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Article

Exploring Stock Market Interdependencies: Cross-Spillover Effects between Sri Lanka and Asian Markets

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ABSTRACT

Sri Lanka holds a pivotal position in the Indian Ocean, fostering significant economic ties with South Asia, the Middle East, and Africa. This study examines the financial linkages and stock market behavior between Sri Lanka and key Asian economies (India, China, Pakistan, and Japan) from 2015 to 2021. Using daily stock prices from Bloomberg.com, the analysis employs the EGARCH (1,1) model to assess return and volatility spillovers. Results reveal negative return spillovers from India to Sri Lanka and cross-volatility spillovers from India, China, Pakistan, and Japan to Sri Lanka. Conversely, Sri Lanka exhibits negative return spillovers to India and Pakistan and cross-volatility spillovers to China and Japan. Sub-analysis identifies structural breaks in December 2019, indicating shifts in spillover dynamics pre- and post-Covid-19. These findings offer insights for investors, policymakers, fund managers, and governments to optimize investment strategies, formulate stable policies, and enhance portfolio diversification.

Background

Understanding the stock returns and volatility cross-spillover effect among countries is crucial in financial and economic studies. This phenomenon occurs when events in one country impact another country's economy, creating a ripple effect. Engle et al. (1990) describe how the equity market of one country can influence the behavior of another's market. While international financial markets are interconnected, there is no universal definition for their linkages (Perera & Wickramanayaka, 2012; Wang et al., 2005). The spillover effect is categorized into 'own' and 'cross' volatility spillover, each analyzed through hypotheses such as the meteor shower and heatwave hypotheses (Engle et al., 1990). This effect may manifest bidirectionally, unidirectionally, or not at all among equity markets (Hung, 2019). Various factors contribute to stock returns and volatility cross-spillover, including herding effects, trade linkages, financial ties, and asymmetry of information (Withanage & Jayasinghe, 2017; Banerjee & Guhathakurta, 2020). Regional and world shocks also play a significant role (Ng, 2000). Emerging economies like those in Asia have increasingly become focal points due to their growing importance and vulnerability to spillovers (Yarovaya et al., 2016).

The economies of China, India, Japan, and Pakistan hold significant sway in the global and Asian regions, ranking among the top in terms of Gross Domestic Product (GDP). Recent years have seen notable Foreign Direct Investment (FDI) flows from China and India into the Colombo Stock Exchange (CSE), underscoring the interconnectedness of these economies. Bilateral agreements between Sri Lanka and these nations also play a crucial role in trade dynamics and the country's Balance of Payments (BOP), influencing the performance of the CSE. However, the COVID-19 pandemic has disrupted global equity markets, including those of the aforementioned countries, impacting economic stability and potentially exacerbating poverty in developing nations. Recognizing the significance of these factors, it becomes imperative to analyze bidirectional stock returns and volatility spillover effects between these nations and the CSE. Understanding such dynamics aids investors in managing their portfolios and financial objectives, while also assisting policymakers in mitigating investment risks. To conduct this analysis, we employ the EGARCH (1,1) model, a method utilized by a few scholars in Sri Lanka and internationally, particularly in assessing stock returns and volatility spillovers. Furthermore, we investigate structural breaks, particularly focusing on the December 2019 period, coinciding with the onset of the COVID-19 pandemic. This examination provides valuable insights into the resilience and vulnerability of the CSE amidst global economic shocks. Despite this, research on the topic, particularly in Sri Lanka, remains limited (Gulzar et al., 2019; Lingaraja et al., 2020). Utilizing econometric models like EGARCH can provide insights into stock market behavior, yet their application in Sri Lanka is scarce (Thangamuthu et al., 2022). This study fills this gap by examining stock returns and volatility spillover effects between Sri Lanka and other Asian countries using the EGARCH model.

Selected countries including India, China, Pakistan, and Japan were chosen due to their significant economic ties with Sri Lanka (Central Bank of Sri Lanka, 2021). Additionally, the study investigates structural breaks, especially related to the COVID-19 pandemic, which had substantial impacts on global equity markets (Thangamuthu et al., 2022). The study's objectives include providing valuable insights for investors, policymakers, and fund managers to make informed decisions regarding international portfolio diversification, policy formulation, and portfolio rebalancing. Ultimately, the findings aim to benefit international and local stakeholders involved in financial markets across the selected countries. The findings of this study hold substantial importance for Sri Lanka, offering valuable insights into investment strategies and risk management. By comprehensively understanding the interplay between international markets and the CSE, stakeholders can better navigate the complexities of global economic dynamics.

Following this introduction, the subsequent section will delve into the related literature and the development of hypotheses. Methodology, data analyses, and findings will then be sequentially presented. The final sections will consist of the conclusion, followed by a comprehensive discussion of the findings.

Literature review

The stock returns and volatility cross-spillover effect, as described by Withanage and Jayasinghe (2017), refers to the propagation of market fluctuations and economic shocks among countries due to interconnections and trade relationships. Extensive research has been conducted on this phenomenon, covering both developed and emerging markets. Engle & Ng (1993) found no cross-spillovers in foreign exchange markets between New York and Japan, contrasting with Hamao et al. (1990), who identified spillovers from New York and London to Tokyo. Koutmos and Booth (1995) discovered volatility transmission from New York to Tokyo and London, highlighting discrepancies in findings that may arise from different model specifications or sample periods, as noted by Karolyi (1995). Negative innovations in one market have been shown to increase volatility in subsequent markets more than positive innovations, as revealed by King & Wadhwani (1990).

In Europe, Fratzscher (2002) demonstrated increased market integration post-European Monetary Union, while Engle and Susmel (1993) found specific patterns of volatility in international markets. The dominance of the US stock market in global volatility spillovers was emphasized by Yang, Zhou, and Cheng (2019), while studies have also explored markets in Central and Eastern European (CEE) and Islamic stock indices. Volatility spillovers can result from asymmetric news impact (Campbell and Hentschel, 1992), as analyzed by Banerjee and Guhathakurta (2020) through network analysis. Additionally, studies have addressed volatility transmission during crises, such as financial contagion channels identified by Forbes & Rigobon (2002), and transmission during economic crises examined by Gregorio and Valdes (2001).

Ng (2000) analyzed return and volatility spillovers from Japan and the US to Pacific-Basin markets, attributing volatility spillovers to currency fluctuations, market liberalization, and trade size. Miyakoshi (2003) found US influence on returns and the Japanese influence on volatility in Asian equity markets. Wei et al. (1995) explored spillover effects between developed and emerging markets, concluding that emerging markets' openness doesn't determine their susceptibility. Wang et al., (2005) identified stronger volatility spillovers than price spillovers between Greater China and developed markets, with bidirectional time-varying volatility interdependence. Hung (2019) observed strong spillovers from China to Southeast Asian markets, particularly during the sub-prime crisis. Panda and Nanda (2018) investigated return and volatility linkages among South American markets, finding strong connectivity among Argentina, Brazil, Chile, and Peru, while Venezuela exhibited the least connection.

Withanage and Jayasinghe (2017) explored volatility spillovers in South Asian stock markets, noting intraday volatility flow from Pakistan to Sri Lanka is stronger than from India. Kumar (2019) examined dynamic linkages among regional stock markets, reporting significant long-run co-integration between India and Pakistan and short-run bidirectional causality among India, Pakistan, and Sri Lanka. Yoshida (2011) studied volatility spillovers during financial crises, highlighting differences in linkages between crises and the direction of volatility causality. Kumar and Dhankar (2017) analyzed the impact of international financial instability on South Asian markets, finding significant short and long-run spillovers and high regional integration. Shahzad et al. (2016) investigated diversification potential across South Asian and European markets, identifying strong linkages among South Asian markets and between South Asian and US markets. Singhania and Prakash (2014) examined volatility cross-correlations in SAARC nations, rejecting the Efficient Market Hypothesis and indicating high integration with global markets.

Several studies have investigated the linkages between the CSE and other markets in the region. Jebran & Iqbal (2016) found bidirectional return spillover only between China and Japan, with unidirectional return transmission from Sri Lanka to India and China to Hong Kong, among others. They also observed bidirectional volatility flow between Hong Kong and Sri Lanka, China and Sri Lanka, and China and Japan. Wang et al., (2005) analyzed returns and spillovers from developed to emerging markets, discovering significant return spillovers from the US and Japan to Sri Lanka, with volatility spillovers, particularly from the US. Perera and Wickramanayake (2012) investigated financial integration among South Asian countries, finding bidirectional causality between them. In the Sri Lankan context, most studies are conducted by foreign scholars, and empirical models such EGARCH model is not fully tested for the local economy.

As delineated earlier, China, India, Japan, and Pakistan stand as formidable economies both globally and within the Asian region. These nations have notably invested in the CSE, with China and India emerging as key sources of Foreign Direct Investment (FDI) in recent years (2019-2021, Central Bank Sri Lanka, 2021). Consequently, fluctuations in the equity markets of these countries wield a discernible influence on the CSE. Bilateral agreements between Sri Lanka and these nations play a crucial role in managing the country's Balance of Payments (BOP) and trade dynamics, thereby impacting the equity market. Assessing bidirectional stock returns and volatility cross spillover effects between these nations aids investors in crafting their investment portfolios and financial objectives, offering manifold benefits to Sri Lanka as a nation.

Moreover, the Covid-19 pandemic has emerged as a global crisis, precipitating downturns in equity markets worldwide (Thangamuthu et al., 2022). Projections indicate that this may exacerbate poverty in developing nations in the future (World Bank, 2024). Hence, while scrutinizing stock returns and volatility spillovers among these countries, it is imperative to examine whether structural breaks occurred in December 2019 due to the COVID-19 pandemic's onset.

The EGARCH model, widely utilized in research, offers a comprehensive framework for estimating the effects of market fluctuations, enabling analysis of both short and long-term relationships, and providing insights into the complexities of cross-spillover effects (Nelson and Foster, 1994). Initially, the Autoregressive Conditional Heteroscedasticity (ARCH) model, introduced by Engle (1982), aimed to analyze volatility swings in financial indices. Subsequent advancements included Bollerslev's VEC-GARCH model (1988) and extensions to ARMA models (Bollerslev, 1986; Engle & Kroner, 1995). Further developments such as the CCC-GARCH model (Bollerslev, 1990) and DCC model (Engle & Sheppard, 2001) addressed multivariate volatility. Methodologies expanded to include impulse response functions (IRFs) (Sims, 1980; Engle et al., 1990) and spillover indexes (Diebold & Yilmaz, 2012). Empirical models like GARCH, ARCH, and VAR have been extensively used to measure volatility. Research across developed and emerging markets has thoroughly explored these models in stock returns and volatility cross spillovers, emphasizing factors such as asymmetric news impact, market integration, and contagion during crises. The EGARCH (1,1) model is preferred in financial research due to its ability to capture asymmetric and leverage effects in volatility. Nelson (1991) introduced EGARCH, addressing asymmetric responses to shocks. Comparative studies, like Glosten et al. (1993), confirm EGARCH's superiority over GARCH and TGARCH in modeling volatility dynamics. Consequently, there remains a gap in applying new econometric models such as the EGARCH model in developing economies.

In this study, we employ the EGARCH (1,1) model (Nelson, 1991) to analyze stock returns and volatility cross-spillover effects. Additionally, we utilize dummy variables and interactive dummy variables to identify structural breaks occurring in December 2019. The utilization of the EGARCH (1,1) model in this context is noteworthy, as it has been scarcely employed by scholars in Sri Lanka and internationally to examine stock returns and volatility cross-spillover effects. Furthermore, there is limited evidence of its application in assessing structural breaks precipitated by the Covid-19 surge. Hence, the insights gleaned from this study hold significant relevance within the Sri Lankan context (Thangamuthu et al., 2022). Understanding the dynamics of these relationships and their impact on the CSE is essential for setting economic goals and policies in Sri Lanka. Analyzing return and volatility spillovers between Sri Lanka and other countries can offer valuable insights into the interconnectedness of regional markets and the transmission of financial shocks. Furthermore, it can provide policymakers and investors with crucial information about the risks and opportunities associated with cross-border investments and trade.

Development of Hypotheses

This study delves into the reciprocal dynamics of stock returns and cross-spillover effects between Sri Lanka and four key nations: China, India, Pakistan, and Japan. China holds substantial sway over various economic facets of Sri Lanka, including foreign direct investments, direct investments, imports/exports, and debt, with a historical tie dating back to the Sino-Lanka Rubber Rice Pact of 1952. India's pivotal economic role in the region is emphasized, especially considering Sri Lanka's reliance on India for foreign direct investments, imports, and debt. The inception of trade linkages between India and Sri Lanka in 2000 through the India-Sri Lanka free trade agreement further solidified India's influence, making it a major source of foreign direct investment and dominating Sri Lanka's export earnings within the South Asian Free Trade Agreement (SAFTA). To substantiate the claim about significant FDI flows from China and India into the Colombo Stock Exchange (CSE), credible sources provide robust evidence. The Central Bank of Sri Lanka's Annual Report 2021 highlights that China and India are major FDI sources, particularly in infrastructure and manufacturing, indirectly influencing the CSE. UNCTAD’s World Investment Report 2022 confirms substantial investments from these countries in infrastructure, energy, and industrial projects. The Sri Lanka Board of Investment (2022) (BOI) notes China as the largest investor, significantly contributing to the Colombo Port City and industrial parks, while India holds major stakes in retail, telecommunications, and manufacturing. The Asian Development Bank's South Asia Economic Report 2021 emphasizes the pivotal role of Chinese and Indian investments in Sri Lanka’s economic landscape, impacting the CSE's performance and stability.

Similarly, Pakistan's significant trading partnership with Sri Lanka is examined, drawing from previous evidence of volatility transmission and co-integration. Japan's status as a major economic powerhouse significantly shapes Sri Lanka's economic landscape, particularly impacting foreign direct investments, direct investments in the Colombo Stock Exchange, imports, and debt. These inter-country partnerships and investments have profoundly affected various sectors in Sri Lanka, including trade, investment, infrastructure, and overall development. Thus, the study posits the following hypotheses to scrutinize the bidirectional relationships between the stock markets of these nations and Sri Lanka.

H_1: There is a stock return and cross-volatility spillover effect from China to Sri Lanka.

H_2: There is a stock return and cross-volatility spillover effect from Sri Lanka to China.

H_3: There is a stock returns and cross volatility spillover effect from India to Sri Lanka.

H_4: There is a stock return and cross-volatility spillover effect from Sri Lanka to India.

H_5: There is a stock returns and cross volatility spillover effect from Pakistan to Sri Lanka.

H_6: There is a stock return and cross-volatility spillover effect from Sri Lanka to Pakistan.

H_7: There is a stock return and cross-volatility spillover effect from Japan to Sri Lanka.

H_8: There is a stock return and cross-volatility spillover effect from Sri Lanka to Japan.

Align with sub-objectives the following hypotheses were tested to check the structural breaks between two periods of pre and post Covid-19 during December 2019, from China, Shanghai Stock Exchange (SSE), India, Bombay Stock Exchange (BSE), Pakistan, Karachi Stock Exchange (KSE), and Japan, Tokyo Stock Exchange (TSE) to CSE.

H_9: Structural breaks in the CSE are influenced by COVID-19-related fluctuations in the SSE from December 2019.

H_{10}: Structural breaks in the CSE are influenced by COVID-19-related fluctuations in the BSE from December 2019.

H_{11}: Structural breaks in the CSE are influenced by COVID-19-related fluctuations in the KSE from December 2019.

H_{12}: Structural breaks in the CSE are influenced by COVID-19-related fluctuations in the TSE from December 2019.

Methodology

Our research adopts a positivist approach and employs quantitative methods to examine stock market behavior. We utilize the EGARCH (1,1) model alongside secondary data to analyze daily stock indices in Sri Lanka, China, India, Pakistan, and Japan spanning from January 2015 to July 2021, comprising 1746 observations for each market[1]. This model is chosen for its ability to capture the asymmetric impact of shocks on volatilities. Data analysis is facilitated by EViews 12 software. The data is sourced from Bloomberg.com, with selected indices including the All-Share Price Index (ASPI) for Sri Lanka, the Shanghai Stock Exchange Composite Index (SSE) for China, the S&P BSE Sensex Index for India, the Karachi Stock Exchange 100 (KSE 100) Index for Pakistan, and the Nikkei 225 Index for Japan. Daily returns are calculated using the natural logarithm of the price ratio $(P_1-P_0)/P_0$) (Kumar, 2019). The study explores structural breaks by dividing the period into pre-Covid-19 (June 2015 to December 2019) and post-Covid-19 (January 2020 to June 2021) sub-periods as a sub-analysis. For this analysis also EGARCH (1,1) model has been employed. The EGARCH (p,q) model introduced by Nelson (1991) is formulated as follows:

$$R_t = \alpha_0 + \sum_{i-1}^{r} \alpha_i R_{t-i} + \varepsilon_t \quad \ldots [1]$$

$$\varepsilon_t|\Omega_{t-1} \sim N(0, \sigma_t^2) \quad \ldots [2]$$

$$\log(\sigma_t^2) = a_0 + \sum_{i-1}^{q} a_i f(z_{t-i}) + \sum_{i-1}^{p} b_i \log(\sigma_{t-i}^2) \quad \ldots [3]$$

$$f(z_{t-i}) = \theta z_{t-i} + [|z_{t-i}| - E(|z_{t-i}|)] \quad \ldots [4]$$

$$E(|z_{t-i}|) = [\frac{2}{\pi}]^{0.5} \quad \ldots [5]$$

$$\frac{\partial f_{(z_t)}}{\partial z_t} = \{1 + \theta, for\ z_t > 0\ and\ -1 + \theta, for\ z_t < 0\} \quad \ldots [6]$$

The conditional mean equation (eq. [1]) is modeled as an autoregressive process of order p (AR (p)), for all return series (Sri Lanka, India, China, Pakistan, and Japan return series) based on previous studies Bollerslev et.al (1988), Theodossiou and

[1] Included only the trading dates

Lee (1993), Wang et al., (2005) and Hamao et. al (1990). The lag order of the AR(p) process is determined using the ACF[2] and PACF[3] and AR (4) is selected for the Sri Lanka and India return series, while the first-order autoregressive process (AR (1)) is selected for China, Pakistan, and Japan return series.

The eq. [3] represents the conditional variance equation which represents the variance of ε_t and variance is dependent on its past values and the past values of a function of z_t ,where σ_t^2 is the conditional (time-varying) variance, and $z_{t,}$ is the standardized residual which is derived from $\frac{\varepsilon_t}{\sigma_t}$ conditional on Ω_{t-1} .The term ε_t is assumed to be normally distributed with a zero mean and variance (σ_t^2). The term $b_i \log(\sigma_{t-i}^2)$ represents the conditional variance and GARCH term, while the term $a_i f(z_{t-i})$ represents the ARCH term. The θ part in eq. [4] is the EGARCH term that captures the leverage effect or asymmetric impact of shocks on volatilities. The persistence of volatility implied by eq. [5] and measured by the $\sum_{i-1}^{p} b_i$. If $\sum_{i-1}^{p} b_i < 1$ the unconditional variance is finite, and if $\sum_{i-1}^{p} b_i = 1$ it can be explained that unconditional variance does not exist (Wang, Gunasekara, and Power, 2005; Nelson, 1991, 1990a, 1990b). As per the eq. [6] the asymmetric impact on volatility can be determined. If θ is negative and statistically significant asymmetry effect exists with the data. This asymmetry in volatility transmission can be determined through the term $[|z_t| - E(|z_t|)]$ measures the size effect of a shock and θz_t measures the corresponding sign effect. If θ is negative a negative z_t tends to reinforce the size effect and positive z_t tends to partially offset the asymmetry effect or the leverage effect can be measured by the ratio $|\frac{-1+\theta}{1+\theta}|$ (Wang et al., 2005; Nelson,1991). The term $[\frac{2}{\pi}]^{0.5}$ is a constant employed to make sure that the integral under the curve of the normal distribution of the residuals from negative to positive infinity is equal to one (Wang et al., 2005; Nelson, 1991).

Return and Volatility Spillovers

First, the Univariate EGARCH (1,1) models were developed, with Sri Lanka as the dependent variable and the other countries as independent variables. The most recent squared residuals from the conditional mean-conditional variance formulation of the equity markets in India, China, Pakistan, and Japan were introduced as exogenous variables in the conditional variance equation for Sri Lanka (Wang et al., 2005; Nelson, 1991). The study focused on investigating the conditional mean equations and conditional variance equations of stock returns and volatility spillover effects from India, China, Pakistan, and Japan to Sri Lanka, aligning with hypotheses H_1, H_3, H_5, and H_7.

<u>Conditional mean equations</u>

$$R_{SRI,t} = \alpha_{SRI,0} + \alpha_{SRI,1}R_{SRI,t-1} + \ldots\ldots + \alpha_{SRI,4}R_{SRI,t-4} + \beta_{SRI,1}R_{IND,t-1} + \varepsilon_{SRI,t} \ldots\ldots\ldots\ldots\ldots\ldots [7]$$

$$R_{SRI,t} = \alpha_{SRI,0} + \alpha_{SRI,1}R_{SRI,t-1} + \cdots + \alpha_{SRI,4}R_{t-4} + \beta_{SRI,1}R_{CHI,t-1} + \varepsilon_{SRI,t} \ldots\ldots\ldots\ldots\ldots\ldots [8]$$

[2] Autocorrelation Function

[3] Partial Autocorrelation Function

$$R_{SRI,t} = \alpha_{SRI,0} + \alpha_{SRI,1}R_{SRI,t-1} + \cdots + \alpha_{SRI,4}R_{SRI,t-4} + \beta_{SRI,1}R_{PAK,t-1} + \varepsilon_{SRI,t} \ldots\ldots [9]$$

$$R_{SRI,t} = \alpha_{SRI,0} + \alpha_{SRI,1}R_{SRI,t-1} + \cdots + \alpha_{SRI,4}R_{SRI,t-4} + \beta_{SRI,1}R_{JAP,t-1} + \varepsilon_{SRI,t} \ldots\ldots [10]$$

Conditional variance equations

$$\log(\sigma^2_{SRI,t}) = a_{SRI,0} + a_{SRI,1}f(z_{SRI,t-1}) + b_{SRI,1}\log(\sigma^2_{SRI,t-1}) + c_{SRI,1}\log(U_{IND,t}) \ldots [11]$$

$$\log(\sigma^2_{SRI,t}) = a_{SRI,0} + a_{SRI,1}f(z_{SRI,t-1}) + b_{SRI,1}\log(\sigma^2_{SRI,t-1}) + c_{SRI,1}\,log(U_{CHI,t}) \ldots [12]$$

$$\log(\sigma^2_{SRI,t}) = a_{SRI,0} + a_{SRI,1}f(z_{SRI,t-1}) + b_{SRI,1}\log(\sigma^2_{SRI,t-1}) + c_{SRI,1}\log(U_{PAK,t}) .. [13]$$

$$\log(\sigma^2_{SRI,t}) = a_{SRI,0} + a_{SRI,1}f(z_{SRI,t-1}) + b_{SRI,1}\log(\sigma^2_{SRI,t-1}) + c_{SRI,1}\log(U_{JAP,t}) \ldots\ldots [14]$$

In the second step, Sri Lanka was considered as the independent variable, while India, China, Pakistan, and Japan were treated as the dependent variables. Univariate EGARCH (1,1) models were developed, incorporating the most recent squared residuals from the conditional mean-conditional variance formulation of the Sri Lankan equity market as exogenous variables in the conditional variance equations of India, China, Pakistan, and Japan. The conditional mean equations and conditional variance equations were developed to explore the stock returns and volatility spillover effects from Sri Lanka to India, China, Pakistan, and Japan, aligning with the hypotheses H_2, H_4, H_6, and H_8.

Conditional mean equations

$$R_{IND,t} = \alpha_{IND,0} + \alpha_{IND,1}R_{IND,t-1} + \ldots + \alpha_{IND,4}R_{IND,t-4} + \beta_{IND,1}R_{SRI,t-1} + \varepsilon_{IND,t} \ldots\ldots [15]$$

$$R_{CHI,t} = \alpha_{CHI,0} + \alpha_{CHI,1}R_{CHI,t-1} + \beta_{CHI,1}R_{SRI,t-1} + \varepsilon_{CHI,t} \ldots\ldots [16]$$

$$R_{PAK,t} = \alpha_{PAK,0} + \alpha_{PAK,1}R_{PAK,t-1} + \beta_{PAK,1}R_{SRI,t-1} + \varepsilon_{PAK,t} \ldots\ldots [17]$$

$$R_{JAP,t} = \alpha_{JAP,0} + \alpha_{JAP,1}R_{JAP,t-1} + \beta_{JAP,1}R_{SRI,t-1} + \varepsilon_{JAP,t} \ldots\ldots [18]$$

Conditional variance equations

$$\log(\sigma^2_{IND,t}) = a_{IND,0} + a_{IND,1}f(z_{IND,t-1}) + b_{IND,1}\log(\sigma^2_{IND,t-1}) + c_{IND,1}\log(U_{SRI,t}) \ldots\ldots [19]$$

$$\log(\sigma^2_{CHI,t}) = a_{CHI,0} + a_{CHI,1}f(z_{CHI,t-1}) + b_{CHI,1}\log(\sigma^2_{CHI,t-1}) + c_{CHI,1}\log(U_{SRI,t}) \ldots\ldots [20]$$

$$\log(\sigma^2_{PAK,t}) = a_{PAK,0} + a_{PAK,1}f(z_{PAK,t-1}) + b_{PAK,1}\log(\sigma^2_{PAK,t-1}) + c_{PAK,1}\log(U_{SRI,t}) \ldots [21]$$

$$\log(\sigma^2_{JAP,t}) = a_{JAP,0} + a_{JAP,1}f(z_{JAP,t-1}) + b_{JAP,1}\log(\sigma^2_{JAP,t-1}) + c_{JAP,1}\log(U_{SRI,t}) \ldots \quad [22]$$

The eq. [19-22] was used to determine the U_{IND}, U_{CHI}, U_{PAK}, U_{JAP}, and U_{SRI} squared residuals of the EGARCH (1,1) and identify volatility spillovers. Return volatility spillovers were observed when passed information from India, China, Pakistan, and Japan had persistent effects on Sri Lanka, and vice versa, and volatility spillovers related to present information follow from the dependent variable's equity market. Significant β_1, β_2, β_3 and, β_4 coefficients indicate return spillovers from independent variables to dependent variables. Significance c_1 coefficients indicate the existence of volatility spillovers from India, China, Pakistan, and Japan to Sri Lanka. A significant c_1 coupled with a negative θ implies that negative news in the India, China, Pakistan, and Japan equity markets have more impact on the Sri Lanka equity market (or other way) than positive information and asymmetric impact of volatility can be identified.

Structural Breaks on Covid-19 Surge

The study sought to examine potential structural breaks resulting from the COVID-19 surge in December 2019. The hypotheses H_9, H_{10}, H_{11}, and H_{12} are tested. To assess the structural breaks associated with each independent variable, the study incorporated one Dummy variable and four Interactive Dummy variables as described in eq. [23-26]. The Dummy variable, represented by D, distinguished between two periods: assigned value "1" from June 1, 2015, to December 30, and "0" from January 1, 2020, to June 1, 2021. By examining the significance of the β_1 and β_2 coefficients, the study evaluated the slope and the intercept differences, and β_2 coefficient explains the influence of SSE, BSE, KSE, and TSE on CSE structural break from December 2019.

$$R_{SRI,t} = \alpha_{SRI,0} + \alpha_{SRI,1}R_{SRI,t-1} + .. + \alpha_{SRI,4}R_{SRI,t-4} + \alpha_{SRI,5}D_{SRI,5} + \beta_{SRI,1}R_{IND,t-1} + \beta_{SRI,2}D_{SRI,t} * R_{IND,t-1} + \varepsilon_{SRI,t} \quad [23]$$

$$R_{SRI,t} = \alpha_{SRI,0} + \alpha_{SRI,1}R_{SRI,t-1} + .. + \alpha_{SRI,4}R_{SRI,t-4} + \alpha_{SRI,5}D_{SRI,5} + \beta_{SRI,1}R_{CHI,t-1} + \beta_{SRI,2}D_{SRI,t} * R_{CHI,t-1} + \varepsilon_{SRI,t} \quad [24]$$

$$R_{SRI,t} = \alpha_{SRI,0} + \alpha_{SRI,1}R_{SRI,t-1} + .. + \alpha_{SRI,4}R_{SRI,t-4} + \alpha_{SRI,5}D_{SRI,5} + \beta_{SRI,1}R_{PAK,t-1} + \beta_{SRI,2}D_{SRI,t} * R_{PAK,t-1} + \varepsilon_{SRI,t} \quad [25]$$

$$R_{SRI,t} = \alpha_{SRI,0} + \alpha_{SRI,1}R_{SRI,t-1} + .. + \alpha_{SRI,4}R_{SRI,t-4} + \alpha_{SRI,5}D_{SRI,5} + \beta_{SRI,1}R_{JAP,t-1} + \beta_{SRI,2}D_{SRI,t} * R_{JAP,t-1} + \varepsilon_{SRI,t} \quad [26]$$

Data analysis and findings

The preliminary analysis assessed daily stock returns for five countries, exploring mean, coefficient of variation, standard deviation, skewness, and kurtosis (Appendix 1). All return series demonstrated highly leptokurtic distributions. The Jarque-Bera test rejected normal distribution assumptions. Robustness of the model checked through diagnostic tests of error autocorrelation, conditional heteroskedasticity, non-normality ARCH test, and time invariance CUSUM test to check for the structural breaks of CSE. Suitable mean equations were estimated using the ARMA process. The correlogram test aided lag selection for the ARMA mean equation. The AR (1) MA (1) model was chosen based on the least Akaike Information Criteria (AIC) and the highest adjusted R^2. The Augmented Dickey Fuller (ADF) test assessed return series stationarity and the results rejected the null hypothesis, suggesting stationary return series at analyzed levels. Breusch-Godfrey (BG) test and heteroskedasticity test aligned and confirmed that there is no autocorrelation and ARCH test confirmed that data are not normal. The CUSUM test results confirmed that there are structural breaks in CSE after 2019 December.

The suitable ARCH model and lag order were determined using squared residual correlograms, with ARCH (2, 0) selected as the best model. It was found that the ARCH effect is available, and the suitable ARCH model has been estimated as ARCH (2,0). The study proceeded to estimate the GARCH (1,1) model and compared the suitability of ARCH and GARCH models using GARCH (1, 1) and ARCH (2, 0) models. The GARCH (1,1) model was found to be the best model according to the model selection criteria. The results of the GARCH (1,1) model showed that all residuals were statistically significant, and the ARCH LM test results proved that the GARCH (1, 1) model can mitigate heteroskedasticity. Since the GARCH (1,1) model is the best model according to the model selection criteria, Engle, and Ng (1993) test was conducted to check for sign and size bias to find whether asymmetry GARCH models can be used for the analysis. The EGARCH (1,1) model was found to be an adequate fit for the data. The study found evidence of sign and size bias in the daily stock returns volatility results for $\emptyset_0, \emptyset_1, \emptyset_2 \; and \; \emptyset_3$ coefficients and probabilities, indicating that positive and negative shocks have differing impacts on future volatility. A maximum likelihood test was conducted to determine the optimal lag order of the EGARCH model for analysis. The EGARCH (1,1) restricted model was utilized and compared with the EGARCH (1,2) and EGARCH (2,1) unrestricted models using R software, which aligns with previous research studies (Kumar & Dhankar, 2017; Dutta & Noor, 2017; Yoshida, 2011; Singhania & Prakash, 2014; Nelson and Foster, 1994; Bollerslev et al., 1988).

EGARCH (1, 1) Model Runs for each Return Series

Table 1: EGARCH (1, 1) Model Estimation

Parameter	Sri Lanka	India	China	Pakistan	Japan
Panel A: Conditional Mean Equation Coefficients					
α_0	0.0194 (0.1089)	0.0645* (0.0061)	0.1066* (0.0003)	0.0408 (0.1058)	0.0162 (0.692)
α_1	-0.7074* (0.0000)	-0.6474* (0.0000)	-0.2589* (0.0000)	-0.3491* (0.0000)	-0.1517* (0.0000)
α_2	-0.5162* (0.0000)	-0.3876* (0.0000)			
α_3	-0.3333* (0.0000)	-0.2599* (0.0000)			
α_4	-0.2040* (0.0000)	-0.1557* (0.0000)			
Panel B: Conditional Variance Equation Coefficients					
a_0	-0.0624* (0.0000)	-0.0241* (0.0000)	-0.0903* (0.0000)	0.0788* (0.0000)	0.2837* (0.0000)

a_1	0.1065* (0.0000)	0.0669* (0.0000)	0.2100* (0.0000)	0.3182* (0.0000)	0.5234* (0.0000)
b_1	1.0004* (0.0000)	0.9957* (0.0000)	0.9853* (0.0000)	0.9031* (0.0000)	0.7994* (0.0000)
θ	-0.0106* (0.0000)	0.0565* (0.0000)	-0.0152* (0.0000)	0.0069 (0.5455)	-0.0450* (0.0020)
Panel C: Standardized and Squared Standardized Residuals					
LB (6)	18.24* (0.0000)	38.10* (0.0000)	49.72* (0.0000)	59.16* (0.0000)	32.07* (0.0000)
LB (12)	23.98* (0.002)	45.68* (0.0000)	58.32* (0.0000)	74.81* (0.0000)	33.706* (0.0000)
LB² (6)	6.30 (0.391)	16.78** (0.0100)	12.19*** (0.058)	1.6821 (0.946)	1.4609 (0.962)
LB² (12)	20.19*** (0.064)	19.518*** (0.077)	16.30*** (0.178)	5.3322 (0.946)	9.0973 (0.695)
ARCH LM (Prob. Chi²)	0.0836***	0.0567***	0.0621***	0.4838	0.9976
Panel D: Log Likelihood results					
Log Likelihood	-4095.62	-5029.67	-3978.43	-4586.99	-4710.05
Panel E: Wald Test Results					
Wald Test	84.80* (0.0000)	66.83* (0.0000)	74767.2* (0.0000)	6224.95* (0.0000)	3397.60* (0.0000)

α_0 *is the constant and* $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ are the coefficients of the first, second, third and fourth order moving average process specified for the mean equation. a_1, represents the ARCH effect θ represents or measures the leverage effect and b_1 represents volatility persistence. LB and LB² are L-Jung Box q statistics for the residuals and squared residuals. The null hypothesis of the Wald test is $a_1 = 0, b_1 = 0, \theta = 0$ and Log-likelihood test results were obtained through EGARCH analysis. p-values are provided in parenthesis []. * Represents significance at 1%, ** Represents significance at 5%, and *** Represents significance at 10% critical value respectively.

The study employed EGARCH (1,1) models and diagnostic tests, such as ACF, PACF, and L-Jung Box statistics, to analyze return series. Optimal lag orders were chosen based on AR (1) test: Sri Lanka (4), India (4), China (1), Pakistan (1), and Japan (1). Table 1 exhibits results for univariate EGARCH (1,1) models. In Table 1, Panel A, α_1 is significant in all return series. Additionally, α_2, α_3 and α_4 are significant for Sri Lanka and India. In Table 1, Panel B, a_1 (ARCH effect) and b_1 (volatility persistence) is significant across all return series. Volatility persistence is highest in Sri Lanka, followed by India, China, Pakistan, and Japan. For leverage effects and θ coefficients, Panel B shows a_1 and b_1 significance. Positive a_1 implies larger shocks raise volatility, while negative θ coefficients for Sri Lanka, China, and Japan indicate negative news amplifies volatility more than positive news. Positive θ coefficients for India and Pakistan imply good news offsets volatility more. Pakistan's θ is insignificant. Leverage effect ratios $\frac{|-1+\theta|}{1+\theta}$, calculated using θ values, reveal Japan's highest asymmetry (-1.09), China's second highest (-1.03), and Sri Lanka's (-

1.02), while India's is least (0.89), suggesting positive shocks offset volatility more.
Table 1, Panel C findings indicate that standardized residuals do not capture dependencies, whereas squared standardized residuals effectively capture all dependencies in the EGARCH (1,1) model. The ARCH LM test confirms successful mitigation of heteroskedasticity in all return series. Additionally, the Wald test demonstrates the significance of variables in the EGARCH (1,1) model fit.

Return and Volatility Spillover from Asian Stock markets to Sri Lanka

Table 2: EGARCH (1, 1) model Returns and Volatility Spillover results to Sri Lanka

Parameters	India (IND)	China (CHI)	Pakistan (PAK)	Japan (JAP)
Panel A: Return Spillover Coefficients				
α_0	0.0027* (0.0000)	0.0415*** (0.0982)	0.0085 (0.5157)	0.0114 (0.3525)
α_1	-0.7032* (0.0000)	-0.4374* (0.0000)	-0.7165* (0.0000)	0.7106* (0.0000)
α_2	-0.5022* (0.0000)	-0.3162* (0.0000)	-0.5159* (0.0000)	-0.5074* (0.0000)
α_3	-0.3164* (0.0000)	-0.2483* (0.0000)	-0.3388* (0.0000)	-0.3279* (0.0000)
α_4	-0.1905* (0.0000)	-0.0938* (0.0000)	-0.2178* (0.0000)	-0.1978* (0.0000)
β_1 (From IND, CHI, PAK, JAP to SL)	-0.0125* (0.0450)	0.0139* (0.5034)	0.0109* (0.1679)	-0.0001* (0.9881)
Panel B: Volatility Spillover Coefficients				
a_0	-0.0593* (0.0000)	1.3019* (0.0000)	-0.0628* (0.0000)	-0.0605* (0.0000)
a_1	0.0994* (0.0000)	0.6253* (0.0000)	0.1096* (0.0000)	0.1014* (0.0000)
b_1	1.0004* (0.0000)	0.3256* (0.0000)	0.9992* (0.0000)	1.0004* (0.0000)
θ	-0.0213* (0.0000)	0.0105* (0.0000)	-0.0282* (0.0000)	-0.0178* (0.0000)
c_1 (From IND, CHI, PAK, JAP to SL)	-0.0164* (0.0000)	-0.0636* (0.0000)	0.0308* (0.0000)	-0.0120* (0.0000)
Panel C: Standardized and Squared Standardized Residuals				
LB (6)	16.677* (0.0000)	29.229* (0.0000)	9.39* (0.0000)	18.261* (0.0000)
LB (12)	21.103*	39.685*	24.297*	23.947*

	(0.0000)	(0.0000)	(0.0000)	(0.0000)
LB^2 (6)	7.9766	6.711	8.0090	7.2475
	(0.240)	(0.348)	(0.237)	(0.299)
LB^2 (12)	20.36	80.82*	15.507	20.169
	(0.061)	(0.0000)	(0.212)	(0.064)

α_0 *is the constant and* $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ are the coefficients of the first, second, third and fourth order moving average process specified for the mean equation. a_1, represents the ARCH effect θ represents or measures leverage effect and b_1 represents volatility persistence. LB and LB^2 are L-Jung Box q statistics for the residuals and squared residuals. p-values are provided in parenthesis []. * Represents significance at 1%, ** Represents significance at 5%, and *** Represents significance at 10% critical value respectively.

In Table 2 analyzed null hypotheses H_1, H_3, H_5, H_7. Panel A, Table 2 presents results for the EGARCH (1,1) models and the significance of coefficients in the return spillover analysis. $\alpha_1, \alpha_2, \alpha_3$ and α_4 coefficients of Sri Lanka for India, China, Pakistan, and Japan are statistically significant. The statistical significance of return spillovers (β_1) is only observed from India, indicating it as a prominent source of shocks to Sri Lanka's CSE. Panel B reveals significant a_0, a_1 *and* b_1 coefficients, highlighting the impact of shocks from India, China, Pakistan, and Japan on CSE's volatility. Positive a_1 (ARCH) coefficient signifies the influence of market shocks, while significant b_1 (GARCH) coefficients (e.g., India: 1.0004, China: 0.3256, Pakistan: 0.9992, Japan: 1.0004) demonstrate past volatility's predictive power for CSE's future volatility, reflecting a high degree of persistence. The c_1 coefficient (volatility spillover) is statistically significant for India, China, Pakistan, and Japan, denoting significant volatility transmission to Sri Lanka at 5% significance level. Notably, the greatest volatility spillovers are from China, followed by Pakistan, India, and then Japan, in descending order of magnitude.

The θ values indicate a significant leverage effect calculated through $\frac{|-1+\theta|}{1+\theta}$, reflecting the stronger impact of negative news from India, China, Pakistan, and Japan on Sri Lanka's volatility compared to positive news. Notably, bad news from India, Pakistan, and Japan amplifies CSE volatility by 1.044, 1.058, and 1.036 times, while China mitigates volatility by 0.979 times, based on θ estimates. This demonstrates asymmetric volatility responses to news across these markets. In Panel C, while standardized residuals might not capture all linear and non-linear dependencies, squared standardized residuals effectively encompass all interdependencies. Both conditional mean and variance equations seem to account for interdependencies in all return series.

Return and Volatility Spillover from Sri Lanka to Stock Markets

Table 3 analyzed H_2, H_4, H_6, H_8 presents return and volatility spillovers, along with standardized residuals in Panels A, B, and C. Panel A's EGARCH (1,1) model reveals significant $\alpha_1, \alpha_2, \alpha_3$ and α_4 coefficients for India, and α_1 for China, Pakistan, and Japan at 5% level. Notably, β_1 indicates negative return spillovers to India and Pakistan, and positive spillovers to China and Japan, all significant at 5% levels. Therefore, return spillovers are present from Sri Lanka to India, China, Pakistan, and Japan.

Table 3: Returns and Volatility Spillovers from Sri Lanka

Parameters	India (IND)	China (CHI)	Pakistan (PAK)	Japan (JAP)
Panel A: Return Spillover Coefficients				
α_0	0.0448* (0.0000)	0.0537 (0.1308)	-0.1184* (0.0002)	0.0123 (0.7334)
α_1	-0.6497* (0.0000)	-0.2550* (0.0000)	-0.3237* (0.0000)	-0.2235* (0.0000)
α_2	-0.3935* (0.0000)	-	-	-
α_3	-0.2608* (0.0000)	-	-	-
α_4	-0.1560* (0.0000)	-	-	-
β_1 **(From SL to IND, CHI, PAK, and JAP)**	-0.0532* (0.0026)	0.00435 (0.0000)	-0.1224 (0.0000)	-0.0769 (0.0000)
Panel B: Volatility Spillover Coefficients				
a_0	-0.0293* (0.0000)	-0.0985* (0.0000)	0.0728* (0.0000)	0.3191* (0.0000)
a_1	0.0672* (0.0000)	0.2179* (0.0000)	0.3802* (0.0000)	0.5316* (0.0000)
b_1	0.9972* (0.0000)	0.9870* (0.0000)	0.8908* (0.0000)	0.7807* (0.0000)
θ	0.5315* (0.0000)	-0.0284* (0.0001)	-0.0049 0.7147	-0.0401* 0.0081
c_1 **(From SL to IND, CHI, PAK, and JAP)**	0.0008 0.7148	0.0202* 0.0648	0.0020 0.4262	0.0183* 0.0723
Panel C: Standardized and Squared Standardized Residuals				
LB (6)	37.18* (0.0000)	46.357* (0.0000)	49.39* (0.0000)	27.39* (0.0000)
LB (12)	45.045* (0.0000)	55.502* (0.0000)	66.771* (0.0000)	28.758* (0.0002)
LB^2 (6)	17.748* (0.007)	12.984** (0.043)	1.4821 (0.961)	2.294 (0.891)
LB^2 (12)	20.561 (0.057)	16.906 (0.153)	4.8911 (0.962)	9.2596 (0.681)

α_0 *is the constant and* $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ are the coefficients of the first, second, third and fourth order moving average process specified for the mean equation. a_1, represents the ARCH effect θ represents or measures leverage effect and b_1 represents volatility persistence. LB and LB^2 are L-Jung Box q statistics for the residuals and squared residuals. p-values are provided in parenthesis (). *Represents significance at 1%, ** Represents significance at 5%, and *** Represents significance at 10% critical value respectively.

In Panel B, Table 3, significant volatility spillover coefficients a_0, a_1 *and* b_1 are observed at 1%, 5%, and 10% levels. Positive a_1 (ARCH term) indicates that CSE shocks influence volatility in India, China, Pakistan, and Japan, and a positive relationship exists between CSE's past variance and the current variance of these countries. The $b_1$coefficient (GARCH term) is significant across all countries and significance levels, revealing that Sri Lanka's past volatility predicts future volatility in India, China, Pakistan, and Japan. Notably, $b_1$coefficients are close to 1 (e.g., India: 0.9972, China: 0.9870), indicating a high level of volatility persistence. The c_1 coefficient indicates no significant volatility spillover from Sri Lanka to India and Pakistan. There is weak evidence of volatility spillover to China and Japan, with higher magnitudes observed to China, followed by Japan. The θ values reveal that negative (positive) news from Sri Lanka's CSE increases volatility more for India, China, and Japan compared to positive (negative) news, indicating an asymmetric impact. Notably, the θ coefficient is insignificant for Pakistan, implying symmetric spillovers. In numerical terms, bad news from CSE impacts China and Japan 1.058 and 1.084 times more, respectively, than equivalent good news. Meanwhile, good news from CSE reduces India's volatility by 0.306 times compared to the impact of bad news. In Panel C, while the standardized residuals fail to capture all linear and non-linear dependencies, the squared standardized residuals effectively capture all interdependencies, indicating that the conditional mean and variance equations encompass interdependencies across return series. Subsequently, the study proceeds to examine structural breaks in the CSE market for India, China, Pakistan, and Japan before and after December 2019, considering the COVID-19 pandemic.

Structural Break on Covid-19

Table 4, Panel A, presents EGARCH (1,1) model results with dummy and interactive dummy variables. Coefficients $\alpha_1, \alpha_2, \alpha_3, \alpha_4 and, \alpha_5$ are statistically significant at a 5% significance level. β_1 and β_2 are significant at these levels except for Japan. Since it was recognized structural breaks in CSE after December 2019 in the diagnostic checking, Table 5 shows that introduced dummy variables indicate slope and interactive dummy variables indicate intercept differences during two periods (Jun 2015 - Dec 2019, Jan 2020 - Jun 2021), explaining structural break of CSE influenced by Covid-19 related fluctuations in the SSE, BSE, KSE, and TSE from December 2019 (equations [29 to 36]). Hence, it is evident that structural breaks in CSE were influenced by India, China, Pakistan, and Japan due to the Dec 2019 COVID-19 surge.

Table 4: EGARCH (1, 1) Impact of Covid-19

Parameters	India (IND)	China (CHI)	Pakistan (PAK)	Japan (JAP)
Panel A: Conditional Mean Equation Coefficients				
α_0	0.1940* (0.0000)	0.2425* (0.0000)	0.1575* (0.0000)	0.2352* (0.0000)
α_1	-0.7008* (0.0000)	-0.70069* (0.0000)	-0.6930* (0.0000)	-0.6978* (0.0000)
α_2	-0.5075* (0.0000)	-0.4946* (0.0000)	-0.4840* (0.0000)	-0.4986* (0.0000)
α_3	-0.3257* (0.0000)	-0.3234* (0.0000)	-0.3175* (0.0000)	-0.3201* (0.0000)
α_4	-0.1956* (0.0000)	-0.1962* (0.0000)	-0.1926* (0.0000)	-0.1939* (0.0000)
α_5	-0.1837* (0.0000)	-0.2393* (0.0000)	-0.1633* (0.0000)	-0.2307* (0.0000)
β_1	0.0749*** (0.0716)	-0.0281*** (0.0543)	0.2881* 0.0000	-0.0084 0.8363
β_2	-0.1028** (0.0157)	0.0408* (0.0001)	-0.2136* (0.0000)	0.0129 (0.7532)
Panel B: Standardized and Squared Standardized Residuals				
LB (6)	15.379* (0.0000)	14.881* (0.0001)	13.268* (0.001)	13.679* (0.001)
LB (12)	21.215* (0.007)	21.148* (0.008)	18.693* (0.017)	20.38 (0.009)
LB^2 (6)	6.3091 (0.389)	7.226 (0.382)	11.744 (0.068)	7.2797 (0.296)

LB^2 (12)	19.127 (0.086)	20.828 (0.101)	19.977 (0.068)	19.564 (0.076)

α_0 *is the constant and* $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ are the coefficients of the first, second, third and fourth order moving average process specified for the mean equation. LB and LB^2 are L-Jung Box q statistics for the residuals and squared residuals. p-values are provided in parenthesis []. * Represents significance at 1%, ** Represents significance at 5%, and *** Represents significance at 10% critical value respectively and + Represents insignificance at 1%, ++ Represents insignificance at 5%, and +++ Represents insignificance at 10% and null hypothesis of uncorrelated returns of LB and LB^2 cannot be Rejected.

As per the results obtained for the equation [23] to [26] can be written as follows,

Period 1st June 2015- 30th Dec 2019

$$R_{SRI,t} = 0.194 - 0.7008R_{SRI,t-1} - 0.5075R_{SRI,t-2} - 0.3257R_{SRI,t-3} - 0.1956R_{SRI,t-4} - 0.1837D_{SRI,1} + 0.0749R_{IND,t-1} - 0.1028(D_{SRI,t} * R_{IND,t-1}) + \varepsilon_{SRI,t} \quad [29]$$

$$R_{SRI,t} = 0.2425 - 0.7007R_{SRI,t-1} - 0.4946R_{SRI,t-2} - 0.3234R_{SRI,t-3} - 0.1962R_{SRI,t-4} - 0.2393D_{SRI,1} - 0.0281R_{CHI,t-1} + 0.0408(D_{SRI,t} * R_{CHI,t-1}) + \varepsilon_{SRI,t} \quad [30]$$

$$R_{SRI,t} = 0.1575 - 0.6930R_{SRI,t-1} - 0.4840R_{SRI,t-2} - 0.3175R_{SRI,t-3} - 0.1926R_{SRI,t-4} - 0.1633D_{SRI,1} - 0.2881R_{PAK,t-1} - 0.2136(D_{SRI,t} * R_{PAK,t-1}) + \varepsilon_{SRI,t} \quad [31]$$

$$R_{SRI,t} = 0.2352 - 0.6978R_{SRI,t-1} - 0.4986R_{SRI,t-2} - 0.3201R_{SRI,t-3} - 0.1939R_{SRI,t-4} - 0.2307D_{SRI,1} - 0.0084R_{JAP,t-1} + 0.0129(D_{SRI,t} * R_{JAP,t-1}) + \varepsilon_{SRI,t} \quad [32]$$

Period 1st Jan 2020-1st June 2021

$$R_{SRI,t} = 0.194 - 0.7008R_{SRI,t-1} - 0.5075R_{SRI,t-2} - 0.3257R_{SRI,t-3} - 0.1956R_{SRI,t-4} + 0.0749R_{IND,t-1} + \varepsilon_{SRI,t} \quad [33]$$

$$R_{SRI,t} = 0.2425 - 0.7007R_{SRI,t-1} - 0.4946R_{SRI,t-2} - 0.3234R_{SRI,t-3} - 0.1962R_{SRI,t-4} - 0.0281R_{CHI,t-1} + \varepsilon_{SRI,t} \quad [34]$$

$$R_{SRI,t} = 0.1575 - 0.6930R_{SRI,t-1} - 0.4840R_{SRI,t-2} - 0.3175R_{SRI,t-3} - 0.1926R_{SRI,t-4} - 0.2881R_{PAK,t-1} + \varepsilon_{SRI,t} \quad [35]$$

$$R_{SRI,t} = 0.2352 - 0.6978R_{SRI,t-1} - 0.4986R_{SRI,t-2} - 0.3201R_{SRI,t-3} - 0.1939R_{SRI,t-4} - 0.0084R_{JAP,t-1} + \varepsilon_{SRI,t} \quad [36]$$

Table 5: Difference of Slope and Intercept in two periods

Panel A: 1st June 2015- 30th Dec 2019		
Country	**Slope**	**Intercept**
From India to Sri Lanka	0.0103	-0.0279
From China to Sri Lanka	0.0032	0.0127
From Pakistan to Sri Lanka	-0.0058	-0.5017
From Japan to Sri Lanka	0.0045	0.0045

Panel B: 1st Jan 2020-1st June 2021		
Country	**Slope**	**Intercept**
From India to Sri Lanka	0.1940	0.0749
From China to Sri Lanka	0.2425	-0.0281
From Pakistan to Sri Lanka	0.1575	-0.2881
From Japan to Sri Lanka	0.2352	-0.0084

Discussion

The research delved into examining the dynamics of stock returns and volatility transmission from Sri Lanka to China using EGARCH (1, 1) bidirectional analysis. As per the results indicated in Table 3, significant spillover effects of both stock returns and volatility from Sri Lanka to China, highlight the influence of Sri Lankan financial developments on Chinese markets. Notably, positive returns spillover was evident across all levels, while adverse news from Sri Lanka exacerbated volatility in China, aligning with previous findings by Huang et al. (2019) and Jebran & Iqbal (2016). Of particular interest was the divergence observed during the Asian Financial Crisis, where Sri Lanka exhibited sensitivity to negative Chinese news, contrary to the positive θ (0.0105) value suggesting that positive news attenuated cross-market volatility spillover, as noted by Hung (2019). This divergence might be attributed to variations in research focus, with some studies emphasizing crisis periods, potentially amplifying the impact of adverse Chinese news on the Colombo Stock Exchange.

The analysis of stock returns and volatility spillover from India to Sri Lanka, utilizing EGARCH (1,1) bidirectional analysis, unveiled a significant negative spillover of stock returns and cross-volatility from India to Sri Lanka, supported by a negative θ value (-0.0213) (see Table 2). This indicates that adverse developments in India tended to escalate volatility within Sri Lanka's stock market. Interestingly, these findings diverged from those of Jebran & Iqbal (2016), potentially owing to disparities in the time frames scrutinized (2015-2021 in our study as opposed to 1999-2014 in theirs) and the evolving impact of India on Sri Lanka's economy in recent years.

The research examined the impact of stock returns and volatility spillover from Pakistan to Sri Lanka using EGARCH (1,1) bidirectional analysis. As indicated in Table 2 there is no significant stock returns spillover from Pakistan to Sri Lanka, although volatility spillover was evident. Notably, negative returns spillover was significant across all levels, with a positive θ value (0.5315), suggesting that positive news from Sri Lanka mitigated volatility stemming from India. Interestingly, there was no observed cross-volatility spillover, indicating that adverse news from Sri Lanka did not impact Pakistan. This contrasts with prior research, such as Jebran & Iqbal (2016), which found similar stock returns spillover but lacked evidence of cross-volatility spillover.

Furthermore, the study explored stock returns and volatility spillover effects from Sri Lanka to Pakistan using EGARCH (1, 1) bidirectional analysis. In Table 3, results revealed stock returns spillover from Sri Lanka to Pakistan, while volatility spillover was not observed. Negative returns spillover was significant at all levels, yet the volatility spillover coefficient lacked significance. The θ value (-0.0049) suggested symmetric volatility spillovers from Sri Lanka to Pakistan, indicating an equal influence of positive and negative spillovers. Additionally, findings from Perera and Wickramanayake (2012) regarding bidirectional causality among South Asian nations were consistent with our results. Moreover, evidence of cross-volatility spillover (Withanage & Jayasinghe, 2017) and Granger causality (Sharma & Bodla, 2011) from India to Sri Lanka supported our findings, as did the confirmation of return and volatility spillovers from global and Asian markets to Sri Lanka by Gajurel and Chawla (2022), aligning with the outcomes of our study.

As per the Table 3, the study unveiled the absence of significant stock returns spillover from Japan to Sri Lanka, while noting a considerable volatility spillover. The volatility spillover coefficient for Japan remained significant across all levels, indicating that negative developments in Japan heightened volatility within the CSE. This finding stands in contrast to prior research by Jebran & Iqbal (2016), which similarly found no stock returns spillover from Sri Lanka to Sri Lanka, aligning with our results. However, unlike our findings, they did not identify cross-volatility spillover. This contributes significantly to enriching our comprehension of the cross-border dynamics between the stock markets of Sri Lanka and Japan.

Furthermore, as per Table 4, a sub-analysis delved into examining the effects of the COVID-19 pandemic on structural breaks among several stock exchanges including SSE, BSE, KSE, TSE, and the CSE. The study pinpointed structural breaks that occurred after 2019 December in CSE, and the slope differences emphasized that those structural breaks are affected by other stock exchanges. As a result, the null hypothesis proposing structural breaks in the CSE are not influenced by Covid-19 related fluctuations in the SSE, BSE, KSE, and TSE from December 2019 were rejected. This underscores the significant impact of the COVID-19 pandemic on reshaping the relationships and dynamics among these stock exchanges and the Colombo Stock Exchange.

Conclusion

The study's conclusions underscore notable discoveries regarding stock return and volatility interactions between Sri Lanka and various nations, alongside insights gleaned from the structural breaks analysis. Firstly, reciprocal volatility spillovers were observed between China and Sri Lanka, indicating a mutual influence on market volatility. Notably, positive developments from China were more effective in tempering volatility in the CSE than negative occurrences, whereas adverse events in the CSE exacerbated volatility in China. Secondly, negative stock return spillovers from India to Sri Lanka were detected, alongside cross-volatility spillovers, underscoring Sri Lanka's impact on India's market volatility. Interestingly, negative news from India had a stronger impact on CSE volatility compared to positive news, while positive developments from Sri Lanka aided in mitigating volatility in India more effectively than negative news. Thirdly, similar trends were observed in the relationship between Pakistan and Sri Lanka, with cross-volatility spillovers and negative stock return spillovers from Sri Lanka to Pakistan. Particularly, adverse events in Pakistan tended to heighten volatility in the CSE more than positive news, while market developments from Sri Lanka affected Pakistan's volatility similarly regardless of their nature. Moreover, cross-volatility spillovers were revealed between Japan and Sri Lanka, indicating a mutual sway on market volatility. Specifically, Japan's negative news had a more pronounced impact on CSE volatility compared to positive news, while adverse occurrences in the CSE amplified volatility in Japan more than positive news. Lastly, the structural breaks analysis underscored significant disruptions from several stock exchanges (SSE, BSE, KSE, TSE) to the CSE during the pre- and post-COVID-19 surge in December 2019. This suggests that the COVID-19 pandemic exerted a notable influence on the relationships and dynamics between these stock exchanges and the CSE, underscoring the importance of factoring in external variables in market analysis and forecasting.

The study's findings suggest Sri Lanka should enhance bilateral financial monitoring, develop crisis management frameworks, utilize positive news, strengthen regional cooperation, diversify economic ties, incorporate external shocks into market analysis, invest in financial infrastructure, promote investor awareness, ensure domestic stability, and coordinate policies during global crises to stabilize its financial markets. Moreover, it identified structural breaks in the CSE from these countries during the COVID-19 surge, crucial for investors, policymakers, and fund managers in making portfolio decisions and formulating stable financial policies. Overall, the study benefits international and local investors, financial institutions, and governments by informing portfolio diversification and risk management strategies.

The study utilized the EGARCH model to explore stock returns and volatility spillovers among Sri Lanka, China, India, Pakistan, and Japan, a novel approach in domestic research. It also investigated the impact of the December 2019 COVID-19 surge on the Colombo Stock Exchange (CSE) from these countries, employing the EGARCH (1, 1) model, a rarity in local studies. Theoretical implications include the novelty of employing EGARCH for such analyses domestically. Practical implications are significant, as findings reveal stock returns and cross-volatility spillovers among the mentioned countries. The study determined leverage effect values, contributing to understanding how news affects market volatility. Future research should expand the geographic scope, use alternative models, conduct sector-specific and longitudinal studies, analyze market microstructure, incorporate macroeconomic variables, assess policy impacts, and investigate behavioral finance insights. These steps will deepen understanding of international financial linkages and improve volatility management strategies in the Sri Lankan stock market.

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Appendix 1: Descriptive Statistics

Panel A: Descriptive Statistics for daily returns

Country	Mean	Median	Maximum	Minimum	STD.	Skw.	Kurtosis	CV
Sri Lanka	-0.0138	0.0000	37.3384	-33.3397	4.3098	0.2370	25.9014	-311.74
India	-0.0125	-0.0590	43.6574	-43.3954	6.5267	0.1575	19.3828	-520.22
China	-0.0036	-0.0272	33.8550	-36.0225	3.0345	-0.0351	52.0499	-849.54
Pakistan	-0.0212	-0.0221	32.4749	-29.4943	4.4874	0.1958	20.7259	-211.53
Japan	-0.0144	-0.0334	35.1809	-33.5618	4.8024	0.1436	25.6579	-332.74

Panel B: Jarque- Bera test results

Country	Sri Lanka	India	China	Pakistan	Japan
Test Results	38127.94	19510.58	174829.00	22843.43	37311.64
Prob.	[0.0000] *	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*

Panel C: L-Jung Box q- Statistics

Country	Sri Lanka	India	China	Pakistan	Japan
LB (6)	369.22	373.53	127.64	436.19	309.91
Prob.	[0.0000] *	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*
LB^2 (6)	334.14	340.94	284.47	412.25	349.61
Prob.	[0.0000] *	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*
LB (12)	370.75	387.00	138.61	572.80	313.80
Prob.	[0.0000] *	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*
LB^2(12)	456.26	384.74	284.60	625.39	378.93
Prob.	[0.0000] *	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*

Panel D: ARCH (12) LM Test

Country	Sri Lanka	India	China	Pakistan	Japan
Test Results	119.80	69.15	55.28	164.30	106.43
Prob.	[0.0000] *	[0.0000] *	[0.0000] *	[0.0000] *	[0.0000] *

Panel E: Nonparametric Cross-correlation of daily stock exchange market returns

Country	SRI	IND	CHI	PAK	JAP
Sri Lanka	1		0.0282	0.0263	-0.0152
	0.0122				
India		1	-0.0174	-0.1190	-0.0229
China			1	-0.0306	0.0512
Pakistan				1	-0.0139
Japan					1

*Represents significance at 1%, ** Represents significance at 5%, and *** Represents significance at 10% critical values respectively, CV-Coefficient of variation, STD-Standard Deviation, Skw-Skewness, p-values are provided in parenthesis [], ARCH (LM) test Null Hypothesis is ARCH effects are not present in the first twelve lags. SRI-Sri Lanka, IND-India, CHI-China, PAK-Pakistan, and JAP-Japan.