



Exchange Rate and Stock Prices Volatility Connectedness and Spillover during Pandemic Induced-Crises: Evidence from BRICS Countries

Muntazir Hussain¹ · Usman Bashir² · Ramiz Ur Rehman¹

Accepted: 13 May 2023 / Published online: 1 June 2023

© The Author(s), under exclusive licence to Springer Japan KK, part of Springer Nature 2023

Abstract

This paper investigated exchange rate and stock price volatility connectedness and spillover in Brazil, Russia, India, China, and South Africa (BRICS) during pandemic-induced crises. We first extracted volatility using the Generalized Auto-Regressive Conditional Heteroskedasticity (GARCH) model. Then volatility connectedness and spillover were investigated by using (Diebold and Yilmaz, *International Journal of Forecasting*, 28(1), 57–66, 2012) method. We find that exchange rate volatility and stock return volatilities are connected during pandemic-induced crises. The study also finds volatilities spillover among countries in the sample. Russia has strong volatility connectedness with India in these financial markets. The direction of volatility spillover is from Russia to India. Similarly, Brazil has strong volatility connectedness with South Africa and the direction volatility spillover is from Brazil to South Africa. Finally, China has a weak volatility connection with the remaining BRICS countries. Thus, the volatility transfer in these financial markets and across BRICS countries has economic implications.

Keywords Volatility connectedness · Volatility spillover · Exchange rate · Stock prices · Pandemic

JEL E44 · F31 · C58 · F36 · G15

✉ Muntazir Hussain
mhussain@su.edu.om

Usman Bashir
bbashir.usman@gmail.com

Ramiz Ur Rehman
ramiz_rehman@hotmail.com

¹ Faculty of Business, Sohar University, Al-Jamia Street, 311 Sohar, Oman

² Department of Economics and Finance, College of Business, University of Bahrain, Manama, Kingdom of Bahrain

1 Introduction

The link between exchange rates and stock prices has been investigated by various scholars across the globe see e.g., (Chkili & Nguyen, 2014; Dahir et al., 2018; Huang et al., 2021; Hussain & Bashir, 2013; Kumar et al., 2019). Literature reports two types of explanations for the possible link between these two variables. The first possible explanation, i.e., the “Flow Oriented Model” is also called the “Good Market Approach” and the second one is called the “Stock Oriented Model” or “Portfolio Balance Approach”. The first approach as stated by (Dornbusch & Fischer, 1980) that stock prices are affected by the exchange rate. The rationale to justify this argument is that depreciation/appreciation in exchange rate increases/decreases trade competitiveness. Trade competitiveness affects the real output and stock prices see e.g., (Bashir et al., 2016; Hussain & Bashir, 2013; Pan et al., 2007; Phylaktis & Ravazzolo, 2005; Rai & Garg, 2021; Ülkü & Demirci, 2012; Wong, 2017).

On the other hand, the “Portfolio Balance Approach” or “Stock Oriented Model” suggested by (Branson & Henderson, 1985) states that stock prices affect the exchange rate. The empirical studies suggest that stock prices increase foreign investors’ attraction. This attraction leads to buying more and more stocks and hence increasing demand in the domestic stock market. The increasing demand and capital inflow from abroad lead to exchange rate depreciation (Bashir et al., 2016; Branson & Henderson, 1985; Koulakiotis et al., 2015; Rai & Garg, 2021; Ülkü & Demirci, 2012; Wong, 2017).

The two halves of the literature report mixed evidence and remain inconclusive. Our purpose is not to report the literature in the current paragraph. But we are trying to report the brief of recent studies that have investigated such variables and so far, there is no clear consensus on the said relationship. The direction of causality also reports mixed evidence. For example, studies that advocate unidirectional causality (exchange rate affects stock prices) can be found in studies, see. e.g., (Kumar, 2019; Sheikh et al., 2020). Similarly, the studies also report there is no impact of the exchange rate on the stock price. For example, (Adeniyi & Kumeka, 2020) reports no relationship between exchange rate and stock prices. Furthermore, some studies also report the direction of causality from stock prices to exchange rates. The topic under discussion has been investigated by various scholars through various methodologies. The methods include, autoregressive distributed lag model (ARDL), granger causality, autoregressive conditional heteroskedasticity (ARCH), generalized autoregressive conditional heteroskedasticity (GARCH), non-linear ARDL, de-trended cross-correlation analysis (DCCA) see e.g., (Adeniyi & Kumeka, 2020; Akbar et al., 2019; Bashir et al., 2016; Dahir et al., 2018; Huang et al., 2021; Kumar, 2019; Mohamed & Elmahgop, 2020; Sheikh et al., 2020).

Unlike the previous literature, we have used a different approach to explore the dynamics of exchange rates and stock prices. Our main focus is on volatility connectedness and spillovers. The current study is unique concerning the approach applied. It extracts volatility from the exchange rate and stock price series through

volatility models (GARCH) and then explores the volatility connectedness by using (Diebold & Yilmaz, 2012) methodology. This method has several advantages. For example, it is capable of measuring pairwise exchange rate volatility connectedness. It measures the transmission of volatility shock from the exchange rate to stock prices and stock price volatility transmission to the exchange rate. This study method quantifies the volatility of “Giver” and “Receiver”. In other words, how much volatility is in the stock market itself? How much stock market volatility is transmitted to the foreign exchange market? On the other hand, it also investigates how much volatility the exchange rate has. How much exchange rate volatility is transmitted to the stock market? Similarly, this study also investigated volatility shock transmission across BRICS, i.e., volatility transmission from the foreign exchange market in one country to the stock market in another country and vice versa. Furthermore, the focus of this paper is volatility connectedness and spillover during pandemic-induced crises. How do exchange rate and stock prices connectedness and spillover behave during pandemic-induced crises? We depart from previous literature that only focuses on financial crises such as Global Financial Crises 2008 (GFC) and Asian Financial Crises 1997 (AFC).

Keeping in view the above discussion, this study contributes to the empirical literature in several ways. First, the empirical literature has either investigated the direction of causality from exchange rate to stock prices or stock prices to exchange rate. The results are inconclusive. Our study departs from empirical literature by investigating the volatility connectedness of exchange rates and stock prices. Our main focus is on volatility connectedness not the direction of causality. The connectedness between exchange rates and stock price volatility is important because it affects the economy’s overall health, the performance of financial markets, and the financial stability of countries. Likewise, the volatility of stock prices can affect investor confidence, which can have implications for financial markets and the broader economy. Additionally, if exchange rates and stock prices become too volatile, it can lead to financial crises and increase systemic risk, which can deteriorate the economic and financial health of the country. Therefore, policymakers must be cognizant of financial connectedness across borders to maintain financial stability and ensure sustainable economic growth. Second, this study methodology measures the volatility of “Giver” and “Receiver”. The study investigated the transmission of volatility shocks across BRICS countries, which involves measuring the level of volatility transmission from the foreign exchange market of one country to the stock market of another country, and vice versa. Measuring volatility giver and receiver is significant because it helps policymakers understand how volatility shocks are spread across financial markets and countries. This information can guide policymakers in developing policies to reduce risks and maintain financial stability. If a country is a giver of volatility, policymakers can take measures to manage its financial markets to prevent volatility shocks from givers (transmitters). If a country is a receiver of volatility, policymakers can enhance its financial resilience to mitigate the impact of volatility shocks from other countries. This knowledge can also inform policymaking, enabling policymakers to design effective policies while considering potential risks and their consequences. Finally, we have investigated exchange rate and stock price volatility connectedness during Covid-19 which is scant in previous

studies. During the Covid-19 pandemic, there has been significant volatility in financial markets, particularly in exchange rates and stock prices. This volatility has several policy implications for policymakers, including the use of monetary and fiscal policies to stabilize the economy, promote international cooperation, and implement regulatory reforms to enhance financial resilience.

The motive of sample selection (BRICS countries) comes from the fact that BRICS countries play a significant role in the world economy due to their large land area, population, and trade volume (Huang et al., 2021; Larionova & Shelepov, 2022). These countries have emerged as global economic players, with their combined GDP accounting for nearly 25% of the world's total GDP. They are also crucial players in global trade and investment, with their rapid economic growth providing a stimulus to the global economy (Huang et al., 2021). BRICS contributed fifteen percent to the world's GDP in the 2008 financial crisis (Huang et al., 2021). Similarly, the BRICS played a vital role in world economic recovery by accelerating financial stabilization. Moreover, BRICS is the emerging powerhouse of investment, trade, and investment and has a high potential for economic development. So the importance of BRICS cannot be ignored in the world economy. Hence, the academic community, international organizations, governments, and investors have a keen interest to monitor BRICS economies (Diko & Sempijja, 2021; Huang et al., 2021). Having strong ties among BRICS economies, financial markets volatility transmission would have consequences. As mentioned earlier, if BRICS economies can contribute to world economic recovery from the 2008 financial crisis, the collapse of BRICS markets would have unbearable consequences (Diko & Sempijja, 2021).

The findings of this study suggest significant volatility connectedness and spillover in BRICS financial markets. The Russian financial market, for example, is strongly connected to India, with volatility spillover occurring from Russia to India. Brazil is also strongly connected to South Africa, with volatility spillover occurring from Brazil to South Africa. However, China's financial market has weak volatility connections with other BRICS countries. These findings have important policy implications for policymakers in BRICS countries. To reduce the impact of volatility spillover, policymakers must consider promoting cooperation among central banks, congruent regulatory frameworks, and enhancing financial market integration. Moreover, policymakers should focus on strengthening their macroeconomic fundamentals to reduce vulnerability to external shocks which would lead to promoting financial stability and economic growth in BRICS countries and the global economy as a whole.

The rest of the paper is arranged into four (04) sections, i.e., literature review, methodology, results, and conclusion.

2 Literature Review

The classical relationship between exchange rates and stock prices during a financial crisis like the Asian Financial Crisis of 1997 (AFC) and the Global Financial Crisis of 2008 (GFC) is usually explained using two models (Rai & Garg, 2021). The first one is the stock-oriented (SO) model (Frankel, 1992). The SO model

fundamentally assumes that the portfolio diversification of any economy depicts the exchange rate. Accordingly, the performance of domestic stock attracts international investors, including ex-pats, which causes the domestic currency to outperform. The second model is the 'flow-flow oriented' (FO) model (Dornbusch & Fischer, 1980). The critical assumption in the FO model is that the exchange rate changes at a certain point in time (i.e. during the crisis in our case) impact the national trade balances and international competitiveness of the economy. Which, in turn, affects the stock prices and tangible economic outputs to demonstrate the health of a national economy.

Based on the above theoretical rationale, different scholars have tested such relationships on various static models such as GARCH, Co-integration, Granger Causality, Quantile Regression, etc. For example, (Liu & Wan, 2012) investigated stock prices and exchange rates in the Chinese economy. The result does not find any long-run relationship between the exchange rate and stock prices. However, the author reports a cross-correlation between exchange rates and stock prices. No evidence of causality was found from the exchange rate to stock prices. Similarly, Tsai (2012) investigate the exchange rate and stock price relationship using Quantile Regression. The results suggest that stock prices and exchange rates are negatively correlated in six Asian countries. Similarly, recent studies (Yang, 2017) found a long-run relationship between exchange rates and stock prices in four Asian economies (Singapore, Hong Kong, Taiwan, and South Korea). Tule et al. (2018) investigated the relationship between exchange rate and stock price volatility spillovers and found bi-directional spillovers in Nigerian financial markets. Mahapatra and Bhaduri (2019) investigated exchange rate and stock return volatility spillover in Indian financial markets using two factor arbitrage pricing model. The result support exchange rate volatility spillovers from the foreign exchange market to stock returns. Some authors also report an asymmetric relationship between stock prices and exchange rates. For example, (Kumar, 2019; Sheikh et al., 2020; Sikhosana & Aye, 2018) argue an asymmetric relationship between exchange rates and stock prices. In this context, (Kumar, 2019; Sheikh et al., 2020; Sikhosana & Aye, 2018) investigated the volatility spillovers between stock prices and exchange rates in South-African financial markets using an asymmetric GARCH model. The author supports bi-directional spillovers in financial markets in South Africa.

Apart from different methods applied in various studies, the literature also explains several possible explanations for Covi-19 impact on financial markets. For example, the first possible explanation comes from the link between Covid-19, global supply chain, production, and business costs. Covid-19 caused disruptions in global supply chains, which lead to decreased production and increased costs for businesses (Meyer et al., 2022; Panwar et al., 2022). Affecting core business fundamentals resulted in lower profits for companies, and consequently, a decline in the stock prices (Carter et al., 2022). The second possible explanation comes from changes in consumer behavior during Covid-19. Covid-19 impacted consumer behavior, which caused a decline in consumer spending (AbdulHussein, Cozzarin, & Dimitrov, 2022; Truong & Truong, 2022). Such decline in consumer spending adversely affected industries such as hospitality, tourism, and retail, which caused a decline in the stock prices in these industries (Kaushal & Srivastava, 2021; Pramana

et al., 2022). Third, Covid-19 had affected investor behavior and risk appetite. It is documented in Covid-19 studies that investors became more risk averse during Covid-19 and increased uncertainty and risk aversion among investors, causing them to sell off stocks and seek safer assets which caused stock price decline and increased volatility (Mnif, Salhi, Mouakha, & Jarboui, 2022; Ortmann et al., 2020; Yuan et al., 2022). Finally, Covid-19 impacted the global economy as a whole, leading to a decrease in global GDP and an increased risk of a recession (Gagnon et al., 2023; Havrland et al., 2021), and impacted financial markets worldwide.

Substantial work has been done to check the possible impact of Covid-19 on financial markets and volatility connectedness see e.g., (Ali et al., 2022; Bouri et al., 2021; Fasanya et al., 2021; Li et al., 2021; Umar & Gubareva, 2021). For example, Umar and Gubareva (2021) have investigated the impact of media coverage on Islamic stock volatility. Similarly, Li et al. (2021) suggest strong evidence of Covid-19 death cases. The stock market reacts more to death cases than patients' recovery cases. In addition, Ali et al. (2022) investigated volatility spillover between oil and stock markets and found that oil and stock market returns commove positively. The exchange rate, stock, and oil market also confirm co-movement (Bashir et al., 2016; Hussain et al., 2017). Furthermore, Fasanya et al. (2021) have found significant evidence of volatility connectedness and spillover in the global exchange market. While, Bouri et al. (2021) investigated spillover and connectedness among the oil market, stock market, and foreign exchange market and found spillover among these assets markets. Recent studies have also found a connection between environment, social, and governance stocks (Shaik & Rehman, 2023); financial markets and systematic risk (So et al., 2021); financial market connectedness in G-7 (Das, Rout, & Khatun, 2023); stock market connectedness in BRICS (Hung, 2021a). The outbreak of Covid-19 has caused a significant impact on financial markets worldwide (Baek et al., 2020). The uncertainty surrounding the pandemic has led to heightened volatility, as investors struggle to accurately predict the long-term economic effects of the virus (Baek et al., 2020). Stock prices have experienced significant declines, as investors become increasingly risk-averse and seek safer assets such as bonds and gold (Trabelsi, 2019). The energy sector has also been hit hard, as the pandemic has led to a decrease in demand for oil and gas (Hussain & Rehman, 2023). Central banks around the world have responded to the crisis by cutting interest rates and injecting liquidity into the financial system (Elgin et al., 2021). Governments have also implemented fiscal stimulus measures to support their economies and mitigate the impact of the virus (Elgin et al., 2021; Long et al., 2022).

Literature related to BRICS on the topic under discussion accelerates investigation after Global Financial Crises (2008). For instance, in recent studies, Dahir et al. (2018) investigated the stock market and exchange rate dependence in BRICS using the dependence-switching-cupola approach. The study reports a negative correlation between foreign exchange and stock prices in BRICS countries. Chkili and Nguyen (2014) also investigate exchange rate and stock price dynamics using the VAR model and concluded that there is no relationship between stock prices and exchange rates in BRICS. Huang et al. (2021) investigate the relationship between exchange rate and shock price in BRICS using the VAR model. The result finds out the main driver of exchange rate and stock price. The main driver of exchange rate and stock price in

Brazil is driven by financial account, whereas in Russia the main driver is the current account. But China, India, and South Africa are driven by both of these factors.

After a careful review of the literature, we have found few studies relevant studies that have applied a similar approach. For example, Hussain and Rehman (2023) investigated the volatility connectedness of GCC stock markets and study extends global oil prices volatility connectedness and spillover across GCC stock markets. It is worth mentioning that our study has significant differences in scope and sample countries selected (Hussain & Rehman, 2023). Our focus is on exchange rate and stock price volatility connectedness in BRICS whereas (Hussain & Rehman, 2023) investigated stock market connectedness in GCC. A very similar analysis can also be found in (Hung, 2021b) where the author investigated stock market connectedness in GCC. Adding on, Hung (2021a) has investigated economic policy uncertainty and stock markets in BRICS. Our study is also different from (Hung, 2021a) as we have investigated the exchange rate-stock market volatility connectedness in BRICS. Hung (2021a) only stock market connectedness in BRICS. Furthermore, Ali et al. (2022) examined the oil-stock market volatility nexus which is different from our study. Our focus is on exchange rate-stock market volatility connectedness across BRICS. Finally, Umar and Gubareva (2021) focus on media new-stock market volatility connection; (Li et al., 2021) focus on G-20 stock market connectedness; and (Fasanya et al., 2021) only investigate the foreign exchange market connection (in our case exchange rate-stock market volatility connectedness).

Keeping in view the discussion above, we believe this paper can contribute to empirical literature in several ways. First, we have applied a slightly different approach to the existing literature on the dynamics of exchange rates and stock return volatilities. Unlike the previous literature see e.g., (Bashir et al., 2016; Hussain & Bashir, 2013; Pan et al., 2007; Phylaktis & Ravazzolo, 2005; Rai & Garg, 2021; Ülkü & Demirci, 2012; Wong, 2017), we have focused on volatility connectedness and spillover instead of causality. We have investigated the pairwise volatility spillovers and connectedness between stock price returns and exchange rates across BRICS. We have quantified the volatility of “Giver” and “receiver”. Second, the previous literature either solely investigates stock market connectedness or exchange market connectedness. We have quantified volatilities (exchange rate and stock market) and checked for possible connections across BRICS financial markets. Finally, we have investigated exchange rate and stock price volatility connectedness during Covid-19 which is scant in previous studies. During the Covid-19 pandemic, there has been significant volatility in financial markets, particularly in exchange rates and stock prices. This volatility has several policy implications for policymakers, including the use of monetary and fiscal policies to stabilize the economy, promote international cooperation, and implement regulatory reforms to enhance financial resilience.

Table 1 Variables and data sources

Country name	Stock market index	Exchange rate	Data source
Brazil	BOVESPA	Brazilian Real/USD	Investing.com
Russia	RTS	Russian Ruble/USD	Investing.com
India	NIFTY50	Indian Rupee/USD	Investing.com
China	S.E	RMB/USD	Investing.com
South Africa	FTSE JSE	South African Rand/USD	Investing.com

Table 1 Present variable and data sources. The first column provides countries included in the sample; column 2 provides detail of the respective country stock market symbol; column 3 provides detail related to the exchange rate of each country; and column 5 provides data sources

3 Data and Methodology

3.1 Data

We have used daily data on exchange rates and stock prices. The data range from January 2019 to June 2021. We have selected the sample period based on the objective of this paper. Our main objective is to investigate the topic under discussion in the Covid-19 scenario. Previous studies that explore the effects of Covid-19 have a similar sample period selection (Ali et al., 2022; Fasanya et al., 2021; Li et al., 2021; Umar & Gubareva, 2021). For example, Ali et al. (2022) have applied (01/01/2019–31/03/2021). Similarly, Fasanya et al. (2021) have applied a data sample (31/12/219–10/04/2020). The shortest sample period of six months (January 2020 to June 2020) can also be found in previous studies see. e.g., (Umar & Gubareva, 2021). In addition, (Li et al., 2021) also used data from September 30, 2019, to June 11, 2020. The countries in the analysis include Brazil, Russia, India, China, and South Africa (BRICS). The stock market index and the exchange rate used in this table are reported in Table 1. We have calculated exchange rate returns and stock returns by taking the first difference. The direct exchange rate was used for all countries (domestic currency per dollar).

4 Model and Estimation Procedure

We have employed the (Diebold & Yilmaz, 2012) method. We have specified pairwise volatility connectedness of exchange rate and stock returns in BRICS. Before applying the (Diebold & Yilmaz, 2012) method, we extracted volatility through Generalized ARCH (GARCH) models and stored them. We have used the GARCH model for extraction of volatility based on previous studies see, e.g., (Al-Yahyaee et al., 2019; Hansen & Huang, 2016; Hussain & Rehman, 2023;

Kanniainen et al., 2014). All model specification test was applied before applying GARCH. For example, we tested for possible nonlinearities using Ramsey’s RESET test and BDS test.¹ Similarly, all series were tested for possible ARCH effects. We have extracted the volatility of both exchange rate returns and stock price returns through GARCH (1,1) model. The following variance equation GARCH (1,1) was estimated.

$$\delta_t^2 = \alpha_0 + \alpha_1 \mu_{t-1}^2 + \beta \delta_{t-1}^2 \tag{1}$$

Once the exchange rate returns and stock price returns volatility are estimated and we named it as volatility of exchange rate returns and stock prices returns as VOL. Then we followed the (Diebold & Yilmaz, 2012) method in the second step to explore the volatility connectedness and spillovers between exchange rate returns and stock price returns. This method uses vector auto-regressions (VARs) (Inekwe, 2020; Koop et al., 1996) and forecast variance error decomposition. This approach can be applied to both returns and returns volatilities and allow the establishment of dynamic links (Diebold & Yilmaz, 2012; Inekwe, 2020). The decomposition process generates a refined measure of directional transmission. Similarly, it also identifies the recipient and transmitter of shock from one variable to another. So it enables us to pairwise volatility connectedness of exchange rate and stock returns in BRICS.

Diebold and Yilmaz (2012) specified the VAR (p) framework with “N” covariance stationary variables $VOL_t = (VOL_{1t}, \dots, VOL_{Nt})$ as follow,

$$VOL_t = \sum_{i=1}^p \delta_i VOL_{t-i} + \varepsilon_t \tag{2}$$

The variable VOL_t denotes $N \times 1$ vector of endogenous variables, δ_i denotes coefficients of auto-regressive variables $N \times N$ metrics and ε_t is the error term. Similarly, the moving averages can be generated using VAR by the following equation,

$$VOL_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i} \tag{3}$$

The coefficient A_i follows recursion and $A_i = 0$ for $i < 0$

$$A_i = \gamma_1 A_{i-1} + \gamma_2 A_{i-2} + \gamma_3 A_{i-3} + \dots + \gamma_p A_{i-p} \tag{4}$$

Furthermore (Diebold & Yilmaz, 2012) constructed a generalized spillover index (GSI) represented by the H-step-ahead forecast error variance of VOL_i as follows,

$$\theta_{ij}(H) = \frac{\sigma_{ij}^{-1} \sum_{h=0}^{H-1} (e_i' A_h \Sigma_e e_j)^2}{\sum_{h=0}^{H-1} (e_i' A_h \Sigma_e A_h' e_i)} \tag{5}$$

¹ These tests were conducted for all variables in BRICS. We have not reported that for brevity purpose.

where Σ_ϵ is the variance matrix of the vector of errors ϵ . σ_{jj} is the standard deviation of the error term of the j^{th} equation, and e_i is a selection vector with a value of one for the i^{th} element and zero otherwise. A_h stands for $N \times N$ matrix of MA coefficients corresponding to the forecast horizon h . Note that the sum of the own- and cross-variable variance contributions do not equal one under generalized decompositions. So to normalize the variance decomposition matrix the following procedure (each entry normalized by row sum) is followed,

$$\tilde{\theta}_{ij}(H) = \frac{\theta_{ij}(H)}{\sum_{j=1}^N \theta_{ij}(H)} \tag{6}$$

Similarly, (Diebold & Yilmaz, 2012) estimated the total connectedness index (C), directional spillover, and net spillover as shown in Eq. 7, Eq. 8–9, and Eq. 10 respectively.

$$C(H) = \frac{\sum_{i,j=1, i \neq j}^N \tilde{\theta}_{ij}(H)}{\sum_{i,j=1}^N \tilde{\theta}_{ij}(H)} \times 100 = \frac{\sum_{i,j=1, i \neq j}^N \tilde{\theta}_{ij}(H)}{N} \times 100 \tag{7}$$

$$C_{i \leftarrow j}(H) = \frac{\sum_{j=1, i \neq j}^N \tilde{\theta}_{ij}(H)}{N} \times 100 \tag{8}$$

$$C_{i \rightarrow j}(H) = \frac{\sum_{j=1, i \neq j}^N \tilde{\theta}_{ji}(H)}{N} \times 100 \tag{9}$$

$$C_{i \leftarrow j}(H) - C_{i \rightarrow j}(H) \tag{10}$$

Equation 9 denotes the volatility received by asset “i”. Similarly, how much volatility is transmitted from asset “i” to other assets is given in the equation.

5 Results

5.1 Volatility spillover and its properties

Table 2 contains volatility spillover descriptive statistics. There are three panels in Table 2. Panel A contains volatility spillover to countries in the sample, panel B volatility spillover from these countries, and panel C reports net spillover during the study period. Panel A of Table 2 shows that on average China is dominant in transmitting volatility and receiving volatility shocks during the study period. It is evident from the mean values (see panel A: mean value 11.011, panel B mean value 10.441) in Table 2. It is not surprising because China was hit by a pandemic first which might have created turbulence in both the foreign exchange market and the stock market. Panel A of Table 2 also shows that the Russian foreign exchange

Table 2 Descriptive statistics

Variable	Obs	Mean	Std. Dev	Min	Max
<i>Panel A: Descriptive Statistics–Volatility Spillover to (Transmitters)</i>					
Brazil	572	8.497	5.957	.323	48.293
India	572	8.376	5.262	.72	32.882
China	572	11.011	6.571	.296	30.614
Russia	572	10.7	6.747	.877	72.033
South Africa	572	6.62	4.743	.242	33.92
<i>Panel B: Descriptive Statistics–Volatility Spillover from (Receivers)</i>					
Brazil	572	6.845	2.694	1.692	19.717
India	572	9.097	4.149	1.646	19.98
China	572	10.441	3.948	3.068	19.928
Russia	572	9.389	3.801	1.754	18.751
South Africa	572	9.432	5.092	1.107	19.707
<i>Panel C: Descriptive Statistics–Volatility Spillover Net</i>					
Brazil	572	1.652	6.2	– 18.664	41.188
India	572	– .721	5.758	– 18.389	25.976
China	572	.569	8.372	– 19.479	25.42
Russia	572	1.311	7.468	– 14.992	70
South Africa	572	– 2.812	6.993	– 18.544	28.907

Table 3 Provides details regarding descriptive statistics, i.e., mean standard deviation, minimum, and maximum. Panel A of Table 2 provides descriptive statistics related to the transmitter, panel B reports descriptive related to the receiver and panel C reports net volatility spillover

and stock market transmitted the second-highest volatility shock. On average, Brazil stood as the third country in transmitting volatility shocks whereas India ranked fourth (see. Panel A).

On average, the Chinese foreign exchange market and the stock market received the most volatility shocks. Similarly, South Africa, Russia, and India have the highest recipients of volatility shocks in foreign exchange and stock markets (see panel B Table 2). Panel C of Table 2 indicates that the highest net spillovers were observed in South African and Indian foreign exchange and stock markets. Indian and South African financial markets received more volatility shocks compared to their transmission of volatility to other countries' financial markets. Similarly, on average the net spillover as the transmitter, Brazil, and Russia are dominant (see panel C Table 2). Brazil and Russian financial markets (foreign exchange and stock market) transmitted more volatility to sample countries than receiving volatility shocks. Similarly, we have also compared and tested the mean volatilities of BRICS pairwise. The statistical significance was tested by t-statistics. For brevity purposes, we have just reported a pairwise mean comparison of Brazil with the rest of the sample countries. The results are reported in Table 3.

Table 3 Comparison of Means Spillover

	Obs	Mean 1	Mean 2	Diff	St. Error	t value	P value
<i>Panel A: Volatility Spillover To (Transmitter)</i>							
Brazil–South Africa	572	8.498	6.620	1.877	.339	5.55	0
Brazil–India	572	8.498	8.376	.121	.354	.35	.732
Brazil–China	572	8.498	11.011	−2.513	.365	−6.85	0
Brazil–Russia	572	8.498	6.620	1.877	.339	5.55	0
<i>Panel B: Volatility Spillover From (Receiver)</i>							
Brazil–South Africa	572	6.846	9.432	−2.587	.232	−11.15	0
Brazil–India	572	6.846	9.097	−2.251	.174	−13	0
Brazil–China	572	6.846	10.441	−3.596	.193	−8.65	0
Brazil–Russia	572	6.846	9.389	−2.544	.16	−15.9	0
<i>Panel C: Volatility Spillover Net (Net)</i>							
Brazil–South Africa	572	1.652	−2.812	4.464	.481	9.30	0
Brazil–India	572	1.652	−0.721	2.373	.366	6.5	0
Brazil–China	572	1.652	0.570	1.083	.471	2.3	.022
Brazil–Russia	572	1.652	−2.812	4.464	.481	9.3	0

Table 3 Provides a mean comparison of volatility spillover receiver, transmitter, and net volatility spillover. Panel A, B, and C in Table 3 provide volatility spillover of the transmitter, receiver, and net volatility spillover respectively. Column 1 reports the BRICS countries. Column 2 provides information related to observations, column 3 provides mean 1, and column 4 reports mean 2. The difference between mean 1 and mean 2 is reported in column 5

The respective *t* value and *P* values are reported in columns 7 and 8 respectively.

A *P* value less than 0.05 reject the null hypothesis of no difference in the mean. In most cases of BRICS countries, we are rejecting the null hypothesis except in Brazil-India (see panel A).

Table 3 panel A shows that the mean volatility spillover of Brazil (as a transmitter) is significant in almost all cases except (Brazil-India). Similarly, the *t*-statistics in panel B of Table 3 show that the mean difference of volatility spillover is significant in all cases. The same conclusion can be drawn from panel C as well. Similarly, the visual of stock market volatility spillover is shown in Fig. 1 given below. Volatility below zero represents the market receiving volatility stocks (net) from other countries. A positive value indicates the country's stock market is transmitting volatility (net) shocks to other countries. As shown in Fig. 1, the Brazilian stock market is transmitting high-volatility stock to other countries (2019–2020). Positive volatility shocks (transmitter) are more dominant compared to negative volatility (receiver). Later on, the negative spikes are dominant for a limited period and such spillover fades away. Similarly, the Indian stock market has dominant-negative volatility spillover. Despite the initial high spikes, the Indian stock market is the recipient during the study period. Chinese stock market (2019–01 to 2020–07) is the net recipient of volatility spillovers. However, later on, the Chinese stock market became a transmitter of volatility shocks till the end of the study period. South African stock market is a dominant receiver of net volatility spillover

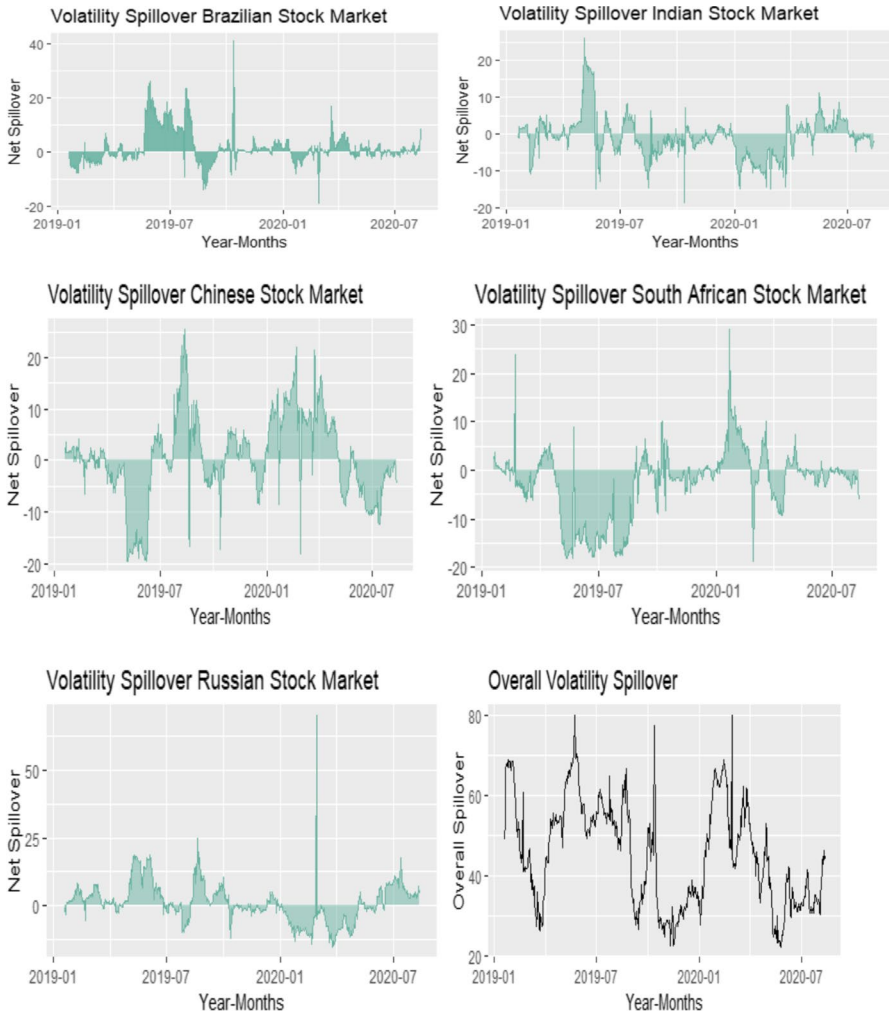


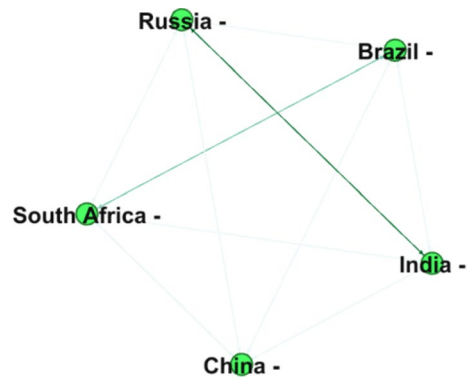
Fig. 1 Volatility Spillover in BRICS Financial Markets

(except for a few months with high positive spikes). Russian stock market (2019–2020), the positive spikes are dominant compared to negative volatility spillovers. Later on, the Russian stock market has mixed positive and positive spikes till the end of the study period. Overall, the bust and boom can be seen in the total spillover during the study period.

Table 4 Volatility spillover across BRICS countries

	I	II	III	IV	V	VI
	Brazil	India	China	Russia	South Africa	Contribution from
Brazil	0.8018	0.0003	0.0012	0.0002	0.1965	0.1982
India	0.0001	0.4985	0.0031	0.4983	0.0001	0.5015
China	0.0018	0.0028	0.9866	0.0029	0.0059	0.0134
Russia	0.0000	0.4984	0.0029	0.4986	0.0001	0.5014
South Africa	0.2351	0.0003	0.0092	0.0003	0.7551	0.2449
Contribution to other	0.2370	0.5018	0.0163	0.5017	0.2025	1.4594
Including own contribution	1.0388	1.0003	1.0030	1.0003	0.9576	

The results of volatility connectedness across BRICS are given in Table 4. Column I, II, III, IV, and V report pairwise volatility spillover of BRICS countries. Column VI excludes the volatility of its own country (contribution from) and reports the total volatility received from other countries in the sample. Similarly, the second last row reports volatility contribution to other countries in our sample

Fig. 2 Volatility Connectedness across BRICS Countries

6 Volatility Connectedness and Spillover across BRICS

The results of volatility connectedness across BRICS are given in Table 4 and Fig. 2. Column I, II, III, IV, and V report pairwise volatility spillover of BRICS countries. Column VI excludes the volatility of its own country (contribution from) and reports the total volatility received from other countries in the sample. Similarly, the second last row reports volatility contribution to other countries in our sample. The result has a clear pattern in volatility connectedness. As shown in last column VI, Brazil receives 19.82% volatility spillover from other countries (India, China, Russia, and South Africa). The major volatility spillover received from South Africa is 19.65% (see column V). The Brazilian financial markets have a clear connection with South African financial markets. The volatility connection of Brazil with India, China, and Russia is negligible (see columns II, III, and VI). Similarly, Indian financial markets receive 50.15% volatility from Brazil, Russia, China, and South Africa. Of 50.15% volatility spillover, the Indian financial market is receiving 49.83% volatility shock

from Russian financial markets. The Chinese financial market is receiving less volatility spillover from Brazil, India, Russia, and South Africa which is approximately 1.34% (see column VI). However, the Chinese financial markets have a volatility of 98.66% (see column III).

Similarly, Russian financial markets are receiving 50.14% volatility from Brazil, India, China, and South Africa. The major volatility received from India is approximately 49.84% (see column II). Finally, South Africa is receiving 24.49% volatility from Brazil, India, China, and Russia. Of 24.49% volatility spillover, Brazil is contributing 23.51%. On the other hand, as a transmitter (Contribution to other, second last row of Table 4), India and Russia have the same approximately the same contribution in volatility spillovers (see columns II and IV 50.18%, 50.17% respectively) other countries in our sample. Brazil, China, and South Africa contribute 23.7%, 1.63%, and 20.25% respectively.

Keeping in view the findings above, this study has found three major trends in financial market volatility connectedness. First, the Russian financial markets (stock market and foreign exchange market) have a strong connection with Indian financial markets. We believe that many reasons can explain such a strong connection. For example, the Russian and Indian economies have been increasingly interconnected in recent years due to economic cooperation and bilateral relations (Kapoor, 2019; Mukherjee, Bhattacharya, & Roy Chowdhury, 2022; Raghavan, 2016). The growing economic ties between the two countries, the opening up of the Indian economy, and the development of Russia's financial markets have increased economic activities between Russia and India (Cai, 2018; Kapoor, 2019; Raghavan, 2016). There has been a significant increase in the number of joint ventures and collaborations between Russian and Indian companies in various sectors, which has facilitated cross-border investments and financial flows (Cai, 2018; Raghavan, 2016). The establishment of the India-Russia Strategic Economic Dialogue (IRSED) in 2018 has also helped to strengthen the economic and financial ties between the two countries. Moreover, the Indian government's efforts to liberalize its financial sector have opened up new investment opportunities for Russian investors (Levi, 1999; Pentecost & Moore, 2006). To attract foreign investment, the Indian government has made significant initiatives to ease investment and developed financial markets instruments (Ataullah*, Cockerill, & Le, 2004; Pentecost & Moore, 2006).

Similarly, Russian authorities are also keen to develop financial markets, especially, the development of the Moscow Exchange which plays a key role in equity investments. The Russian government has established National Settlement Depository (NSD) to facilitate bond and equity investment. Moreover, the development of the Russian Trading System (RTS) has helped investors acquire relevant information and trade efficiently (Abramov, Radygin, & Chernova, 2021; Gorjaev, 2004; Matytsin, 2021; Mukherjee et al., 2022). The developments of NSD and RTS have facilitated investment and enhanced the efficiency, and transparency of trading in Russian capital markets. Such characteristics of Russian financial markets have attracted more investors from the globe including India (Cai, 2018; Kogut & Spicer, 2002).

Second, the result of this study also suggests strong volatility connectedness in Brazilian and South African financial markets. We have a humble belief that such results might be driven by the fact that Brazil and South Africa have also strong

political and economic ties. Especially, the multi-national corporations working in Brazil and South Africa have joint ventures and collaborations (Alden & Vieira, 2005; Diko & Sempijja, 2021; Mukherjee et al., 2022) which results in cross-border investments and flow of funds in Brazil and South Africa (Alden & Vieira, 2005; Vieira & Alden, 2011). Both countries (Brazil and South Africa) have observed tremendous development in financial markets (the development of the B3 stock market in Brazil and the Johannesburg Stock Exchange) has improved foreign and bilateral investment between these two countries (Oshikoya & Ogbu, 2000).

Finally, the Chinese financial is considered a relatively restrictive financial system (Hussain & Bashir, 2019, 2020; Hussain et al., 2021). China's weak financial market connections with other BRICS countries can be attributed to a range of factors, including regulatory barriers (Bao & Qiu, 2010; Blackman & Wu, 1999; Ghodsi, 2020), currency restrictions (Dobson & Masson, 2009), and differences in economic development levels. One of the main challenges facing China's financial market integration with other BRICS countries is regulatory barriers (Ouattara, 2017). China's strict capital controls make it difficult for foreign investors to invest in Chinese stocks or bonds, while also limiting the ability of Chinese investors to invest overseas (Ouattara, 2017). Such regulatory, trade, exchange rate, and investment barriers isolate the Chinese economy from the rest of the BRICS countries.

Similar connections are summarized in Fig. 2 given above. Figure 2 depicts the volatility spillover connectedness in BRICS in network structure. Each node is connected with the countries in our sample. The direction of the arrow shows the direction of volatility. The mild lines show weak connection and bold lines show a high magnitude of spillover. As shown in a network diagram, the Russian financial market has strong volatility connectedness with India. The direction of volatility spillover is from Russia to India. Similarly, Brazil has strong volatility connectedness with South Africa and the direction is from Brazil to South Africa. Finally, China has a weak volatility connection with BRICS countries.

7 Conclusion and Policy Implications

We enhance our understanding of exchange rate and stock price volatility connectedness and spillover during pandemic-induced crises. We have investigated pairwise connectedness and spillover in these financial markets in Brazil, Russia, India, China, and South Africa. The exchange rate and stock price mechanism can be explained by famous models, i.e., Stock Oriented and Flow Oriented models. Numerous studies have already been conducted on such dynamics. We depart from existing literature by focusing on pairwise volatility connectedness and spillover in the foreign exchange market and the stock market. We also find volatility connectedness across BRICS. The study also extends the literature by specifically focusing on the connection and volatility of these markets in pandemic-induced crises.

The study result finds that foreign exchange and stock markets are connected and volatility spillover occurred during pandemic-induced crises. Similarly, the evidence of volatility connectedness and spillover across BRICS countries are also significant. Three countries in the sample of this study, namely, India, Russia, and South

Africa have provided strong evidence of volatility connectedness and spillover. Russia-India has strong volatility connectedness. The spillover occurred from Russia to India in the study period. Similarly, Brazil-South Africa has connectedness and spillover occurred from Brazil to South Africa. China has weak volatility connectedness with remaining countries in BRICS.

The findings of the study suggest a strategy for optimizing portfolios by reducing risk and diversifying. Interestingly, the study also reveals differences in volatility connectedness among BRICS countries, allowing for the grouping of countries with lower volatility connectedness to assign optimal portfolio weights. This information can also help identify highly connected BRICS countries, where volatility in one market is creating volatility in others, increasing portfolio risk. For example, Russia-India has strong volatility connectedness. The spillover occurred from Russia to India in the study period. Similarly, Brazil-South Africa has connectedness and spillover occurred from Brazil to South Africa. China has weak volatility connectedness with remaining countries in BRICS. Such categorization can play a vital role in portfolio fund allocation. Similarly, the identification of major transmitters and receivers would help in optimal portfolio construction, and portfolio risk diversification. In addition to volatility connections across BRICS financial markets, the study also identifies major volatility receivers and givers in BRICS. Investors can consider the major receiver and giver into account when determining optimal portfolio allocation strategies and portfolio weights. Additionally, if a country is a giver of volatility, policymakers can take measures to manage its financial markets to prevent volatility shocks from givers (transmitters). If a country is a receiver of volatility, policymakers can enhance its financial resilience to mitigate the impact of volatility shocks from other countries. This categorization can also inform policymaking, enabling policymakers to design effective policies while considering potential risks and their consequences. Furthermore, the study's COVID-19 impact analysis posits new insights related to financial investment decisions. Investors typically overlook infectious diseases when making investment decisions, but the study shows significant effects of COVID-19 on net volatility spillover in the BRICS financial markets. This result emphasizes the importance of considering infectious diseases when evaluating investment returns.

Declarations

Conflict of interest The authors does not have any conflict of interest to disclose.

References

- AbdulHussein, A., Cozzarin, B., & Dimitrov, S. (2022). Changes in consumer spending behavior during the COVID-19 pandemic across product categories. *Electronic Commerce Research*. <https://doi.org/10.1007/s10660-022-09618-9>
- Abramov, A., Radygin, A., & Chernova, M. (2021). Russian stock market: Trends, challenges and solutions. *Academic view Voprosy ekonomiki*, 11, 5–32.
- Adeniyi, O., & Kumeka, T. (2020). Exchange rate and stock prices in Nigeria: Firm-Level evidence. *Journal of African Business*, 21(2), 235–263.

- Akbar, M., Iqbal, F., & Noor, F. (2019). Bayesian analysis of dynamic linkages among gold price, stock prices, exchange rate and interest rate in Pakistan. *Resources Policy*, 62, 154–164.
- Alden, C., & Vieira, M. A. (2005). The new diplomacy of the South: South Africa, Brazil. *India and Tri-lateralism. Third World Quarterly*, 26(7), 1077–1095.
- Ali, S. R. M., Mensi, W., Anik, K. I., Rahman, M., & Kang, S. H. (2022). The impacts of COVID-19 crisis on spillovers between the oil and stock markets: Evidence from the largest oil importers and exporters. *Economic Analysis and Policy*, 73, 345–372.
- Al-Yahyaee, K. H., Mensi, W., Al-Jarrah, I. M. W., Hamdi, A., & Kang, S. H. (2019). Volatility forecasting, downside risk, and diversification benefits of Bitcoin and oil and international commodity markets: A comparative analysis with yellow metal. *The North American Journal of Economics and Finance*, 49, 104–120.
- Ataullah, A., Cockerill, T., & Le, H. (2004). Financial liberalization and bank efficiency: a comparative analysis of India and Pakistan. *Applied Economics*, 36(17), 1915–1924.
- Baek, S., Mohanty, S. K., & Glambosky, M. (2020). COVID-19 and stock market volatility: An industry level analysis. *Finance Research Letters*, 37, 101748.
- Bao, X., & Qiu, L. D. (2010). Do technical barriers to trade promote or restrict trade? Evidence from China. *Asia-Pacific Journal of Accounting & Economics*, 17(3), 253–278.
- Bashir, U., Yu, Y., Hussain, M., & Zebende, G. F. (2016). Do foreign exchange and equity markets co-move in Latin American region? Detrended cross-correlation approach. *Physica a: Statistical Mechanics and Its Applications*, 462, 889–897.
- Blackman, A., & Wu, X. (1999). Foreign direct investment in China's power sector: Trends, benefits and barriers. *Energy Policy*, 27(12), 695–711.
- Bouri, E., Cepni, O., Gabauer, D., & Gupta, R. (2021). Return connectedness across asset classes around the COVID-19 outbreak. *International Review of Financial Analysis*, 73, 101646.
- Branson, W. H., & Henderson, D. W. (1985). The specification and influence of asset markets. *Handbook of International Economics*, 2, 749–805.
- Cai, C. (2018). Balanced investment treaties and the BRICS. *American Journal of International Law*, 112, 217–222.
- Carter, D., Mazumder, S., Simkins, B., & Sisneros, E. (2022). The stock price reaction of the COVID-19 pandemic on the airline, hotel, and tourism industries. *Finance Research Letters*, 44, 102047.
- Chkili, W., & Nguyen, D. K. (2014). Exchange rate movements and stock market returns in a regime-switching environment: Evidence for BRICS countries. *Research in International Business and Finance*, 31, 46–56.
- Dahir, A. M., Mahat, F., Ab Razak, N. H., & Bany-Arifin, A. (2018). Revisiting the dynamic relationship between exchange rates and stock prices in BRICS countries: A wavelet analysis. *Borsa Istanbul Review*, 18(2), 101–113.
- Das, N. M., Rout, B. S., & Khatun, Y. (2023). Does G7 engross the shock of COVID 19: An ASSESSMENT WITH MARKET VOLATILITY? *Asia-Pacific Financial Markets*. <https://doi.org/10.1007/s10690-023-09398-8>
- Diebold, F. X., & Yilmaz, K. (2012). Better to give than to receive: Predictive directional measurement of volatility spillovers. *International Journal of Forecasting*, 28(1), 57–66.
- Diko, N., & Sempijja, N. (2021). Does participation in BRICS foster South-South cooperation? Brazil, South Africa, and the Global South. *Journal of Contemporary African Studies*, 39(1), 151–167.
- Dobson, W., & Masson, P. R. (2009). Will the renminbi become a world currency? *China Economic Review*, 20(1), 124–135.
- Dornbusch, R., & Fischer, S. (1980). Exchange rates and the current account. *The American Economic Review*, 70(5), 960–971.
- Elgin, C., Yalaman, A., Yasar, S., & Basbug, G. (2021). Economic policy responses to the COVID-19 pandemic: The role of central bank independence. *Economics Letters*, 204, 109874.
- Fasanya, I. O., Oyewole, O., Adekoya, O. B., & Odei-Mensah, J. (2021). Dynamic spillovers and connectedness between COVID-19 pandemic and global foreign exchange markets. *Economic Research-Ekonomska Istraživanja*, 34(1), 2059–2084.
- Frankel, J. A. (1992). Monetary and portfolio-balance models of exchange rate determination *International economic policies and their theoretical foundations* (pp. 793–832): Elsevier.
- Gagnon, J. E., Kamin, S. B., & Kearns, J. (2023). The impact of the COVID-19 pandemic on global GDP growth. *Journal of the Japanese and International Economies*, 68, 101258.
- Ghods, M. (2020). The impact of Chinese technical barriers to trade on its manufacturing imports when exporters are heterogeneous. *Empirical Economics*, 59(4), 1667–1698.

- Goriaev, A. (2004). Risk factors in the Russian stock market. *Emerging Market Review*, 2(1), 67–89.
- Hansen, P. R., & Huang, Z. (2016). Exponential GARCH modeling with realized measures of volatility. *Journal of Business & Economic Statistics*, 34(2), 269–287.
- Havrilant, D., Darandary, A., & Muhsen, A. (2021). Early estimates of the impact of the COVID-19 pandemic on GDP: A case study of Saudi Arabia. *Applied Economics*, 53(12), 1317–1325.
- Huang, Q., Wang, X., & Zhang, S. (2021). The effects of exchange rate fluctuations on the stock market and the affecting mechanisms: Evidence from BRICS countries. *The North American Journal of Economics and Finance*, 56, 101340.
- Hung, N. T. (2021a). Directional spillover effects between BRICS stock markets and economic policy uncertainty. *Asia-Pacific Financial Markets*, 28(3), 429–448.
- Hung, N. T. (2021b). Financial connectedness of GCC emerging stock markets. *Eurasian Economic Review*, 11(4), 753–773.
- Hussain, M., & Bashir, U. (2013). Dynamic linkages of exchange rate and stock return volatility evidence from Pakistan, India and China (PIC). *International Review of Management and Business Research*, 2(2), 345.
- Hussain, M., & Bashir, U. (2019). Impact of monetary policy on bank lending: Does market structure matter? *International Economic Journal*, 33(4), 620–648.
- Hussain, M., & Bashir, U. (2020). Risk-competition nexus: Evidence from Chinese banking industry. *Asia Pacific Management Review*, 25(1), 23–37.
- Hussain, M., Bashir, U., & Bilal, A. R. (2021). Effect of monetary policy on bank risk: Does market structure matter? *International Journal of Emerging Markets*, 16(4), 696–725.
- Hussain, M., & Rehman, R. U. (2023). Volatility connectedness of GCC stock markets: How global oil price volatility drives volatility spillover in GCC stock markets? *Environmental Science and Pollution Research*, 30(6), 14212–14222.
- Hussain, M., Zebende, G. F., Bashir, U., & Donghong, D. (2017). Oil price and exchange rate co-movements in Asian countries: Detrended cross-correlation approach. *Physica a: Statistical Mechanics and Its Applications*, 465, 338–346.
- Inekwe, J. N. (2020). Liquidity connectedness and output synchronisation. *Journal of International Financial Markets, Institutions and Money*, 66, 101208.
- Kannianen, J., Lin, B., & Yang, H. (2014). Estimating and using GARCH models with VIX data for option valuation. *Journal of Banking & Finance*, 43, 200–211.
- Kapoor, N. (2019). *India-Russia Relations: Beyond Energy and Defence*: Observer Research Foundation.
- Kaushal, V., & Srivastava, S. (2021). Hospitality and tourism industry amid COVID-19 pandemic: Perspectives on challenges and learnings from India. *International Journal of Hospitality Management*, 92, 102707.
- Kogut, B., & Spicer, A. (2002). Capital market development and mass privatization are logical contradictions: Lessons from Russia and the Czech Republic. *Industrial and Corporate Change*, 11(1), 1–37.
- Koop, G., Pesaran, M. H., & Potter, S. M. (1996). Impulse response analysis in nonlinear multivariate models. *Journal of Econometrics*, 74(1), 119–147.
- Koulakiotis, A., Kiohos, A., & Babalos, V. (2015). Exploring the interaction between stock price index and exchange rates: An asymmetric threshold approach. *Applied Economics*, 47(13), 1273–1285.
- Kumar, S. (2019). Asymmetric impact of oil prices on exchange rate and stock prices. *The Quarterly Review of Economics and Finance*, 72, 41–51.
- Kumar, S., Tiwari, A. K., Chauhan, Y., & Ji, Q. (2019). Dependence structure between the BRICS foreign exchange and stock markets using the dependence-switching copula approach. *International Review of Financial Analysis*, 63, 273–284.
- Larionova, M., & Shelepov, A. (2022). BRICS, G20 and global economic governance reform. *International Political Science Review*, 43(4), 512–530.
- Levi, S. (1999). India, Russia and the eighteenth-century transformation of the Central Asian caravan trade. *Journal of the Economic and Social History of the Orient*, 42(4), 519–548.
- Li, Y., Zhuang, X., Wang, J., & Dong, Z. (2021). Analysis of the impact of COVID-19 pandemic on G20 stock markets. *The North American Journal of Economics and Finance*, 58, 101530.
- Liu, L., & Wan, J. (2012). The relationships between Shanghai stock market and CNY/USD exchange rate: New evidence based on cross-correlation analysis, structural cointegration and nonlinear causality test. *Physica a: Statistical Mechanics and Its Applications*, 391(23), 6051–6059.
- Long, H., Chang, C.-P., Jegajeevan, S., & Tang, K. (2022). Can Central Bank mitigate the effects of the COVID-19 pandemic on the macroeconomy? *Emerging Markets Finance and Trade*, 58(9), 2652–2669.

- Mahapatra, S., & Bhaduri, S. N. (2019). Dynamics of the impact of currency fluctuations on stock markets in India: Assessing the pricing of exchange rate risks. *Borsa Istanbul Review*, 19(1), 15–23.
- Matytsin, D. E. (2021). Digital technologies of the Bank of Russia for regulating investment relations *Smart Technologies for the Digitisation of Industry: Entrepreneurial Environment* (pp. 227–240): Springer.
- Meyer, B. H., Prescott, B., & Sheng, X. S. (2022). The impact of the COVID-19 pandemic on business expectations. *International Journal of Forecasting*, 38(2), 529–544.
- Mnif, E., Salhi, B., Mouakha, K., & Jarboui, A. (2022). Investor behavior and cryptocurrency market bubbles during the COVID-19 pandemic. *Review of Behavioral Finance*(ahead-of-print).
- Mohamed, O. A. S., & Elmahgop, F. O. M. (2020). Is the effect of the exchange rate on stock prices symmetric or asymmetric? Evidence from Sudan. *International Journal of Economics and Financial Issues*, 10(2), 209.
- Mukherjee, P., Bhattacharya, P., & Roy Chowdhury, S. (2022). Financial Liberalization and Convergence of Financial Development Among BRICS Economies *Revisiting the Indian Financial Sector: Recent Issues and Perspectives* (pp. 85–118): Springer.
- Ortmann, R., Pelster, M., & Wengerek, S. T. (2020). COVID-19 and investor behavior. *Finance Research Letters*, 37, 101717.
- Oshikoya, T. W., & Ogbu, O. (2000). Financial liberalization, emerging stock markets and economic developments in Africa.
- Ouattara, B. S. (2017). Re-examining stock market integration among BRICS countries. *Eurasian Journal of Economics and Finance*, 5(3), 109–132.
- Pan, M.-S., Fok, R.C.-W., & Liu, Y. A. (2007). Dynamic linkages between exchange rates and stock prices: Evidence from East Asian markets. *International Review of Economics & Finance*, 16(4), 503–520.
- Panwar, R., Pinkse, J., & De Marchi, V. (2022). The future of global supply chains in a post-COVID-19 world. *California Management Review*, 64(2), 5–23.
- Pentecost, E. J., & Moore, T. (2006). Financial liberalization in India and a new test of the complementarity hypothesis. *Economic Development and Cultural Change*, 54(2), 487–502.
- Phylaktis, K., & Ravazzolo, F. (2005). Stock prices and exchange rate dynamics. *Journal of International Money and Finance*, 24(7), 1031–1053.
- Pramana, S., Paramartha, D. Y., Ermawan, G. Y., Deli, N. F., & Srimulyani, W. (2022). Impact of COVID-19 pandemic on tourism in Indonesia. *Current Issues in Tourism*, 25(15), 2422–2442.
- Raghavan, P. (2016). India-russia strategic partnership—A mutual commitment. *Indian Foreign Affairs Journal*, 11, 302–307.
- Rai, K., & Garg, B. (2021). Dynamic correlations and volatility spillovers between stock price and exchange rate in BRIICS economies: Evidence from the COVID-19 outbreak period. *Applied Economics Letters*, 29, 1–8.
- Shaik, M., & Rehman, M. Z. (2023). The Dynamic volatility connectedness of major environmental, social, and governance (ESG) stock indices: Evidence based on DCC-GARCH model. *Asia-Pacific Financial Markets*, 30(1), 231–246.
- Sheikh, U. A., Asad, M., Ahmed, Z., & Mukhtar, U. (2020). Asymmetrical relationship between oil prices, gold prices, exchange rate, and stock prices during global financial crisis 2008: Evidence from Pakistan. *Cogent Economics & Finance*, 8(1), 1757802.
- Sikhosana, A., & Aye, G. C. (2018). Asymmetric volatility transmission between the real exchange rate and stock returns in South Africa. *Economic Analysis and Policy*, 60, 1–8.
- So, M. K., Chan, L. S., & Chu, A. M. (2021). Financial network connectedness and systemic risk during the COVID-19 pandemic. *Asia-Pacific Financial Markets*, 28(4), 649–665.
- Trabelsi, N. (2019). Dynamic and frequency connectedness across Islamic stock indexes, bonds, crude oil and gold. *International Journal of Islamic and Middle Eastern Finance and Management*, 12(3), 306–321.
- Truong, D., & Truong, M. D. (2022). How do customers change their purchasing behaviors during the COVID-19 pandemic? *Journal of Retailing and Consumer Services*, 67, 102963.
- Tsai, I.-C. (2012). The relationship between stock price index and exchange rate in Asian markets: A quantile regression approach. *Journal of International Financial Markets, Institutions and Money*, 22(3), 609–621.
- Tule, M., Dogo, M., & Uzonwanne, G. (2018). Volatility of stock market returns and the naira exchange rate. *Global Finance Journal*, 35, 97–105.

- Ülkü, N., & Demirci, E. (2012). Joint dynamics of foreign exchange and stock markets in emerging Europe. *Journal of International Financial Markets, Institutions and Money*, 22(1), 55–86.
- Umar, Z., & Gubareva, M. (2021). Faith-based investments and the Covid-19 pandemic: Analyzing equity volatility and media coverage time-frequency relations. *Pacific-Basin Finance Journal*, 67, 101571.
- Vieira, M. A., & Alden, C. (2011). India, Brazil, and South Africa (IBSA): South-South cooperation and the paradox of regional leadership. *Global Governance*, 17, 507.
- Wong, H. T. (2017). Real exchange rate returns and real stock price returns. *International Review of Economics & Finance*, 49, 340–352.
- Yang, S.-P. (2017). Exchange rate dynamics and stock prices in small open economies: Evidence from Asia-Pacific countries. *Pacific-Basin Finance Journal*, 46, 337–354.
- Yuan, Y., Wang, H., & Jin, X. (2022). Pandemic-driven financial contagion and investor behavior: Evidence from the COVID-19. *International Review of Financial Analysis*, 83, 102315.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.