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DYNAMICS OF PRICE AND VOLATILITY SPILLOVERS AMONG STOCK AND FOREIGN EXCHANGES: EVIDENCE FROM SOUTH ASIAN COUNTRIES

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Our study focused on exploring the volatility spillover between foreign currency and stock markets, as well as the price dynamics of financial instruments traded in South Asian countries. We use daily data from 2001 to 2021 on the closing exchange rates of local currency to the US dollar and closing stock price indices of these countries. To capture the volatility spillover effect, we utilized the GARCH-BEKK model and used Granger Causality test results to test the price dynamics of these markets. Our findings revealed that the own volatility shocks significantly affect current market behavior and volatility effects spill over bi-directionally between foreign exchange rates and stock price indices in these countries. This study provides valuable insights for both domestic and international investors to understand the South Asian stock and foreign exchange markets, enabling them to make more efficient investment decisions based on the best market conditions.

Keywords: GARCH BEKK Model, Volatility Spillover Effect, South Asian Markets
JEL Classification: B22, E44, F31

1. INTRODUCTION

Insights into the sources of volatility and volatility behavior are pivotal to evaluating regulatory proposals pertaining to international capital flows, making asset allocation decisions, implementing hedging strategies, and pricing securities (Ng, 2000). However, the interdependency among the regional countries could cause to increase in the shock spillover intensities and increase the volatility transmission among stocks and foreign exchange markets (Baele, 2005). Nevertheless, the spillover effects are time-varying parallel to the degree of international correlation (Sehgal et al., 2015). Detecting

volatility could allow investors to learn about the impact of other assets or markets on the volatility of one large shock (Hong, 2001). Shared knowledge can affect market participants' anticipation in various ways (Sehgal et al., 2015). Thus, although widespread consensus has confirmed that transmitting information between different assets or markets could result in creating volatility spillovers (Tse, 1999; Ng, 2000; Gagnon and Karolyi, 2006), it is necessary to identify the level of volatility and its repercussions through a detailed study.

The Taliban's recent takeover of Afghanistan caused a disturbance in the global political environment that surprised investors in European and US share markets, according to a BBC News report from 2021. This type of crisis can be compared to the butterfly effect, where even a small cause can lead to significant consequences, as stated by Ghys (2015). Such conditions can create shocks in financial markets that can spill over and impact other markets. Given the economic and political interdependence of India, Pakistan, Sri Lanka, and Bangladesh, which have all experienced challenges in the recent past, this article seeks to contribute to the existing literature by examining how volatility spillovers between stock and foreign exchange markets in these countries unfold.

To determine the extent of volatility spillover and persistence, the authors utilized a Generalized Autoregressive Conditional Heteroscedastic (GARCH) model with the variation of BEKK (Baba et al.,1995; Engle and Kroner, 1995). They analyzed the stock market price index series of each country to assess market volatility and spillovers. This study has two significant contributions to the existing literature. First, it identifies the volatility relationships between each country's exchange rates and stock prices. Second, it explores the dynamic link between stock prices and exchange rates in each South Asian country, providing a more comprehensive understanding of the interdependence among the considered markets.

2. LITERATURE REVIEW

According to Branson and Henderson (1985), there is a connection between fluctuations in currency values and the stock market, which can be explained by the stock-oriented and flow-oriented models. The "flow-oriented" model suggests a positive correlation between stock prices and exchange rates, while the "stock-oriented" model denotes a negative correlation. Empirical studies, such as those conducted by Ajayi and Mougou (1996) and Zhao (2010), support these models and reveal that exchange rates and stock prices are similar to the demand and supply of financial instruments. In particular, the relationship between currency exchange rates and stock prices had a negative correlation under the "stock-oriented" model that can be broken down into a monetary framework and a portfolio-balance framework (Frankel, 1992).

Eun and Shim (1989) found that around 26% of the variance in stock market results is due to developments in other stock markets, while Gavin (1989) suggests that

innovations in stock markets impact an economy's aggregate demand, affecting exchange rates and money demand. In developed markets, price discovery and volatility behavior are well-studied in commodity and equity markets, as evidenced by research conducted by Tse (1999), Harvey and Huang (1991), and Liu and An (2011).

However, there is less attention paid to these topics in the emerging markets of South Asia. Given the increasing significance of foreign exchange rates in promoting investment in the region, it is essential to examine how volatility spillovers occur between exchange rates and the stock markets in South Asian countries.

Bhattarai et al. (2020) found that uncertainty fluctuations in the United States have an adverse impact on emerging market economies, especially on exchange rates and stock markets. Supporting this, Sui and Sun (2016) provide evidence from China, Brazil, and South Africa indicating the influence of the US S&P 500 on different stock markets. Further, significant spillovers have been detected from Japan and the United States to many other Pacific-Basin equity markets (Ng, 2000). However, Bartov and Bodnar (1994) and Jorion (1990) confirmed that the US dollar movements have no significant relationship with the stock returns of US firms.

Erdogan et al. (2020) found that only Turkey showed evidence of a volatility spillover effect from the Islamic stock market to the foreign exchange market, out of the three countries examined (India, Malaysia, and Turkey). However, Chiang and Yang (2003) reported a positive correlation between stock returns and currency prices in nine Asian markets. Despite this, Ramasamy and Yeung (2002) discovered contradictory outcomes when examining the bivariate causation between stock prices and foreign currency exchange rates. Even more so, as per Pan et al. (2007), during the Asian crisis, neither Hong Kong, Korea, nor Singapore exhibited a strong correlation between the prices of stocks and currency rates, with the exception of Singapore. Although there is proof to back such a spillover effect study in the Indian market, we observed scant sources for the South Asian context to reveal the volatility behavior between stock and currency exchange markets.

The family of GARCH models has been used extensively in order to measure the spillover effect. The VARMA-GARCH model (Bollerslev, 1990, 1986) has been used to measure cross-market volatility and return spillovers (Tule et al., 2018). Concurrently, to evaluate the impact of the dynamics of the volatility spillovers in the United States and Japan markets on equity markets of six Pacific–Basin countries, Ng (2000) has used General Asymmetric Dynamic Covariance and BEKK GARCH Models. We observed that the BEKK GARCH model is popular to examine the spillover effects in volatility between different financial instruments [spot, futures, prices, exchange rates] (Caporale et al., 2014; Hung, 2022; Panda and Nanda, 2018; Wong, 2017; Sehgal et al., 2015; Andreoua et al., 2013).

Baele (2005) utilized a regime-switching model to evaluate the time-varying nature and magnitude of volatility spillovers among 13 European equity markets and found statistically and economically significant regime switches between European and US markets. Similarly, Walid et al. (2011) and Chkili and Nguyen (2014) identified a regime-dependent relationship between the foreign exchange and stock market using the

Markov-Switching EGARCH model and Markov-Switching VAR models. Chiang and Yang (2003) examined the domestic and foreign stock marks using the bivariate GARCH model integrating the VAR process and examined the conditional volatility and connection between foreign exchange excess returns. Based on the United States and Chinese Markets, Liu and An (2011) explicated the bidirectional correlation between price and volatility spillovers using the multivariate GARCH model. Yet, we observed that using the GARCH model with different variations is a famous approach to detecting cross-volatility effects (Zhao, 2010; Kroner and Lastrapes, 1993; Kearney and Patton, 2000; Roy and Roy, 2017; Kumar, 2013).

Further, Tse (1999) used the bivariate EGARCH model to analyze the volatility spillovers among markets. In addition, by using the bivariate EGARCH model, Kanas (2000) revealed volatility spillovers from the stock return to exchange rate changes in the United States, United Kingdom, Japan, France, and Canada. Westhuizen et al. (2022), Majumder and Nag (2015), and Yang and Doong (2004) also applied the same model to study the stock prices and exchange rates markets and supported the literature on the volatility behaviours and its spillover effect.

According to Ajayi and Mougouė (1996), there exists a significant short and long-term relationship between exchange rates and stock indices, which was measured using the Error Correction Model (ECM). Nieh and Lee (2001) suggested using the Vector Error Correction Model (VECM) to analyze the connection between currency rates and stock prices among G-7 countries, and they confirmed a long-term equilibrium relationship between the two, as well as short-term intertemporal movements. Sehgal et al. (2015) utilized VECM and Johansen's cointegration test to detect price discovery. Sui and Sun (2016) recommended the use of the ARDL cointegration test to estimate the parameters of the long and short-term relationship between foreign currency exchange rate and local stock return, and VECM to detect long-term relationships among foreign S&P 500. The study also suggested using Vector Autoregression (VAR), Variance Decomposition, and Impulse Response Functions to detect short-term dynamic relationships. Tse (1999) utilized the cointegration model to identify price discovery in the futures market, while Zhao (2010) employed VAR to investigate the dynamic relationship between foreign currency exchange rates and stock prices.

The Granger causality test has been used to detect the dynamic linkages between the same financial instruments considered in this study (Pan et al., 2007). Meanwhile, the spillover effect of US shocks for fifteen evolving markets has been studied using panel VAR (Bhattarai, et al., 2020). Erdoğan et al. (2020) also used the causality-in-variance test to confirm the spillover effects in the volatility behavior of Islamic stocks and currency exchange markets.

Thus, many studies have attempted to detect the interdependency of the different markets expecting to facilitate a rationalized platform for investors to make their investment choices. When streaming literature, we observed a wide range of literature that has attempted to study the spillover effects and price dynamics of the different financial markets in similar capacities We summarized the findings of such studies in Table 1.

Table 1. Summary of Key Literature

No	Author/s	Year	Country/ies and Size of the Sample	Methodology	Variables	Findings
1	Booth et al.	1997	Denmark, Norway, Sweden, and Finland, the period from 2 May 1988 to 30 June 1994.	**E-GARCH**	KFX, OBX, OMX, and FOX indexes	Rare existence of price and volatility spillovers. Volatility spillovers are greater for bad news than good.
2	Liu and Pan	1997	U.S. and Japan, Hong Kong, Singapore, Taiwan, and Thailand,1984 to 1991	**two–stage GARCH**	Stock indices of selected countries	The U.S. market influences Asian returns and volatility more than the Japanese market.
3	Mishra et al.	2007	India, daily data from 4 Jan 1993 to 31 Dec 2003	**different orders of AR-EGARCH and AR-GARCH models**	BSE, BSE National index of 100 scrips, S&P CNX Nifty, S&P CNX 500, Indian rupee per U.S. dollar	Significant bidirectional volatility spillover suggests that these two markets are connected.
4	Nath and Mishra	2008	India and 12 other Asian countries, from July 1997 to April 2008	**GARCH**	The Close-to-Close return, Open to-Close return and Close-to-Open return	India and almost all sample countries have positive, bi-directional intraday return spillover.
5	Singh et al.	2010	15 countries (North American, European, and Asian) from 2000 to 2008	**VAR and AR with exogenous variables, AR-GARCH**	stock market indices of North American, European, and Asian stock markets	indices that open/close immediately before it affects it most. Asian and European stock markets have more regional effects.
6	Xiao and Dhesi	2010	5th January 2004 to 1st October 2009, US and European markets	**MVGARCH) models, namely BEKK and DCC**	CAC, DAX, FTSE100 and S&P500	BEKK model shows European and US stock market volatility spillover. The UK stock market is the leading volatility transmitter in Europe, whereas the US is the main exporter internationally; correlations are conditional and time-varying.

Table 1. Summary of Key Literature (cont')

No	Author/s	Year	Country/ies and Size of the Sample	Methodology	Variables	Findings
7	Abou-Zaid	2011	U.S. and U.K., Egypt, Israel, and Turkey, January 2, 1997, through September 25, 2007	**multivariate GARCH, Trivariate GARCH-M, BEKK**	Stock Indices	Egypt and Israel are influenced by the U.S. stock market, not Turkey.
8	Huang	2011	January 1998 to December 2004, USA and Taiwan	**wavelet-based multi-resolution BEKK-GARCH model**	NASDAQ and TWSI (Taiwan composite stock index)	On the raw data level, NASDAQ returns significantly anticipate TWSI movements, but the prediction strength is inconsistent, and the spillover patterns are distinct. Return and volatility spillovers vary by time scale.
9	Yong et al.	2011	daily data over the study period 1994-2007, Japan and the US as a control	**BEKK-GARCH model**	Japanese stock, the Japanese foreign exchange, and the US stock markets	Eight of ten industrial sectors are affected by Japanese currency market shocks. Five industries showed strong asymmetric effects.
10	Chkili	2012	Hong Kong, Singapore, Malaysia, South Korea, Indonesia, Argentina, Brazil, and Mexico, 12/30/1994-03/13/2009	**BEKK-MGARCH model**	Hong Seng (Hong Kong), straits times (Singapore), KLSE composite (Malaysia), Seoul composite (South Korea), Jakarta composite index (Indonesia), MerVal (Argentina), Bovespa2 (Brazil), and IPC All-Share index (Mexico)	In most emerging nations, foreign exchange market shocks and volatility spillovers are bidirectional.

Table 1. Summary of Key Literature (cont')

No	Author/s	Year	Country/ies and Size of the Sample	Methodology	Variables	Findings
11	Li and Giles	2013	U.S., Japan, China, India, Indonesia, Malaysia, the Philippines, and Thailand, 1993-2012	**asymmetric multivariate GARCH model**	CHSCOMP, IBOMSEN, JAKCOMP, FBMKLCI, PSECOMP, BNGKS50, S&PCOMP, TOKYOSE	During the Asian financial crisis, volatility spillovers are stronger and bidirectional.
12	Kumar	2013	India, Brazil, South Africa, 1 January 2000 to 17 January 2011	**multivariate GARCH with time-varying variance-covariance BEKK model**	India (S&P CNX Nifty), Brazil (Bovespa), and South Africa (FTSE/JSE Top 40 Index) to USD exchange rate	Bidirectional volatility spillover in IBSA markets supports integration.
13	Majdoub and Mansour	2014	US market and five Islamic emerging markets, Turkey, Indonesia, Pakistan, Qatar, and Malaysia, 2008-2013	**multivariate GARCH BEKK, CCC, and DCC**	MSCI Islamic Index USA, Pakistan, Indonesia, Turkey, Qatar, Malaysia	No evidence shows the US market leaks into Islamic emergent equities markets.
14	Baruník et al.	2015	US sectoral Stocks, 7 sectors, August 2004 to December 2011	**VAR**	Global Industry Classification Standard's 21 most liquid U.S. stocks	Disaggregate stock asymmetry. Bad and good volatility spillovers alter over time and in different sectors.
15	Taly	2015	Korea, US, and Japan, January 2002-February 2010.	**trivariate VAR BEKK GARCH (1,1) model**	Weekly stock returns (KOSPI, S&P 500, NIKKEI 225), Korean CDS spread change, and Korean-US and Korean-Japanese exchange rates	Return and volatility spillover from Korean CDS and stock markets. Return and volatility spillover from foreign currency and the US stock market is also significant.
16	Salisu and Oloko	2015	May 1999 to December 2013, Nigeria	**VARMA-AMGARCH model**	Dutch Auction System (WDAS) for FX and All Share Index (ASI) for stocks	Bad market news accentuates stock market volatility, while good FX news moderates it.

Table 1. Summary of Key Literature (cont')

No	Author/s	Year	Country/ies and Size of the Sample	Methodology	Variables	Findings
17	Akkas and Sayilgan	2016	2 January 2002 and 31 December 2015, Turkey	**bivariate VAR-GARCH-BEKK model**	Turkish stock market and the foreign exchange market	unidirectional volatility spillovers from currency to stock markets
18	Shahzad et al.	2017	July 15, 1996, to June 30, 2016: Global Islamic stock market, US, UK, and Japan stock markets	**VAR-based spillover index approach based on the generalized VAR**	DJIM, DJ US, DJ UK, DJ Japan, VIX. Index, 10-yr Treas., WTI oil	Strong interconnections between Islamic and conventional stock markets and considerable return and volatility risk variables.
19	Njegić et al.	2017	From 3 January 2001 to 31 July 2016, seven major emerging markets	**BEKK-GARCH, asymmetric BEKK-GARCH, asymmetric BEKK-GARCH with the structural break, VAR-based volatility spillover**	PX (Czech Republic), WIG (Poland), BUX (Hungary), RTS (Russia), XU100 (Turkey), SENSEX (India), and KOSPI (South Korea).	In developing markets, shock and volatility spillover is mostly from the exchange rate market to the stock market, although the VAR-based model is less obvious.
20	Mikhaylov	2018	Russia and Brazil, 2009-2016	**FIGARCH model of the long memory**	Stock, FX markets	The FIGARCH model can predict exchange rate-to-stock market volatility if structural breaks are included.
21	Jebran	2018	2nd January, 2002 to 31st December, 2013, China	**EGARCH**	Shanghai Stock Exchange Index, exchange rate USD	Post-crisis bidirectional stock and FX volatility spillover
22	Hung	2018	28 July 2000 to 31 July 2018, Chinese, Vietnamese, Singapore, Thailand and Malaysian	**bivariate GARCHBEKK model**	Chinese, Vietnamese, Singaporean, Thai, and Malaysian index closing prices	Chinese market volatility has affected other sample markets. During and after the Global Financial Crisis, China's stock returns were linked to other markets.

Table 1. Summary of Key Literature (cont')

No	Author/s	Year	Country/ies and Size of the Sample	Methodology	Variables	Findings
23	Alkan and Çiçek	2019	January 02, 2006, and December 28, 2018, Turkey	**bivariate diagonal BEKK-GARCH model**	Euro and USD exchange rate to Local currency, BIST100, BIST30, and Selected sectoral Indices	Strong global to the local stock and bond market, stock and exchange to the bond market, and dollar return to stock market spillover. Volatility spilled over between market pairs.
24	Su	2019	From January 2011 to November 2019, Chinese and American	**VAR, BEKK-GARCH and DCC-GARCH model**	Chinese and American stocks and RMB forex	The US has a strong horizontal spillover effect on the Chinese stock market, and its volatility spillover is significant and two-way. The Chinese stock market's volatility affects the RMB foreign exchange market.
25	Erdogan et al.	2020	2013-2019 daily data for India, Malaysia, and Turkey	**MGARCH, Hafner, and Herwartz (2006) procedure**	Dow Jones Islamic market indexes, local currencies vs USD exchange rates	Turkey is the only country where Islamic stock market volatility affects FX.
26	Ahmed and Huo	2020	emerging eleven African countries, 3 January 2007 to 30 December 2016	**VAR-BEKK-GARCH**	oil prices, foreign exchange rates, and stock markets	Local oil-market spillover. Bidirectional oil shock and volatility spillovers are recorded. Some African countries have oil-stock market shock and volatility spillovers.
27	Belhassine and Karamti	2021	From July 12, 2001, through January 31, 2017, major oil-importing and exporting countries	**MGARCH, maximum overlap discrete wavelet transform (MODWT)**	Daily oil prices and stock indexes	Price spillovers and VS exist but depend on stock markets and timescale.
28	Mensi et al.	2021	Australia, Canada, France, Germany, Japan, UK, and the US, Jan. 3, 2000-Feb. 28, 2018	**Multivariate DCC-GARCH model, maximal overlap discrete wavelet transform (MODWT)**	Stock and futures markets (oil and gold)	Total volatility spillovers are more enormous in the short term than in the intermediate and long term, and a diversified portfolio (commodity and stock markets) gives developing and established countries better hedging effectiveness.

Table 1. Summary of Key Literature (cont')

No	Author/s	Year	Country/ies and Size of the Sample	Methodology	Variables	Findings
29	Zhong and Liu	2021	Chinese and five Southeast Asian stock markets, January 1994 through August 2019	**multivariate GARCH models, including BEKK and DCC-GARCH**	FTSE Straits Times Index, Thailand SET Index, Jakarta Composite Index, FTSE Bursa Malaysia Composite Index, and Manila Composite Index (PSPI)	The dynamic conditional correlation between China and five Southeast Asian stock markets peaked during the Asian financial crisis, the U.S. subprime crisis, and the 2015 stock market decline. Using DCC conditional volatilities, estimate dynamic hedge ratios.
30	Jebabli et al.	2021	January 2000-February 2021, Global	**VAR, spillover asymmetry measure (SAM), mean absolute deviation(MAD), multivariate DCC-GARCH**	Brent crude oil and NYMEX natural gas are benchmarks for MSCI world, Emerging, and Europe stock markets.	All stock markets transmitted the 2008 financial crisis instability to energy markets. Their patterns changed throughout Covid-19.
31	Shahzad et al.	2021	January 2, 2019, to September 30, 2020, China	**generalized forecast error variance decomposition (FEVD) to the VMA (∞), VAR, Spillover asymmetry measure (SAM)**	Ten sectors of CSI 300 indexes	Bad volatility spillover shocks overwhelm good volatility spillover shocks under COVID-19's time-varying and severe asymmetry.
32	Belhassine and Karamti	2021	Saudi Arabia, Russia, and Canada exported oil to the U.S., China, and India from July 12, 2001, to January 31, 2017.	**Maximum overlap discrete wavelet transform (MODWT), Wavelet-based VAR–BEKK–AGARCH model with structural breaks**	Daily oil prices and six main oil-importing and oil-exporting countries' stock market indexes	Volatility spillover results are country-specific for oil exporters and importers. India and China offer the most profitable oil hedging options.

Table 1. Summary of Key Literature (cont')

No	Author/s	Year	Country/ies and Size of the Sample	Methodology	Variables	Findings
33	Dehbashi et al.	2022	pre-JCPOA, i.e. 25 March 2009 to 13 July 2015, and post-JCPOA, i.e. 15 July 2015 to 18 July 2018, Iran	**VAR-BEKK-GARCH approach**	Iran's Rials-per-US-dollar, exchange rate, global gold price, and Tehran Stock Exchange Index	One-way volatility spillover from gold to foreign exchange markets pre-JCPOA, two-way spillover between foreign exchange and gold markets post-JCPOA,
34	Ratnawati and Anggraeni	2022	ten Asian developing countries, January 1, 2009, until December 31, 2016	**Trivariate GARCH Model and the Cholesky Decomposition**	the stock market, foreign exchange, and bond market	Volatility spillovers were prevalent in the aforementioned nations' financial markets, notably their stock, foreign currency, and bond markets, showing that the trends of those sectors in each country influence the trends of the same areas in other countries.
35	Zeng et al.	2022	daily data from 2005 to 2020, China	**CoVaR approach, Vine-Copula-CoVaR, VAR-BEKK-GARCH (1,1), and Wald test**	Shanghai Composite Index (SHCI), USD/CNY daily reference rate, West Texas Intermediate (WTI) oil futures	Greater complex USD/CNY dependence on stock markets and WTI crude oil prices; more WTI spillover to Chinese stock market volatility.
36	Hung	2022	Hungary, Poland, Czech Republic, Romania, and Croatia between 1 April 2000 and 29 September 2017	**GARCH-BEKK, CCC, and DCC**	Budapest Stock Exchange BUX, Warsaw Stock Exchange WIG, PragueStock Exchange PX, Bucharest Stock Exchange BET, and Zagreb Stock Exchange ZSE, exchange rate series in US dollars per local currency	Poland's stock market volatility spilled over into the foreign exchange market during the subprime crisis; Hungary and Romania experienced the opposite during the post- and pre-crisis periods.
37	Wu and Chen	2022	From September 10, 2013, to March 7, 2019, China, India, and Russia	**BEKK-GARCH model and wavelet analysis**	CSI 500, SENSEX, RTS	Chinese, Indian, and Russian stock markets display aggregation and spillover effects. Short-, medium-, and long-term spillover effects between China-India, China-Russia, and India-Russia stock markets are essential.

3. METHODOLOGY

3.1. Data and Sample

The preliminary purpose of this study is to analyze how the volatility spills over among foreign exchange and stock markets and the dynamics of prices of the financial instruments considered in the current study with special reference to South Asia. The study utilized series data with daily intervals for stock indices over the sample period from 1st January 2001, the first date of the 21st century, to 31st December 2021[1], the closest whole year.

The research sample encompasses four stock markets in the South Asian region: Dhaka (DSE), Bombay (BSE), Karachi (KSE), and Colombo (CSE) Stock Exchanges, respectively, for Bangladesh, India, Pakistan, and Sri Lanka. Since such stocks are considered more prone to market information, we have used the market indices of each country that represent financially sound and highly liquid stocks in each market. Accordingly, we selected Dhaka Stock Exchange 30 (DS30) for Dhaka Stock Exchange, S&P BSE SENSEX 30 Index for the Bombay Stock Market, the KSE100 Index for Karachi Stock Exchange, and S&P Sri Lanka 20 for Colombo Stock Exchange.

The South Asian Region has a high demand for US Dollars (USD) to maintain its economic activities. For this reason, we placed the emphasis on the local currency to the USD exchange rate for each country when collecting data for exchange rates for the aforesaid sample period. Accordingly, Bangladeshi Taka per the United States Dollar (USD_BDT), Indian Rupees per the United States Dollar (USD_INR), Pakistani Rupees per the United States Dollar (USD_PKR), and Sri Lankan Rupees per the (USD_LKR) have been considered as the exchange rates. Further, we used the day-closing prices of both the foreign currency exchange and stock markets in the countries to avoid timing conflict and capture volatility transmission.

3.2. Statistical Model

The paper will center on two salient segments: the volatility spillover effect among the foreign currency exchange rates and stock price indices and the dynamic linkages between the variables.

In order to measure the spillover effect among the two variables (foreign currency exchange rates and stock price indices), we used BEKK GARCH, which was recommended as a benchmark for the time-varying condition (Hung, 2022).

The mean equation of the mode is as follows.

[1] The sample periods for the study are determined by the availability of data for each country. Specifically, the data spans from 2001 to 2021 for India and Pakistan, from 2013 to 2021 for Bangladesh, and from 2004 to 2021 for Sri Lanka.

$$r_t = \mu + \varepsilon_t. \tag{1}$$

In this equation, r_t represents the defined returns, while μ denotes the mean of returns. We assume that the conditional distribution of the filtered returns, the residual (ε_t), follows a normal distribution.

$$\varepsilon_t | \, \Omega_{t-1} \sim N(O, H_t), \tag{2}$$

where Ω_{t-1} is the adaptive information set at t-1.

The BEKK model is derived with a multivariate GARCH (1,1) specification. The conditional covariance matrices H_t can be expressed as;

$$H_t = C'C + A'\varepsilon_{t-1}\varepsilon'_{t-1}A + B'H_tB. \tag{3}$$

Accordingly, the bi-variate BEKK GARCH (1,1) system will be:

$$\begin{bmatrix} H_{11,t} & H_{12,t} \\ H_{21,t} & H_{22,t} \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{bmatrix}' \begin{bmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}' \begin{bmatrix} \varepsilon^2_{1,t-1} & \varepsilon_{1,t-1}, \varepsilon_{2,t-1} \\ \varepsilon_{2,t-1}, \varepsilon_{1,t-1} & \varepsilon^2_{2,t-1} \end{bmatrix} \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} + \begin{bmatrix} \beta_{11,t} & \beta_{12,t} \\ \beta_{21,t} & \beta_{22,t} \end{bmatrix}' \begin{bmatrix} h_{11,t-1} & h_{12,t-1} \\ h_{21,t-1} & h_{22,t-1} \end{bmatrix} \begin{bmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{bmatrix}.$$

In this system, $H_{11,t}$ represents the stock index variance, $H_{12,t}$ and $H_{21,t}$ denote the covariance between the stock index and the exchange rate, and $H_{22,t}$ indicates the exchange rate variance. The parameters α and β represent the effects of information on news and volatility spillover, respectively. The significance of the volatility spillover effect between the markets is determined by examining whether a_{12} and β_{12} are significantly different from zero.

The conditional correlation of the variables is measured as follows:

$$\rho_{ij,t} = \frac{h_{ij,t}}{\sqrt{h_{ii,t}, h_{jj,t}}}. \tag{4}$$

To estimate the parameters of the BEKK GARCH model, we employed the Quasi Maximum Likelihood (QML) method, assuming that the residuals are randomly distributed. The log-likelihood function is given by:

$$L(\theta) = \frac{T_n}{2} + \ln(2\pi) - \frac{1}{2}\sum_{t=1}^{T}(\ln | \, H_t \, | + \, \epsilon' {H_t}^{-1} \, \varepsilon_t). \tag{5}$$

In this function, θ denotes the estimated parameters, n represents the number of markets, and T is the number of observations.

4. ANALYSIS

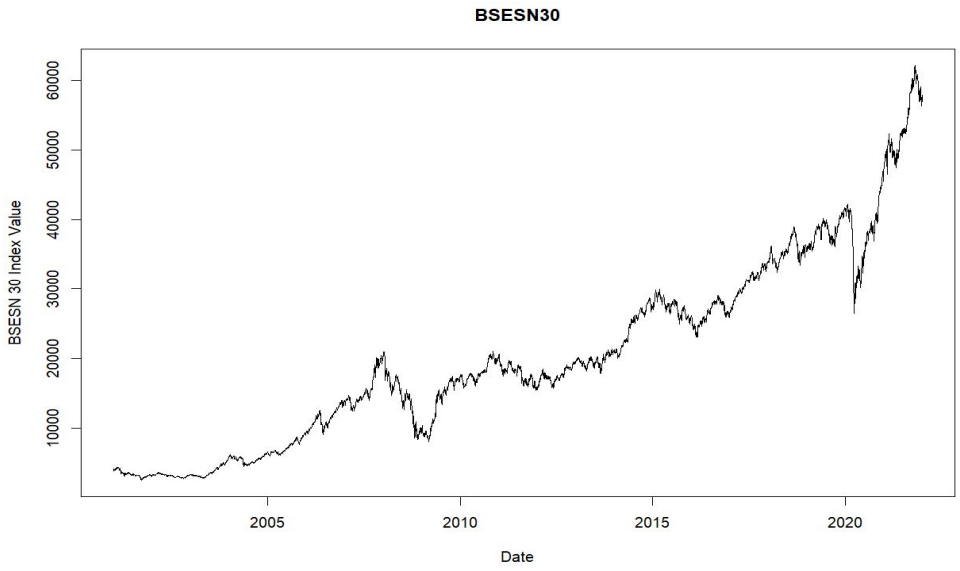
We derived the time-based charts for each share price index and foreign exchange rate time series to understand its behavior throughout the period. Figures 1 to 8 illustrate the plotted diagrams.

Although structural breaks are observed in the price indices of all four countries, only Bangladesh exhibits a downward trend in its DSE 30 price index, while the other three countries demonstrate an upward trend. The upward trend in the price indices indicates a higher volume of transactions in the markets and a growing interest from domestic and international investors. However, when examining the foreign exchange rates, all four countries demonstrate an upward trend. This implies that the local currencies of these countries have consistently depreciated against the US dollar over time.

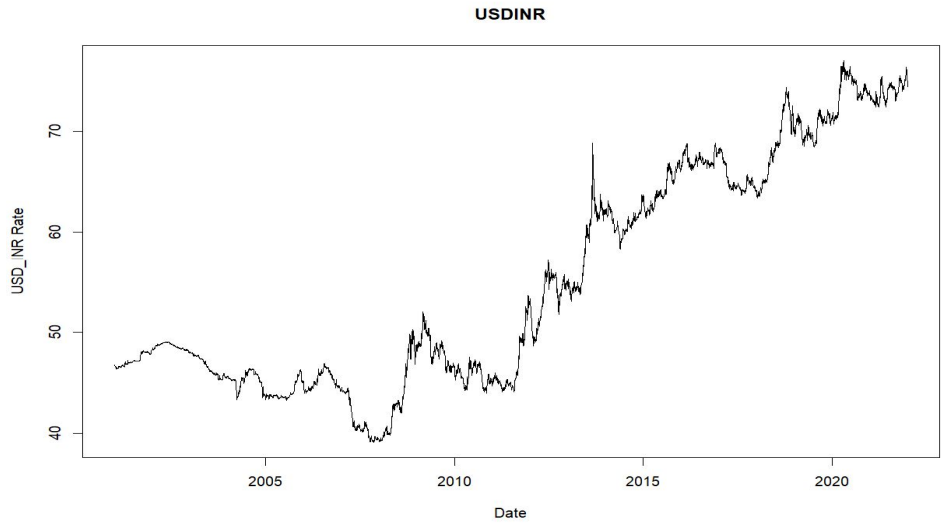
Table 2. Dispersion of Data

	Bangladesh		**India**	
	DSE30	USD_BDT	BSESN30	USD_INR
Skewness	0.0883	0.4632	0.3565	0.5273
Kurtosis	2.6312	1.4839	2.1769	1.7680
Jarque-Bera	9.567	180.600	234.411	519.849
Probability	0.0084	0.0000	0.0000	0.0000
	Pakistan		**Sri Lanka**	
	KSE100	USD_PKR	S&P20_SL	USD_LKR
Skewness	0.9683	0.1228	-0.4061	0.7572
Kurtosis	2.7360	1.4046	1.7565	2.3956
Jarque-Bera	685.408	467.523	374.006	450.752
Probability	0.0000	0.0000	0.0000	0.0000

Table 2 displays that Bangladesh's price indices have symmetrical distributions, while India's and Pakistan's price indices have right-skewed distributions. In contrast, the S&P20 Sri Lanka price index exhibits a left-skewed distribution. The positive kurtosis values of all four countries indicate platykurtic distributions with fewer extreme positive or negative values and thinner tails. This type of distribution implies a lower risk for investors, making these markets more attractive to risk-averse investors. The positive skewness of India and Pakistan suggests that outliers in the markets act as a motivator for investors, while the negative skewness in Sri Lanka serves as a demotivator. The foreign exchange markets of all four countries also have platykurtic distributions with skewed values, indicating fewer extreme events for currency depreciation against the US dollar.

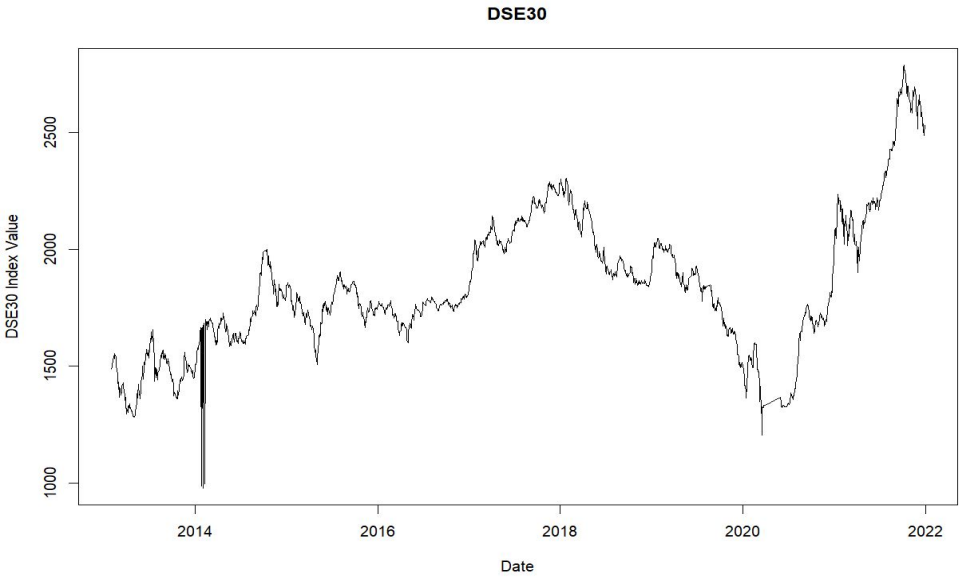


a) BSESN30

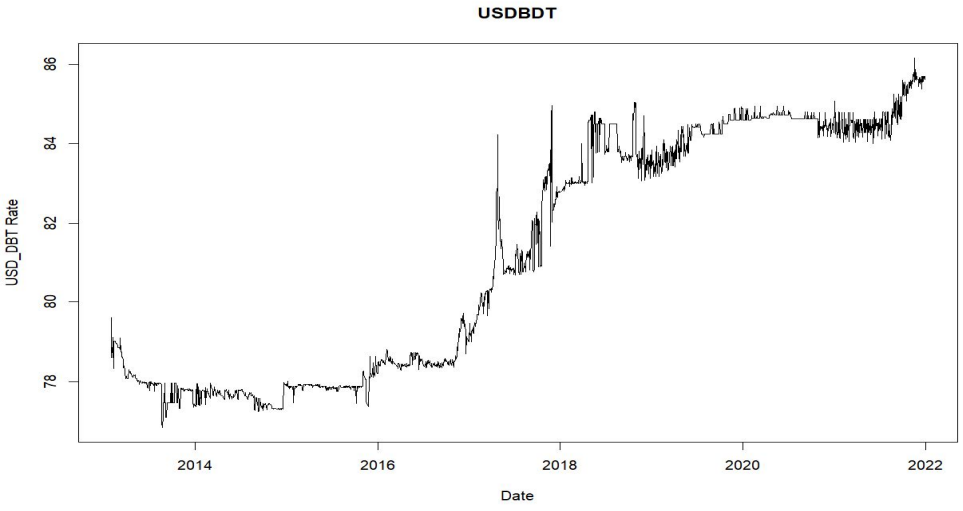


b) USD

Figure 1. Time series plots of Stock Indices and Exchange Rates of the Selected Countries

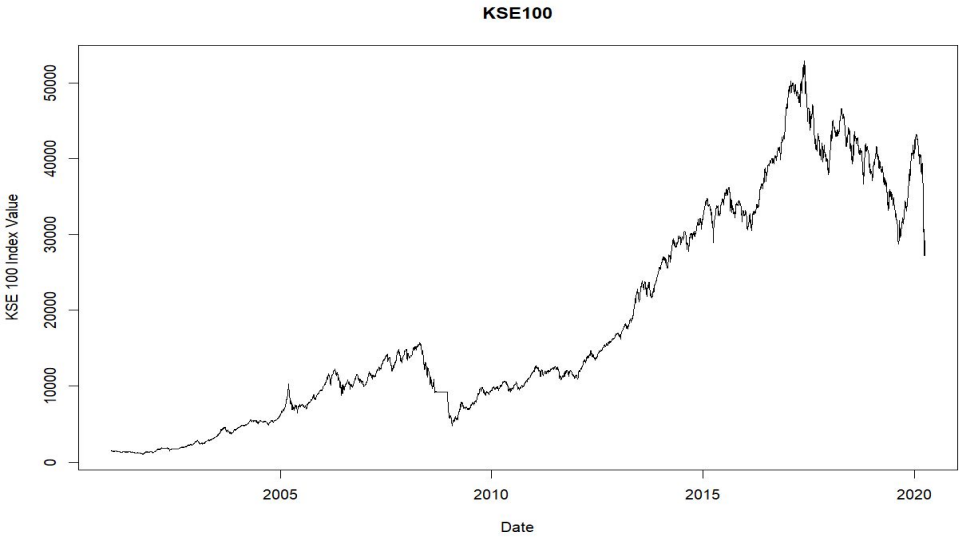


c) DSE30

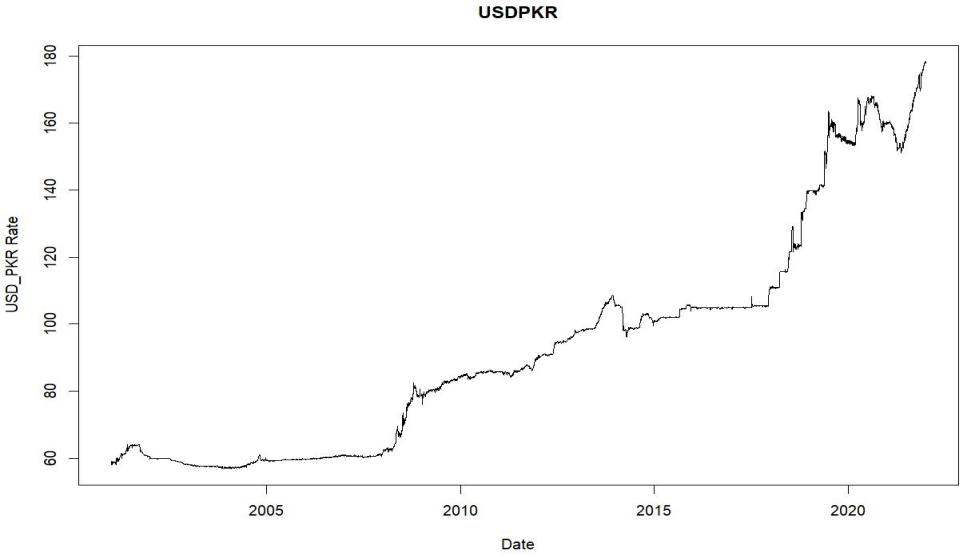


d) USD_BDT

Figure 1. Time series plots of Stock Indices and Exchange Rates of the Selected Countries (cont')

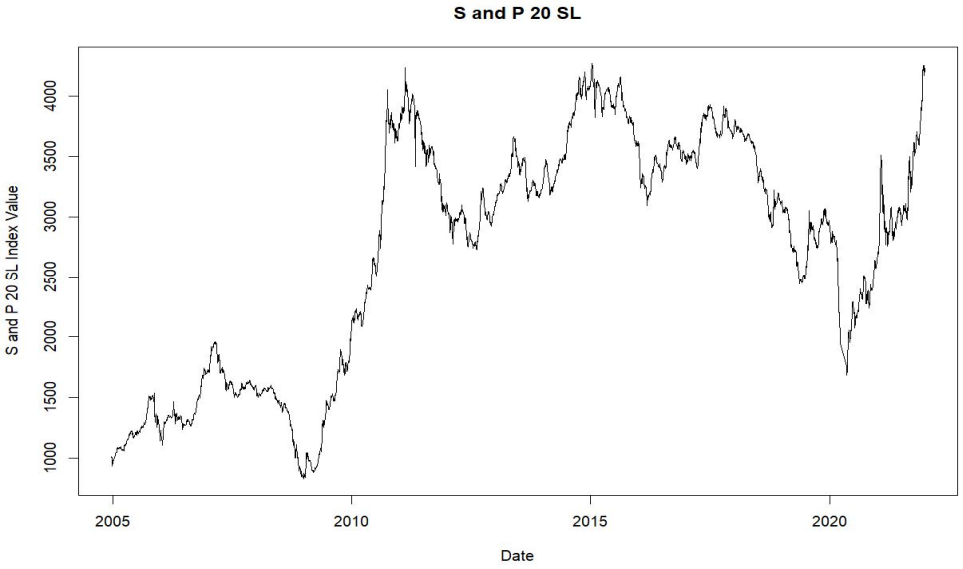


e) KSE100

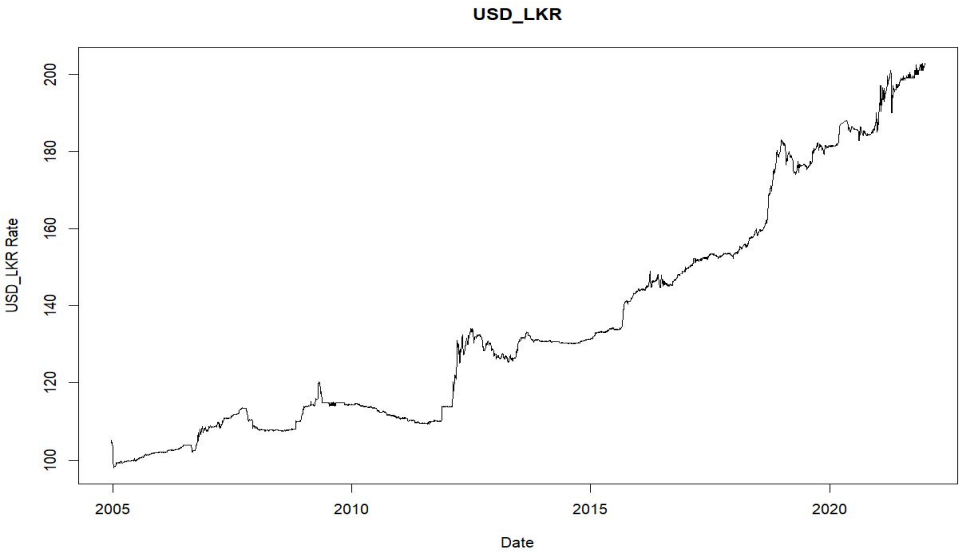


f) USD_PKR

Figure 1. Time series plots of Stock Indices and Exchange Rates of the Selected Countries (cont')



g) S&P20_SL



h) USD_LKR

Figure 1. Time series plots of Stock Indices and Exchange Rates of the Selected Countries (cont')

Table 3. Dickey-Fuller Test

	Bangladesh		**India**	
	DSE30	USD_BDT	BSESN30	USD_INR
I(0)	-1.6345	-0.4336	-0.0449	0.1800
t-Statistic	0.4646	0.9009	0.9533	0.9714
p-value				
I(1)	-33.109	-38.9072	-70.8057	-28.4723
	Pakistan		**Sri Lanka**	
	KSE100	USD_PKR	S&P20_SL	USD_LKR
I(0)	0.5751	1.4213	-1.2012	1.8924
t-Statistic	0.9891	0.9991	0.6762	0.9998
p-value				
I(1)	-55.7309	-69.0098	-55.6174	-37.7222

Table 4. Results of the BEKK GARCH Model

	Bangladesh	**India**	**Pakistan**	**Sri Lanka**
μ_1	7.473***	10.184***	1.032e+01***	8.077***
μ_2	4.371***	4.143***	4.625***	4.886***
C_{11}	0.025	0.155***	1.97e-01	8.61e-02
C_{21}	0.003	0.043***	3.86e-02	2.219e-02***
C_{22}	0.006	0.027***	2.87e-02	3.44e-02
α_{11}	1.000***	0.953***	9.614e-01***	9.665e-01***
α_{12}	-0.018*	0.003*	7.633e-03*	4.946e-04*
α_{21}	0.000*	-0.001*	-4.490e-04*	-6.617e-05*
α_{22}	0.992***	0.957***	9.657e-01***	9.672e-01***
β_{11}	0.056***	0.004**	1.000e-06*	1.000e-06*
β_{12}	0.006*	-0.006*	1.345e-08*	2.689e-06*
β_{21}	0.001*	0.001*	1.153e-09*	8.747e-08*
β_{22}	0.074**	1.000e-06**	1.000e-06***	2.700e-06**

Note: P-values are in parentheses, ***, **, and *. The estimated coefficients are referred to as ***, **, and * are significant at 1%, 5%, and 10%, respectively.

The p-value of the Jarque-Bera statistic of all four countries [<0.05] further confirms that the data doesn't follow a normal distribution. We directed that data analysis identify the data distributions' stationarity.

The time series data for share markets and foreign exchange markets of the four South Asian countries have a unit root at its level I(0); that is non-stationary (Table 3). However, for improved predictability, it is necessary to have stationary time series data. By taking the first difference of all data series, we have determined that they are

stationary. This implies that within the first difference data, there will be a pattern of large value trends followed by small values and vice versa. Therefore, we have chosen to use the log-likelihood function to derive the BEKK GARCH model.

Table 4 presents the estimated parameters of the bivariate BEKK-GARCH. The coefficients of α_{11}, α_{22}, and β_{11}, β_{22} are significant in ARAMA (1,1) and GARCH (1,1) models for all 04 countries considered in the study. Thus, the model can be considered to be the most appropriate one for detecting volatility spillovers between the two markets.

The coefficient of α_{11} and α_{22} of all 04 counties confirmed the presence of the own-volatility shocks among the price indices of stock exchanges and foreign exchange rates in all countries. Accordingly, we can ensure that South Asia's foreign currency exchange markets and stock markets are much more sensitive to their trends and own positive and negative information flows. Indicating a strong GARCH (1,1) process for all countries, the statistically significant parameters of β_{11} and β_{22} lead to conditional variance of all four pair-vice indices. Thereby, it can be inferred that past shocks and volatilities of the respective time series will significantly affect the conditional variance of indices in all South Asian countries considered in the study.

We observed the off-diagonal parameters of matrices α and β to capture the cross-market shocks and volatility spillovers among the foreign currency exchange and stock market indices in all South Asian countries. Further, we observed a bi-directional correlation between stock market indices and foreign currency exchange markets since all pairs of α_{12} and α_{21} parameters are statistically significant, thus indicating a strong linkage between stock exchange price indices and USD to the local current foreign exchange rate. Finally, the model detects statistically significant bi-directional volatility linkage among stock exchange price indices and foreign exchange markets [β_{12} and β_{21}] for all South Asian Markets.

Table 5. Pairwise Granger Causality Test Results

Null Hypothesis	F-Statistic	Prob.	Decision
Bangladesh			
USD_BDT does not Granger Cause DSE30	0.566	0.568	No Causality
DSE30 does not Granger Cause USD_BDT	2.986	0.051	No Causality
India			
USD_INR does not Granger Cause BSESN30	253.462	0.002	Causality
BSESN30 does not Granger Cause USD_INR	3.445	0.032	Causality
Pakistan			
USD_PKR does not Granger Cause KSE100	2.439	0.087	No Causality
KSE100 does not Granger Cause USD_PKR	2.313	0.099	No Causality
Sri Lanka			
USD_LKR does not Granger Cause S&P20SL	2.636	0.072	No Causality
S&P20SL does not Granger Cause USD_LKR	2.226	0.108	No Causality

Accordingly, this study provides convincing evidence of the integration of stock market price indices and exchange rates of local currency and USD in all South Asian countries considered in the study. However, we can conclude that the degree of integration is considerably weak since the estimated coefficients are relatively low.

According to the results of the pairwise causality test presented in Table 5, only the share price index in India (BSESN30) and the USD to Indian Rupee exchange rate have a causality relationship. However, the share price indices of the other three countries and the foreign exchange rate do not exhibit any causality relationship between each other.

5. CONCLUSION

By exploring the link between stock prices and currency exchange rates in a subset of South Asian economies, this research adds to the current literature. We examine the dynamic relations of foreign exchange and stock markets in four South Asian nations (Bangladesh, India, Pakistan, and Sri Lanka) by examining the volatility spillovers and dynamics of the price using the bivariate GARCH-BEKK (1,1) model and granger causality test respectively. This study stands out from previous literature as it utilizes the GARCH-BEKK model to investigate spillover returns and volatility among various financial markets, whereas most prior studies have focused on the multivariate GARCH model. As a result, we believe that utilizing robust econometric methods to reevaluate the returns and volatility spillovers between the two variables is a robust approach to addressing the underlying issues in the South Asian investment markets.

Based on the results, it can be concluded that adverse shocks in Bangladesh's financial markets are more significant in determining their performance. In contrast, positive shocks in the Indian financial markets are found to be more dominating. However, the behavior of financial markets in Pakistan and Sri Lanka are almost similar. The markets in both countries reveal that the increase in the asset return covariance today will have a strong spillover effect in increasing the asset return covariance tomorrow.

The model revealed that the volatility spills over bidirectionally between the markets of all South Asian countries considered in the study. Further, the model detected its own shocks and volatility in the data series of both the markets considered in the study. Accordingly, the stock market indices and the foreign currency exchange rates are significantly sensitive to their own fluctuations and cross-volatilities. Therefore, the market transmission and deviations in international market conditions could influence each other in determining the performance of the stock market indices and the foreign currency exchange rates in South Asian Countries. The findings of this study is complying with the results of the study conducted for the Indian market (Mishra et al., 2007), Brazilian market (Morales, 2008), and South African market (Anoruo and Braha,

2009). Regarding returns and volatility, Diebold and Yilmaz (2009) reveal the two-way spillovers between the stock and foreign exchange markets. Both the “heat wave” and the “meteor wave” hypotheses offered by Engle et al. (1990) are supported by this research.

Studying returns and volatility spillover is important for market players and policymakers alike. Understanding the sources and transmission processes of spillover can lead to better prices, optimal investments, and choices. The presence of spillover and volatility effects implies market inefficiencies in stock prices and currency rates, which strengthens the case for technical analysis. Historical correlations between currency exchange rates and stock market indices can be used to predict the future behavior of both variables by traders. Multinational corporations seeking to forecast the value of their currency could also benefit from using the stock market as a tool. Additionally, portfolio managers may find the spillover effect on the stock and currency exchange markets to be an intriguing consequence. With this information, a well-performing fund could potentially be developed.

Given that the market structure may affect the growth of the financial markets, the findings of this study can also help the regulators and policymakers in South Asian nations build their investment and foreign trading policies. As the stock market rises (falls), international investors pour money into the economy by selling domestic currency in exchange for foreign currency. This means that a rise (fall) in stock prices will lead to a higher (lower) exchange rate. Moreover, a rise (or fall) in the stock market leads to a rise (or fall) in the wealth of domestic investors, which, in turn, increases (or decreases) the demand for the local currency and drives up (or down) the local interest rates. If interest rates are raised (lowered), more money will flow into (out of) the country, which will then cause the currency's value to rise (fall). Accordingly, the rising (falling) stock market may impact monetary and fiscal policies that aim to control interest and exchange rates. Thus, regulators and policymakers can consider the detected behavior patterns when designing and implementing capital market and currency rate regulations, which boosts the efficiency with which monetary policy achieves its goal. The effects of stock market shocks must be factored into any policy that affects the foreign exchange markets. Future research can also explore the long-term relationship between currency rates and stock indices, including other variables such as US market data and interest rates. Additionally, the study of global shocks in developed markets and their spillover effects on the South Asian financial market is a promising area for further investigation. Finally, analyzing spillovers in returns and variations across different sub-samples with timely structural breaks for each economy can increase the study's robustness.

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