceived as an opportunity for international diversification. Using the GARCH model, Engle et al. (1990) found the existence of cross-market fluctuations between the US and Japan, which proved the meteor shower phenomenon. Subsequently, intensive investigations were made on the integration among well-established markets, viz., the US, Europe, Canada, and the UK. Among those studies, Hamao et al.(1990) and Panton et al.(1976) found a short-run relationship among the markets, Bekaert et al. (2005) and Koutmos & Booth(1995) found significant interdependence among the equity markets. In contrast to the above findings, Kasa (1992) found a low level of integration, Ewing et al.(1999), Kanas(1998), Malkamäki et al.(1993) and Theodossiou & Lee(1993) found no integration at all among the markets.

In line with the above studies, few investigated the consequences of financial crises on market integration. Chan et al. (1997) focused on the European market crisis of 1987 and proved the non-existence of long-term connections, and similar results were found by Arshanapalli (1993) and Patev et al. (2006) exploring the effect of the Asian financial crisis. However, Li & Giles (2015) observed a stronger and bidirectional instability spread among the markets of US and Asian countries, and additionally, Hung (2020) identified a strong integration among CEE markets. With the coverage of the US subprime financial crisis, Bae & Zhang (2015) and Vo & Ellis (2018), explored integration and found that equity markets exhibit increased integration following a financial crisis. Still, the above studies have not examined the dynamic interdependence in various nations' equity markets, and hence, few researchers have investigated market integration. In focus, using the time-varying correlations, Syllignakis & Kouretas (2011) studied the interconnectedness between the U.S., German, and Russian markets throughout the 2007-2009 financial crises. It proved a significant rise in stock returns with greater integration after the crisis. In addition, Tang et al. (2010) also identified volatility spillovers from established markets to developing economies.

The GARCH model has gained widespread adoption in most studies examining volatility spillover. For example, Mukherjee & Mishra (2010), conducting a study on India and a few Asian countries that used the GARCH model, revealed a positive, two-way connection with much information flowing from Asian markets into India. In the same way, Beirne et al. (2010) utilised VAR GARCH to study the transmission of spillover effects in emerging and developed markets across the Middle East, Europe, Latin America, and Asia and found GARCH-in-mean effects, highlighting the interdependencies among these markets, and Singh et al. (2010) utilised VAR analysis to illustrate a noteworthy regional influence on the stock markets of Europe and Asia. Further Jebran et al. (2017) employed the Exponential GARCH model to investigate volatility spillover in Sri Lanka, Japan, Hong Kong, China, and Pakistan. The research exposed the presence of bidirectional volatility transmission between Hong Kong, China, and Japan.

The ARCH and the GARCH models fail to capture the cross-market and its reaction effects among the different variables, which may result in inaccurate results. The multivariate GARCH model offers a comprehensive solution to overcome this by elucidating the shocks' origins, directions, and intensities between variables. Moreover, the multivariate GARCH model adeptly captures the conditional volatility of present innovations and accounts for the impact of past volatility, as demonstrated by Wei et al. (1995) and Zhong & Liu (2021). Studies have used MGARCH models to explore the interactions among the markets. Gilenko & Fedorova(2014), employing Multivariate GARCH models, assessed the internal and external volatility spillovers and found significant growth in connections between established and developing BRIC equity markets since the incident of the financial crisis. Majdoub & Mansour (2014) investigated the relationship and shockwave transmission between the US and Islamic developing equity markets. The findings indicated a weak integration between Islamic developing markets and the US, with no significant transmission of shocks observed. Mohammadi & Tan (2015) probed the US, China, and Hong Kong equity markets and revealed the unidirectional spillovers of returns from the US, while spillover effects were non-persistent between China and Hong Kong. Hung (2020) recently highlighted the post-2007 financial crisis spillover effects across Central and Eastern European equity markets and discovered that own-volatility spillovers remained consistently lower across markets when compared to cross-volatility, suggesting that domestic factors played a more significant role in driving volatility in these markets rather than external influences. Thus, recent studies have employed MGARCH models to examine volatility spillover among equity markets. The MGARCH models have also examined the volatility spillover from forex markets to equity markets (Hung, 2022; Wong, 2017; Zhao, 2010).

In contrast to the previous studies focusing on financial crises, some studies specifically investigate the interdependence of equity markets regardless of specific economic events. For instance, Panda & Nanda (2018) examined the time series properties of Central and South American market returns using MGARCH. Their findings revealed that Venezuela, Peru, and Chile exhibited the highest degree of dynamic interconnections with the region. Panda et al. (2019), using VAR, VECM, and MGARCH BEKK to explore the interdependencies of the volatility spillover patterns in Middle Eastern countries and Africa, found a limited number of significant causal relationships among the markets.

2.2 South Asian Context

In the case of South Asia, the economic reforms and the easing of investment flows in the 1990s resulted in greater integration of the region's financial markets (Prakash & Nauriyal, 2021). Early studies indicate that markets with significant economic ties and geographic closeness significantly impact one another (Janakiramanan & Lamba, 1998). Further, limited research has been conducted on regional market integration. These studies can be categorised into two groups: a) the influence of developed nations' equity markets on the South Asian equity markets, and b) integration and volatility spillover among the South Asian stock markets. The summarised details of the studies are presented in Table 2.

Table 2: Studies on South Asian Equity Market Integration

Author	**Sample**	**Time period**	**Methodology**	**Results**
Studies on Influence of Developed nations equity markets on the South Asian equity markets				
Kumar and Dhankar (2009)	India, Pakistan, Bangladesh, Sri Lanka, and S & P Global 1200	1995 - 2007	Threshold GARCH	Weak interdependency among South Asian equity markets
Habiba et al. (2020)	India, Pakistan, Sri Lanka and USA	2000 - 2017	EGARCH	Long-term cointegration of the US and South Asian stock markets. Transmission of Volatility from USA to Sri Lanka and India.
Arya and Singh (2022)	Bangladesh, India, Pakistan, and Sri Lanka	2013 - 2021	ARDL	Weak integration found among South Asian equity markets
Studies on integration and volatility spillover among the South Asian equity markets				
Ali et al. (2014)	Bangladesh Sri Lanka, Pakistan, and India	1999 - 2009	VECM (Vector Error Correction Model)	No correlation between equity markets in the short term and the long term.
Kumar and Dhankar (2017)	Bangladesh, Pakistan, India, and Sri Lanka	2000 – 2014	GARCH Model	Pakistan, Sri Lanka, and India exhibit a significant integration within their respective equity markets.

Author	Sample	Time period	Methodology	Results
Sehgal et al. (2018)	Maldives, Bangladesh, Pakistan, India, Nepal, and Sri Lanka	2004 – 2015	Copula GARCH models	Low inter-connectedness between the equity markets.
Khan et al. (2022)	Bangladesh, Pakistan, India, Nepal, and Sri Lanka	1993 - 2015	tetra-variate GARCH-BEKK	Long-run relationship between them.

Source: Authors' calculations

Table 2 presents a comprehensive review of studies examining the integration of equity markets in South Asia. Among these studies, notable findings emerged regarding the relationships among India, Sri Lanka, Bangladesh, and Pakistan stock markets. Specifically, Perera & Wickramanayake (2012) and Latif et al. (2014) identified significant connections between these markets. However, in contrast, Ali et al. (2014) as well as Singhania & Prakash (2014) reported limited or among the sampled stock markets. This juxtaposition of results highlights the diverse perspectives and outcomes observed in the study of South Asia's equity market integration. To sum up, earlier studies attempted to examine the transmission of volatility during various crisis periods or specific events. Therefore, there is a need for examining the shock wave and instability transmission in select South Asian stock markets, explicitly investigating the interdependencies under general market conditions. Hence this study makes an attempt in this direction. Further, it also provides a comprehensive understanding of market interactions by capturing both short-term dynamics and instantaneous effects, as well as examining long-term relationships between countries, which was not addressed previously, making it crucial for effective short- and long-term portfolio management.

2.3 Hypothesis Development

The arguments provided emphasise the need for analysing the presence of volatility spillovers among SAARC stock markets. Hence, we examine it by using Volatility-to-volatility, Volatility to mean and Mean-to-mean, measures of spillover and for testing the volatility spillovers ,the following hypothesis is framed:

Null hypothesis: $H_0 = a_{mn} = b_{mn} = 0$, posits no spillovers, specifically that the coefficients a_{mn} and b_{mn} are zero, indicating no impact of market m on market n.

The alternative hypothesis: $H_a = a_{mn} \neq 0$, $b_{mn} \neq 0$ asserts that at least one of these coefficients is non-zero, suggesting the presence of volatility spillovers from market m to market n. Testing this involves examining whether these coefficients are significantly different from zero, which would uncover the interconnections and volatility spillovers among the markets.

3. Methodology

3.1 The Conditional Volatility Model - MGARCH Diagonal VECH

The GARCH model known as the Vectorized Conditional Variance Matrix (VECH), which was developed by Bollerslev et al. (1988), is presented in the following manner:

$$vech(Ht) = C_0 + \sum_{i=0}^{q} A_i\, vech(\varepsilon_{t-1}\, \varepsilon'_{t-1}) + \sum_{i=1}^{p} B_i vech\,(H_{t-i}) \tag{1}$$

The VECH operator is utilised to convert the lower triangular portion of a symmetric matrix into a vector. In this context, C0 represents a vector of dimension k(k + 1)/2, while Ai and Bi represent the matrices of dimensions k(k + 1)/2 × k(k + 1)/2. When employing the multivariate GARCH model, one must consider several parameters. Bollerslev et al. (1988) developed the Diagonal VECH model, suggests that the A and B matrices in Equation (1) possess a diagonal structure. Consequently, each conditional variance and covariance within the system conform to a univariate GARCH specification without incorporating interdependencies among volatilities or between volatilities and covariances. The DVECH model exclusively considers the diagonal elements of Ai and Bi, disregarding all values where i = j. Mathematically, it can be expressed as:

$$H_t = C + A \circ \varepsilon_{t-1}\, \varepsilon'_{t-1} + B \circ H_{t-1} \tag{2}$$

where ◦ represents the Hadamard product, and A B, and C are now n × n symmetrical matrices.

MGARCH - BEKK (1,1)

In order to enhance our analysis, we leverage a combined approach that integrates a multivariate Generalised Auto-Regressive Conditional Heteroskedasticity (1,1) specification with the conventional BEKK model. This integration allows us to effectively model the conditional covariance matrix, denoted as H_t as,

$$H_t = C'C + A'\varepsilon_{t-1}\, \varepsilon'_{t-1}\, A + B'H_{t-1}\mathrm{B} \tag{3}$$

Within the framework of the BEKK model, matrices A and B are square matrices with dimensions k x k. On the other hand, matrix C denotes a lower triangular matrix composed of constant values, also with dimensions k x k. The diagonal elements of A and B detect the influence of earlier shocks and volatility on the conditional volatility of each market. The elements A(ij) represent the impact of shock spillover, while the B(ij) represents the effect of volatility spillover.

3.2 Conditional Correlation Models

The Constant Conditional Correlation (CCC-MGARCH) model, established by Bollerslev (1990) is a multivariate GARCH model where the conditional correlations persist constant over a period. The conditional variances are subject to a proportionality constraint in this paradigm, resulting in proportional conditional standard deviations. By enforcing this limitation, the number of parameters that have to be assessed is drastically decreased, greatly simplifying the estimating process. The expression for the conditional covariance matrix is as follows:

$$H_t = D_t R D_t = \left(\rho_{ij} \sqrt{h_{ii,t}\, h_{jj,t}}\right) \quad (4)$$

Despite the hypothesis that random shockwaves exhibit a time-invariant conditional correlation, empirical evidence often fails to support this notion. A model called the CCC has been developed to overcome this issue by allowing the conditional correlation matrix to alter over time. The dynamic conditional correlation (DCC) model, developed by Engle (2002) proposes that the covariance matrix can be decomposed as follows:

$$H_t = D_t R_t D_t \quad (5)$$

In this form, the symmetric kk positive definite matrix that represents the standardised residual conditional covariance is indicated by the symbol Q_t.

$$Q_t = (1 - \theta_1 - \theta_2) Q_0 + \theta_1 n_{t-1} n'_{t-1} + \theta_2 Q_{t-1} \quad (6)$$

The determination of the unconditional covariance matrix of nt, denoted as Q_0, follows the definition outlined in Equation (6). Let θ_1 and θ_2 be positive scalar parameters that are $\theta_1 + \theta_2 < 1$. Both of these variables have different functions in the equation: θ_1 stands for the influence of earlier disturbances on the current conditional correlation, while θ_2 stands for the influence of earlier correlations. If the values of θ_1 and θ_2 are statistically significant, the conditional correlation exhibits time variation.

The DCC model may be precisely measured in two phases. To initiate the process, Q_t is utilised for the computation of the dynamic conditional correlation:

$$\rho_{ij,t} = \frac{q_{ij}}{(q_{ii,t}\, q_{jj,t})^{1/2}} \quad (7)$$

Second, $\rho_{ij,t}$ is employed in the estimation of conditional covariance:

$$h_{ij,t} = \rho_{ij} (h_{ii,t} h_{jj,t})^{1/2} \quad (8)$$

The value of $h_{ii,t}$ ($h_{jj,t}$) represents the conditional variance, while the value of $h_{ij,t}$ reflects the conditional covariance produced by employing univariate GARCH models.

4. Empirical Analysis and Discussion

This study examines the daily closing prices of equity market benchmark indices in South Asian countries. Specifically, the countries analysed in this study include India (LBSE), Pakistan (LKSE), Bangladesh (LDSE), and Sri Lanka (LCSE). However, due to insufficient availability of data, Afghanistan, Nepal, Maldives, and Bhutan were excluded from the analysis. The dataset used for this study consists of 2639 observations, covering January 2013 to March 2023, sourced from the Bloomberg database. The chosen timeframe aligns with the data available for Bangladesh, which begins in January 2013. Table 3 displays the benchmark indices of select South Asian regions.

Table 3: Stock Market and Indexes

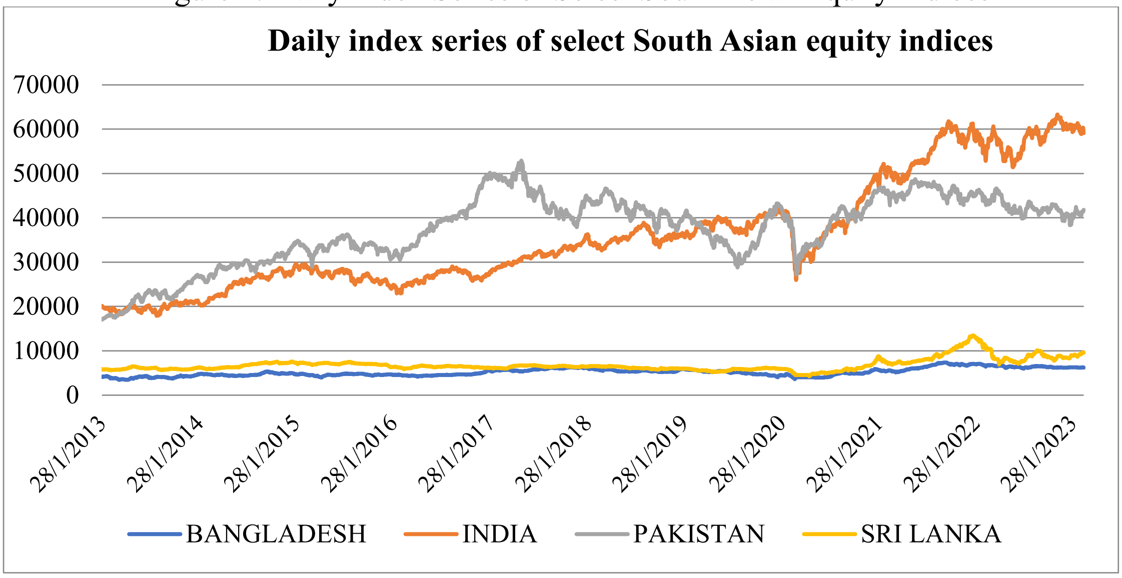
Stock Market	Benchmark
Bangladesh	DSE 30 Index
India	BSE SENSEX
Pakistan	KSE-100 Index
Sri Lanka	CSE all-share index

Source: Authors' calculations

$$R_t = \ln (P_t/P_{t-1}) \times 100$$

The log return of the daily series was calculated using the above-described formula. The natural log of these returns is then multiplied by 100 to eliminate convergence problems during estimation. Table 4 shows the summary statistics for the select South Asian economies' stock market returns. The logarithmic difference return is used to compute these descriptive statistics. The highest predicted return (0.04) is in LBSE, followed by LKSE (0.03), LCSE (0.018), and LDSE (0.015). However, Bangladesh has the highest maximum return of 9.7%, followed by India at 8.5%. India has the highest standard deviation among the countries, indicating it is more volatile, and Bangladesh has the lowest variation. Only Bangladesh has a positive skewness in the return series, whereas the other countries have a negative skewness, indicating a poor yield. The Jarque-Bera test results confirm further marks of non-normal distributions. The plot in Figure 1 depicts the daily index series for select South Asian countries.

Figure 1: Daily Index Series of Select South Asian Equity Indices



Source: Authors' estimates; calculations of the authors

Table 4: Summarise Descriptive Statistics for the Select South Asian Stock Markets

	DSE	BSE	KSE	CSE
Mean	0.01	0.04	0.03	0.01
Maximum	9.79	8.59	4.68	6.58
Median	0.00	0.01	0.00	0.00
Minimum	-6.73	-14.10	-7.10	-8.44
Std. Dev.	0.83	1.05	1.02	0.94
Skewness	0.41	-1.24	-0.60	-0.97
Kurtosis	15.80	22.75	7.57	17.25
Jarque-Bera	18107.09*	43593.46*	2461.26*	22758.04*
Arch Test	441.06*	700.41*	442.62*	543.46*

*Notes: Returns are reported in percentages, and their significance levels are denoted by *,**,*** as <1,<5,<10 percent*
Source: Authors' calculations

Table 5: Stationarity Test

	ADF		PP	
	AT LEVEL	LOG RET	AT LEVEL	LOG RET
LDSE	0.64	-46.59*	0.57	-47.32*
LBSE	1.80	-22.00*	1.80	-51.15*
LKSE	0.55	-44.90*	0.52	-45.27*
LCSE	0.51	-42.07*	0.31	-43.76*

*Notes: significance levels are denoted by *,**,*** as <1,<5,<10 percent*
Source: Authors' calculations

Table 5 displays the stationarity result. In order to evaluate the stationarity of the time series, the Philip Perron (PP) and Augmented Dickey Filler (ADF) tests have been run at the level and log differences. All of the sample countries' time series are non-stationary at the level, indicating the existence of unit roots. In both tests, the differential log return series for all nations is stationary at a significance level of 1%. In addition, the ARCH test confirms that the data have autocorrelation and heteroskedasticity issues. Table 6 shows the unrestricted correlation matrix among the stock market returns. The correlation of the sample countries was very low, ranging from 0.04 to 0.15. LBSE and LKSE have the highest correlation coefficient (0.15) among the select South Asian nations. The lowermost correlation observed between LDSE and LCSE is 0.04, the smallest.

Table 6: Unconditional Correlation Coefficients Matrix of Market Return

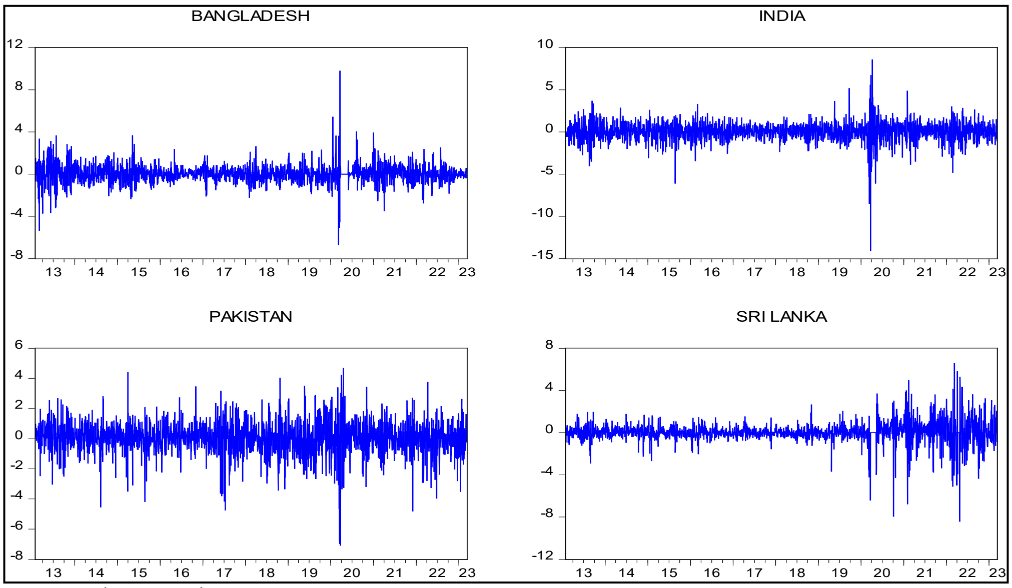
	LDSE	LBSE	LKSE	LCSE
LDSE	1	0.06*	0.08*	0.04**
LBSE		1	0.15*	0.03
LKSE			1	0.05*
LCSE				1

Source: Authors' calculations

This part analyses the estimated outcomes of the BEKK (1,1) model's time-varying variance–covariance. The presence of coefficients in the matrices A(ij) and B(ij) indicates the causal relationship between the variance and covariance components within Ht. The distinguishing characteristic of the BEKK model lies in its ability to elucidate the causal connection between variance and covariance. Table 7 displays the estimated MGARCH BEKK and Diagonal VECH model outcomes. During the empirical investigation, Bangladesh, India, Pakistan, and Sri Lanka are denoted by 1, 2, 3, and 4, respectively.

The MGARCH - BEKK and DVECH estimate results indicate that most combinations are statistically significant. The notable combinations can be observed by examining matrix A, which corresponds to the cross-past shocks. For illustration, A (1,2) coefficient is found to be -0.069. This implies that cross-past shocks are not transferred from the LDSE to LBSE, indicating that the Indian stock market does not expose shocks in the Bangladesh equity market. Similarly, the coefficient A (4,2) is -0.028 and statistically significant, indicating that shocks occurring in the LCSE are also not captured by LBSE. Hence, it can be concluded that shocks originating from both the Sri Lanka and Bangladesh equity markets do not propagate to the Indian market. These outcomes are inconsistent with Habiba et al. (2020), who found unidirectional spillovers from the Indian stock market to the markets of Pakistan and Sri Lanka, and with Singhania & Prakash(2014), who found that the Indian market is negatively correlated with the Pakistani market but positively correlated with the Sri Lankan and Bangladeshi markets. However, there are interesting findings concerning the coefficient A (3,4), which has a value of 0.035. This implies that the LCSE captures the impact of shocks occurring in LKSE. Similarly, the coefficient A (4,3) is 0.04, indicating that the LKSE captures the impact of shocks from the LCSE. These results suggest a bidirectional relationship between Pakistan and Sri Lanka, where shocks from one market affect the other, although at a lower magnitude. In contrast, Kumar & Dhankar (2017)found that the integration between Pakistan's stock markets and Sri Lanka's is high. It is worth noting that although these coefficients are statistically significant, their values are relatively low. The log return series of Bangladesh, India, Pakistan, and Sri Lanka shown in Figure 2.

Figure 2: Individual Log Return Series of Select South Asian Equity Indices



Source: Authors' estimates

Table 7: Estimated Results of MGARCH – BEKK and MGARCH – DVECH

	MV- GARCH, BEKK			MV – GARCH, DVECH		
Variable	**Coeff**	**T-Stat**	**Signif**	**Coeff**	**T-Stat**	**Signif**
Mean (LDSE)	0.02	1.61	0.10	0.02**	2.06	0.03
Mean (LBSE)	0.06*	3.45	0.00	0.07*	3.88	0.00
Mean (LKSE)	0.05*	2.95	0.00	0.07*	4.38	0.00
Mean (LCSE)	-0.00	-0.71	0.47	-0.00	-0.01	0.98
C (1, 1)	0.17*	16.40	0.00	0.01*	6.01	0.00
C (2, 1)	-0.05*	-3.12	0.00	0.01**	2.00	0.04
C (2, 2)	0.12*	9.63	0.00	0.04*	4.86	0.00
C (3, 1)	0.01	0.46	0.64	0.00	1.18	0.23
C (3, 2)	-0.10*	-3.19	0.00	0.00*	2.60	0.00
C (3, 3)	0.32*	14.54	0.00	0.02*	4.10	0.00
C (4, 1)	0.01	1.30	0.19	0.00	0.77	0.44
C (4, 2)	-0.04*	-2.64	0.00	0.07*	4.87	0.00
C (4, 3)	0.05*	5.21	0.00	0.03	0.98	0.32
C (4, 4)	-0.04***	-1.93	0.05	0.00*	4.48	0.00
A (1, 1)	0.43*	31.39	0.00	0.22*	12.56	0.00
A (1, 2)	-0.06*	-3.94	0.00	-	-	-
A (1, 3)	0.02	1.44	0.14	-	-	-
A (1, 4)	0.01	1.22	0.21	-	-	-
A (2, 1)	-0.00	-0.04	0.96	0.07*	3.61	0.00
A (2, 2)	0.16*	15.30	0.00	0.10*	8.36	0.00
A (2, 3)	0.00	0.06	0.94	-	-	-
A (2, 4)	-0.01	-1.68	0.09	-	-	-
A (3, 1)	0.00	0.18	0.85	0.04**	2.31	0.02
A (3, 2)	0.00	0.63	0.52	0.04*	5.49	0.00
A (3, 3)	0.29*	14.68	0.00	0.07*	8.92	0.00
A (3, 4)	0.03*	3.28	0.00	-	-	-
A (4, 1)	0.00	0.96	0.33	0.02	1.60	0.10
A (4, 2)	-0.02**	-2.09	0.03	0.00**	2.53	0.01
A (4, 3)	0.04*	3.87	0.00	0.00	0.45	0.64
A (4, 4)	0.30*	21.52	0.00	0.09*	14.07	0.00
B (1, 1)	0.88*	126.48	0.00	0.76*	52.41	0.00
B (1, 2)	0.05*	8.23	0.00			
B (1, 3)	-0.01	-1.79	0.07	-	-	-
B (1, 4)	-0.00	-1.56	0.11	-	-	-
B (2, 1)	-0.00**	-2.09	0.03	0.26	1.42	0.15
B (2, 2)	0.96*	233.81	0.00	0.84*	45.05	0.00
B (2, 3)	0.01	1.80	0.07	-	-	-
B (2, 4)	0.01*	3.27	0.00	-	-	-
B (3, 1)	0.00	0.84	0.39	0.61*	2.80	0.00
B (3, 2)	0.01	1.79	0.07	0.89*	44.62	0.00
B (3, 3)	0.89*	60.32	0.00	0.90*	80.69	0.00
B (3, 4)	-0.03*	-4.75	0.00	-	-	-
B (4, 1)	-0.00	-0.37	0.70	0.89*	11.34	0.00
B (4, 2)	0.00**	2.27	0.02	-1.00*	-838.53	0.00
B (4, 3)	-0.01*	-2.96	0.00	-0.27	-0.24	0.80
B (4, 4)	0.95*	238.67	0.00	0.90*	153.03	0.00

*Notes: significance levels are denoted by *,**,*** as <1,<5,<10 percent*
Source: Authors' calculations

The matrix B captures the interconnection of South Asian markets in relations of past conditional volatility. Specifically, the coefficient B(1,2) is estimated as 0.059, indicating that the volatility of the LBSE is affected by the volatility of the LDSE. This suggests that the volatility of the Indian equity market is reliant on the volatility of the Bangladesh equity market. In contrast, the coefficient B(2,1) is -0.007, and its statistical significance at the 5% level indicates no observed transfer of volatility from the LBSE to the LDSE. This implies the presence of a unidirectional relationship between Bangladesh and India. Moving on, coefficient B(2,4) is 0.013, at 1% significance, indicating that LCSE volatility depends on LBSE volatility. Conversely, the coefficient B(4,2) is 0.009, which is significant at the 5% level, implying that LBSE volatility depends on LKSE volatility. This suggests the presence of a bidirectional relationship between India and Sri Lanka. The coefficient B(3,4), which is -0.03 and significant at the 1% level, indicates that the past conditional volatility in Pakistan's equity market does not spill over to Sri Lanka. Similarly, the coefficient B(4,3) is -0.015, indicating that Pakistan's volatility is independent of Sri Lanka's volatility. Hence, there is no volatility spillover between Pakistan and Sri Lanka. The remaining coefficients, like B(1,3), B(1,4), B(2,3), B(3,1), B(3,2), and B(4,1), are all statistically non-significant. This suggests the absence of persistence in volatility contagion from Bangladesh and India to Pakistan, Sri Lanka, and Bangladesh. Overall, the outcomes indicate a weak association among the sample equity markets, with all significant values being relatively low. These results are consistent with the earlier studies (Arya & Singh, 2022; Kumar & Dhankar, 2009; Sehgal et al., 2018). However, in both the results, the coefficients A (1,1), A (2,2), A (3,3), and A (4,4) have values of 0.43, 0.16, 0.29, and 0.30, individually. These coefficients are relatively high compared to the cross-market transmission of shock, suggesting the prevalence of own shock spillovers. Similarly, the coefficients B (1,1), B (2,2), B (3,3), and B (4,4) are 0.88, 0.96, 0.89, and 0.95, which are significant at the 1% level. This indicates that the spillover of volatility within each market is much higher than the cross-market effect.

Table 8: Estimated Results from DCC and CCC

Variable	CCC coeff	Signif	t-stat	DCC coeff	Signif	t-stat
Mean(LDSE)	0.02	0.02**	2.20	0.02	0.02**	2.17
Mean(LBSE)	0.07	0.00*	4.28	0.07	0.00*	5.40
Mean(LKSE)	0.07	0.00*	3.87	0.07	0.00*	4.84
Mean(LCSE)	0.00	0.99	0.00	-0.00	0.90	-0.11
C (1)	0.01	0.00*	6.12	0.01	0.00*	5.98
C (2)	0.02	0.00*	3.82	0.02	0.00*	3.84
C (3)	0.04	0.00*	4.90	0.04	0.00*	5.02
C (4)	0.00	0.00*	4.67	0.00	0.00*	4.60
A (1)	0.22	0.00*	12.30	0.22	0.00*	12.36
A (2)	0.07	0.00*	8.60	0.07	0.00*	8.82
A (3)	0.10	0.00*	7.84	0.10	0.00*	8.71
A (4)	0.09	0.00*	14.97	0.09	0.00*	14.90
B (1)	0.76	0.00*	49.87	0.76	0.00*	52.16
B (2)	0.90	0.00*	79.02	0.90	0.00*	79.40
B (3)	0.84	0.00*	42.85	0.84	0.00*	45.81
B (4)	0.90	0.00*	160.81	0.90	0.00*	173.30
R(2,1)	0.04	0.00*	2.64	-	-	-
R(3,1)	0.06	0.00*	3.40	-	-	-
R(3,2)	0.12	0.00*	7.27	-	-	-
R(4,1)	0.04	0.04**	2.03	-	-	-
R(4,2)	0.05	0.00*	3.07	-	-	-
R(4,3)	0.08	0.00*	4.41			
(A) DCC	-	-	-	0.02	0.00*	3.16
(B) DCC	-	-	-	0.64	0.00*	4.25

*Notes: significance levels are denoted by *,**,*** as <1,<5,<10 percents*
Source: Authors' calculations

The CCC and DCC models can gauge the level of market integration by estimating conditional correlations. Estimates provided by CCC primarily achieve significance at the 1% level across all markets. For illustration, from Table 8, the highest CCC estimate that can be found between R(3,2) is 0.12. The CCC estimates that the lowest value of R(2,1) is 0.046. All DCC model parameters are significant, indicating ARCH and GARCH effects. The initial parameter captures the influence of previous shocks on the present conditional correlation, while the second parameter represents the impact of past correlations. On the Bangladesh stock market, values for a(1) and b(1) that are statistically significant are 0.22 and 0.76, respectively. The sums of the parameters of these nations are near one, so it can be deduced that the conditional volatility is relatively constant. Therefore, the DCC model is favoured over the CCC model. Moreover, the sum of this is less than one, indicating that the model places relatively less importance on the past conditional correlation when updating the current conditional correlation. This means that recent observations rather than historical data more influence the correlation dynamics. Additionally, the (B) DCC shows with a value= 0.64, the model assigns a relatively higher weight to the lagged squared residuals when updating the conditional correlation. This indicates that the volatility dynamics of the assets significantly impact the current conditional correlation. The combination of (A) DCC and (B) DCC suggests that the DCC-GARCH model places moderate importance on recent conditional correlation and incorporates volatility dynamics' effects in the correlation updates reverting characteristics in the modelled process. These findings provide crucial insights on interdependencies and volatility spillovers under general market conditions, using advanced volatility models such as MGARCH-BEKK, diagonal VECH, DCC and CCC, and thus enrich the theoretical framework of integration of the select markets by revealing the complex interactions and temporal dynamics of volatility spillovers. Thus, this comprehensive analysis advances the literature focusing on the South Asian region, offering new perspectives on stock market behaviour and intermarket relationships in emerging markets.

5. Conclusion

The globalisation process has increased global investment flows and intensified the need for managing the risk in global investments with an understanding of market integration. The risk of investing in a highly integrated market limits diversification benefits, especially during adverse periods, and therefore, assessing the degree of market integration (high/low) is crucial for optimising portfolio diversification benefits. This paper uncovers the degree of integration in terms of volatility spillover among South Asian stock markets and shows how these markets interact with each other under general market conditions, while existing studies predominantly focus on periods of crises or exceptional events. By using MGARCH-BEKK, diagonal VECH models provide an inclusive view of market interdependencies. The results support the presence of volatility spillover among the markets; however, most of the market pairs exhibit weak but significant integration, aligning with earlier research findings (Arya & Singh, 2022; Kumar & Dhankar, 2009; Sehgal et al., 2018).

The outcome of the study also contrasts with some of the earlier studies reporting such things as no significant relationship (Ali et al., 2014) and strong integration (Kumar & Dhankar, 2017). But these earlier studies used either less frequent data or models examining cointegration or ARCH, which may not adequately capture multiple cross-market effects. Furthermore, the study reveals that the impact of idiosyncratic shocks within individual equity markets surpasses the influence of inter-market shocks, suggesting that market-specific volatility is more pronounced than cross-market spillovers in the South Asian context. In conclusion, these findings suggest that considerable diversification can be attained in the South Asian markets since the markets are weakly integrated, where investors can gain benefits from cross-market diversification.

6. Limitations and Future Research

Despite the practical and theoretical contributions of the study, few limitations do exist in the study. The research is confined to the integration of markets of four countries in the South Asian region. Hence, future studies could be extended to other emerging countries or regional blocks to understand the market dynamics beyond South Asia. Further, employing high-frequency data instead of daily data could result in deeper insights into the dynamic interlinkages among stock markets. Additionally, future research could delve into sectoral integration instead of broad market integration, investigating the factors driving integration across different sectors.

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