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PRE AND POST COVID VOLATILITY SPILL-OVER EFFECTS OF BRICS STOCK MARKETS

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Abstract

We examined the cointegration and volatility spill-over effects of stock markets of BRICS nations during pre and post COVID 19. We estimated the daily volatility of stock markets considering the open, close, high and low price during pre and post crisis. Cointegrated markets exhibit spill-over effects. Applying Johansen Cointegration, we found the stock markets of BRICS countries are cointegrated. VECM is applied to decompose the variance and estimate the spill-over index. The study found there is significant volatility spill-over during pre and post COVID

Key words: Vector Error Correction Model; COVID 19; Volatility Spill-over; BRICS; Johansen co-integration test; Granger Causality Test

Introduction

The advent of globalization has brought the world into a single global village. It has interlinked countries and their markets. Today, the inter-dependence between economies is evident. It is most obvious in financial markets. Several other factors like the relaxation of restriction on capital inflows and foreign investments have also led to this integration (Mishra et al., 2007). This integration has led to some shocks affecting the financial market of a country to also affect the other integrated markets.

Several research studies were done to investigate these relationships between markets. Many authors have studied return and volatility spillovers between markets during a crisis like H1N1, Global Financial Crisis, Asian Crisis, etc. They have used variations of GARCH, ARIMA, Panel Data Regression and wavelet models to find the relationship between markets. Some have found unidirectional and bidirectional return and volatility spillovers.

Covid-19 is one of the global crisis that has adversely affected countries all over the world. The financial contagion has followed the physical contagion from China to Europe and the US. It has affected more than 12 million people and the cases are still increasing rapidly. It has led to closure or suspension of physical markets, industries, public services, schools and infrastructure projects. The economy of countries has been drastically affected by this pandemic. The GDP growth of India plummeted to 3.1% in the fourth quarter of FY20. There have been many actions taken by governments and prominent central banks around the world to revive the economy. The Federal Reserve had cut its benchmark interest rate to 0.00%-0.25% during March 2020. The US government has allocated around $2.8 trillion for its relief packages. So, given these dire impacts on almost all sectors, it has turned out to be a subject of prime importance for investigation.

The objective of the research is to study the financial integration and volatility spill-overs in financial markets of BRICS countries pre- and post-covid. BRICS was chosen for the study because it constitutes the promising emerging markets in the world and constitutes around one-third of global GDP and more than 40% of the global population. They have also accumulated significant foreign reserves in comparison to other trading blocs. China with $3.061 trillion in foreign reserve in March 2020, tops the list of top 10 countries with the biggest forex reserves in the world. This study would be of significant importance for private investors, fund managers and wealth management banks to use these results while deriving strategies for portfolio diversification and hedging. It is also useful for policymakers to make informed decisions and policies.

The Vector Auto-Regression(VAR) and Vector Error Correction Models(VECM) were used in the research since the investigation involved statistical analysis of the linear relationship between multiple time-series data. It is a concrete model with good forecasting capabilities. It is one of the Autoregressive models with variables used in the model exhibiting bi-directional characteristics.

This paper is structured into six sections. Section II covers the Literature Review. Section III explains the methodology used for the study. The Empirical Results and Analysis from the research are enumerated in Section IV. And, the final conclusion is provided in Section V.

Literature Review

There have been numerous financial articles written on the stock volatility spill-over effect and financial integration among global stock markets during a pandemic or a global crisis. There were studies done on stock markets during the Asian Crisis of 1997, Crisis in Russia during1998, Global financial crisis (GFC) of 2007, H1N1 pandemic in 2009, etc.

Bhatt (2011) and L. Li et al. (2012) have investigated the aftermath of global financial crisis (GFC) on the Chinese and Indian economy. They have detailed the effect of the crisis on the financial sector, exports and exchange rates. They also discuss the government’s interventions during different phases of the crisis, to stimulate the economy.

The H1NI pandemic of 2009 was also popular due to its impact on a global scale. Ritterman et al. (2009) proposed that stock price during a pandemic depends on internal and external factors and they used twitter data with internal data and the historical context to predict stock price using SVM regression Classifier.

The COVID-19 pandemic is the latest in the list of the pandemic which has affected around 12 million people worldwide as on 10th July 2020. Due to its global impact there has been several studies on its impact on the financial markets at its nascent stage (Corbet, Hou, et al., 2020; Papadamou, 2020). Goodell (2020), Henry et al. (2020) and Schoenfeld (2020) have analysed the effect of corona on various sectors of economy.

Akhtaruzzaman et al. (2020) studied the financial contagion during Covid-19 using DCC method of GARCH model and Diebold and Yilmaz model and analysed how China and Japan stood as net transmitters of financial contagion similar to virus contagion to BRICS countries. Al-Awadhi et al. (2020) studied the impact of number of confirmed cases and deaths on stock market returns using Panel Data Regression method for various sectors. They have also investigated the impact on A-shares and B-shares.

Ali et al. (2020) and Corbet, Larkin, et al. (2020) have used GARCH and E-GARCH method to determine the volatility changes in Chinese, European and US stock returns, Gold, Oil and Crypto currency as the epicentre of Covid-19 moved from China to Europe and later to US. A similar study by Sharif et al. (2020) has compared the impact of oil price slump and Covid-19 on the US economy. They have used Wavelet Transform method and have considered Geo-political Risk Index (GPR) and also Economic Policy Uncertainty Index (EPU) for studying the effect on stock returns. Zaremba et al. (2020) examined the consequence of various government interventions recorded in the Oxford Covid-19 response tracker on the stock return volatility using Random Effects Estimation method.

The volatility changes observed in stock markets are correlated across regions during any global crisis. Many literatures like Babecký et al. (2013), Baillie (1996), Bhar and Nikolova (2007), and Sharma et al. (2013) have detailed the integration of markets during these adverse situations.

Another common scenario that is evidenced during most crisis is the return and volatility spill-over from the epicentre of the crisis to other regions. It is mainly due to the inter-connectedness brought by globalization (Baele, 2005; Booth et al., 1997; Hu et al., 1997; Jebran & Iqbal, 2016b; Joshi, 2011). Bhar & Nikolova (2009) and Boubaker & Raza (2017) have used EGARCH, VARMA and wavelet models to analyse the volatility spill-over in stock returns and oil prices in BRICS countries. Grobys (2015) and Joshi (2011) have utilized VAR and

GARCH-BEKK model to investigate the return and volatility spill-over in US and Asian stock markets. Jebran et al. (2017) used EGARCH method to investigate the volatility spill-over among stock markets of emerging nations in Asia from normal to turbulent periods. They also studied how negative news has generated more volatility compared to positive news. Kim et al. (2015) investigating the spill-over effects during the Global Financial Crisis, have concluded how the foreign investment and the down fall of Lehman Brothers during the late 2008 has led to a financial contagion in International Equity markets. The return and volatility spill-over effects are of immense importance to International investors looking for portfolio diversification and to optimize return-risk ratios (Syriopoulos et al., 2015).

Some researchers have also investigated the bi-directional return and volatility spill-overs in various stock markets (Y. Li & Giles, 2015; Ng, 2000; Zivkov et al., 2015). Jung and Maderitsch (2014) analysed the time-variation in volatility spill-overs during various structural breaks from 2000 to 2011 in the financial markets of Hong Kong, Europe and US.

The volatility spill-over is not always between global stock markets. It can also be witnessed in domestic markets between various sectors and asset classes. There are literatures comprehending the bi-directional spill-over effects between stock market and foreign exchange rate market (Hong, 2001). Jebran and Iqbal (2016a) studied the spill-over effects between stock market and forex market in India, China, Japan, Pakistan, Hong Kong and Sri Lanka from 1999 up to 2014 using EGARCH method. The results concluded from the study were bi-directional volatility spill-over between both the markets in Pakistan, Hong Kong, China and Sri Lanka; unidirectional volatility transference from Indian stock market to forex market; and no volatility transmission between the two markets in Japan.

Mikhaylov (2018) has done a similar analysis on bi-directional volatility spill-over between stock price and foreign exchange rate in 4 oil-exporting countries, that is, Brazil, Russia, India and China. The price volatility occurs mainly due to either currency fluctuations or change in interest rate. FIGARCH model of the long memory was used for analysis. Modified methods of Iterations for Cumulative Sum of Squares (ICSS) algorithm was used to determine the structural breaks in the available sample. The empirical results from the study showed that there is no major spill-over effect in Chinese stock market.

Mishra et al. (2007) have done a similar study in the Indian scenario using GARCH and EGARCH methods. The study concluded that there is a high level of integration between these markets in India due to a long-run information transfer between these two markets. These results indicate that portfolio investors could use information from one market and use it in the other market. Sui and Sun (2016) have also done a similar study in the markets of BRICS. It was concluded that the spill-over effects were stronger during the Great Recession.

In our research we have compared the volatility spill-over and the financial integration between stock markets in BRICS countries during pre-Covid and post-Covid. It is of vital importance as Covid as turned out to be a global pandemic and a pressing problem to financial markets. And BRICS was chosen as it constitutes 33% of the Global GDP in 2019, 19% of global exports, 16% of global imports and 42% of global population. It is also predicted that by 2030 its economy will exceed the combined economy of US and European countries, making this study as significant for global investors and policy makers.

Methodology

3.1 Data input

We obtained the major stock market index data of BRICS Nations. The following are the indices of stock market, using which we examined the cointegration and estimate volatility spill-over index.

Table 1: Major Indexes in BRICS countries

Index	Country
IBOVESPA	Brazil
MOEX	Russia
SENSEX	India
SSE COMPOSITE	China
FTSE/JSE	South Africa

The sample data for pre-covid covers the period between July and December 2019. The frequency of data includes daily high, low, open and closing index. Post-covid data includes data between January and June 2020.

Return=ln($CO_t|CO_{t-1}$)

where CO_t is the closing price for the current period and CO_{t-1} is the previous period closing price.

3.2 Augmented Dickey-Fuller(ADF) Test

The ADF test is used to examine the stationarity in a given time series data. If there is unit root in the data, the dataset is said to be non-stationary. A non-stationary process has variable variance and mean non-equal to zero, leading to spurious results. A stationary process carries constant variance irrespective of time and mean reverting to zero. This test examines the existence of unit root in the series for three levels i.e. only constant, trend & constant, no trend and constant.

The equation used in the ADF test is,

$$\boxed{\Delta Y_t = \lambda + \gamma Y_{t-1} + \sum_{j=1}^{p} \alpha_j \Delta Y_{t-j} + \beta t + \omega_t}$$

in which λ represents the random walk drift

γ represents constant for linear trend

P represents maximum lag length

β represents constant for time trend

Once the stationarity of data is determined, the co-integration between various index are determined using Johansen co-integration test. Once the integration is estimated, a study on the spill-over index is performed using Vector Auto Regression(VAR) and Vector Error Decomposition models.

3.3 Granger Causality Test

The Granger Causality test is a statistical hypothesis to estimate the causal relationship between two given dataset. The causality may be unidirectional and/or bidirectional.

The test begins by converting the time series data to its first order I(1) and then a regression is performed on the converted data. When "p" is assumed as an autoregressive lag length, the unrestricted equation is estimated as follows using ordinary least squares (OLS):

$$x_t = c_1 + \sum_{i=1}^{p} \alpha_i x_{t-i} + \sum_{i=1}^{p} \beta_i y_{t-i} + u_t$$

$$H_0 : \beta_1 = \beta_2 = \ldots = \beta_p = 0$$

A null hypothesis is determined. After forming the null hypothesis, an F-test is performed using the below restricted equation by OLS.

$$x_t = c_t + \sum_{i=1}^{p} \gamma_i x_{t-i} + e_t$$

Then, their corresponding Sum of Squared Residuals(SSR) are compared

$$RSS_1 = \sum_{t=1}^{T} \hat{u}_t^2 \qquad RSS_0 = \sum_{t=1}^{T} \hat{e}_t^2$$

The investigated test statistic is S_1. If S_1 ,

$$S_1 = \frac{(RSS_0 - RSS_1)/p}{RSS_1/(T-2p-1)} \sim F_{p,\,T-2p-1}$$

is above critical value that is specified, then the null hypothesis which is Y does not Granger-cause X can be rejected.

Empirical Results And Analysis

4.1 Statistics from ADF test

Table 2: ADF test for the returns of stock markets of BRICS

Market	Intercept	Trend and Intercept	No Intercept and Trend
Brazil	-0.822895	-0.835255	-0.822884
	(0.0000)*	(0.0000)*	(0.0000)*
MOEX	-1.137444	-1.148831	-1.13361
	(0.0000)*	(0.0000)*	(0.0000)*
Sensex	-1.092589	-1.092655	-1.090357
	(0.0000)*	(0.0000)*	(0.0000)*
SSE COMPOSITE	-0.965641	-0.985646	-0.95112
	(0.0000)*	(0.0000)*	(0.0000)*
FTSE/ JSE	-1.011393	-1.014319	-1.011322
	(0.0000)*	(0.0000)*	(0.0000)*

H_0: The index data that is investigated is non-stationary.

H_1: The index data that is investigated is stationary.

The significance of the results is tested at **5 %** level.

We apply the unit root test at three levels. The equations for the three levels are, Random walk (No drift and Trend): $\Delta_y = \gamma y_{t-1} + \varepsilon_t$

Drift without linear time trend: $\Delta_y = \alpha_0 + \gamma y_{t-1} + \varepsilon_t$

Drift and linear time trend: $\Delta_{y_t} = \alpha_0 + \gamma y_{t-1} + \alpha_2 t + \varepsilon_t$

The test result indicates the times series data of stock market are stationary at first difference for all three equations.

4.2 Johansen Co-integration test

The Johansen cointegration test (1988, 1995) is used to investigate whether the stock markets of BRICS countries are cointegrated. This test is appropriate to study the long-run relationship between movements in different stock markets. The statistics from the unit root test indicate that the market returns of all BRICS countries are integrated of the same order I(1). Next, unrestricted VAR is performed to identify the number of co-integrating equations. The assumption of **'No intercept and trend'** is made to run the model are no intercept and trend in co-integrating equation and VAR.

Table 3: Statistics from the unrestricted Co-integration Rank Test (Trace)

Hypothesized		Trace(%)	5%	
Number of CE(s)	Eigen value	Test Statistic	Critical Value	Probability**
None *	0.42	202.93	69.82	0.00
At most 1 *	0.33	137.03	47.86	0.00
At most 2 *	0.28	88.94	29.80	0.00
At most 3 *	0.20	48.57	15.50	0.00
At most 4 *	0.16	21.19	3.84	0.00

Table 4: Statistics from the unrestricted Co-integration Rank Test (Maximum Eigen value)

Hypothesized		Max-Eigen(%)	5%	
Number of CE(s)	Eigen value	Test Statistic	Critical Value	Probability**
None *	0.42	65.91	33.88	0.00
At most 1 *	0.33	48.08	27.58	0.00
At most 2 *	0.28	40.38	21.13	0.00
At most 3 *	0.20	27.37	14.26	0.00
At most 4 *	0.16	21.19	3.84	0.00

* indicates the rejection of H_0 at 5% significance.

** indicates MacKinnon-Haug-Michelis (1999) p-values.

Table 5: Statistics of Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I)

BRAZIL	**CHINA**	**INDIA**	**RUSSIA**	**SOUTH AFRICA**
-103.1872	-44.68891	142.0433	-5.97533	98.34538
166.8276	136.9432	50.82651	-169.9005	-39.00204
56.96445	-139.0816	-29.87355	-13.53273	203.2048
65.99005	-81.49028	112.0898	152.6765	-127.879
-26.72359	146.1446	-12.94593	152.1536	-30.60821

Table 6: Statistics of Unrestricted Adj. Coefficients (alpha)

D(BRAZIL)	0.003833	-0.003134	-0.003721	-0.001708	3.87E-06
D(CHINA)	-0.000986	-0.00245	0.000585	0.001356	-0.002223
D(INDIA)	-0.005371	-0.001394	-0.000389	-0.00256	1.60E-05
D(RUSSIA)	0.000934	0.001504	-0.001394	-0.001523	-0.002285
D(SOUTH AFRICA)	-0.001729	0.000257	-0.004522	0.001100	-0.00161

Table 7: Results from Johansen cointegration test of BRICS stock market

Statistics with 1 co-integrating Equation		Log likelihood	2043.372	
Co-integrating coefficients (normalized) (S.E. is represented in parentheses)				
BRAZIL	CHINA	INDIA	RUSSIA	SOUTH AFRICA
1.000000	0.433086	-1.376559	0.057908	-0.953077
	(0.28014)	(0.20824)	(0.27777)	(0.28116)
Adj. Coefficients (S.E. is represented in parentheses)				
D(BRAZIL)	-0.395501			
	(0.10519)			
D(CHINA)	0.101721			
	(0.07693)			
D(INDIA)	0.554222			
	(0.08765)			
D(RUSSIA)	-0.096401			
	(0.07579)			
D(SOUTH AFRICA)	0.178448			
	(0.09800)			

Statistics with 2 co-integrating Equations		Log likelihood	2067.414	

Co-integrating coefficients (normalized) (S.E. is represented in parentheses)				
BRAZIL	CHINA	INDIA	RUSSIA	SOUTH AFRICA
1.000000	0.000000	-3.254201	1.259983	-1.756403
		(0.47047)	(0.62967)	(0.57421)
0.000000	1.000000	4.335500	-2.775608	1.854889
		(0.66681)	(0.89244)	(0.81383)
Adj. Coefficients (S.E. is represented in parentheses)				
D(BRAZIL)	-0.918307	-0.60044		
	(0.19119)	(0.14040)		
D(CHINA)	-0.307083	-0.291519		
	(0.13888)	(0.10199)		
D(INDIA)	0.321678	0.049138		
	(0.16458)	(0.12086)		
D(RUSSIA)	0.154586	0.164277		
	(0.14130)	(0.10376)		
D(SOUTH AFRICA)	0.221388	0.112531		
	(0.18624)	(0.13676)		

Statistics with 3 co-integrating Equations		Log likelihood	2087.603	
Co-integrating coefficients (normalized) (S.E. is represented in parentheses)				
BRAZIL	CHINA	INDIA	RUSSIA	SOUTH AFRICA
1.000000	0.000000	0.000000	-0.762255	0.651521
			(0.21897)	(0.19469)
0.000000	1.000000	0.000000	-0.081424	-1.353134
			(0.22592)	(0.20087)
0.000000	0.000000	1.000000	-0.621424	0.739943
			(0.21433)	(0.19056)
Adj. Coefficients (S.E. is represented in parentheses)				
D(BRAZIL)	-1.130277	-0.082904	0.496311	
	(0.18543)	(0.18177)	(0.13961)	
D(CHINA)	-0.273757	-0.372886	-0.282049	
	(0.14417)	(0.14133)	(0.10855)	
D(INDIA)	0.299535	0.103199	-0.822156	
	(0.17121)	(0.16783)	(0.12891)	
D(RUSSIA)	0.075176	0.358161	0.250813	
	(0.14461)	(0.14176)	(0.10888)	
D(SOUTH AFRICA)	-0.036187	0.741415	-0.097482	
	(0.17278)	(0.16937)	(0.13009)	

Statistics with 4 co-integrating Equations		Log likelihood	2101.288	
Co-integrating coefficients (normalized) (S.E. is represented in parentheses)				
BRAZIL	CHINA	INDIA	RUSSIA	SOUTH AFRICA
1.000000	0.000000	0.000000	0.000000	-0.391804
				(0.14826)
0.000000	1.000000	0.000000	0.000000	-1.464581
				(0.18245)
0.000000	0.000000	1.000000	0.000000	-0.110621
				(0.14005)
0.000000	0.000000	0.000000	1.000000	-1.368734
				(0.19043)
Adj. Coefficients (S.E. is represented in parentheses)				
D(BRAZIL)	-1.243006	0.056303	0.304831	0.299077
	(0.19171)	(0.19307)	(0.16996)	(0.20442)
D(CHINA)	-0.184301	-0.483353	-0.130101	0.621274
	(0.14894)	(0.15000)	(0.13205)	(0.15882)
D(INDIA)	0.130621	0.311789	-1.109072	-0.116624
	(0.17213)	(0.17335)	(0.15260)	(0.18355)
D(RUSSIA)	-0.025311	0.482251	0.080127	-0.474817
	(0.14874)	(0.14979)	(0.13186)	(0.15861)
D(SOUTH AFRICA)	0.036389	0.651791	0.025794	0.195707
	(0.18017)	(0.18145)	(0.15973)	(0.19213)
* indicates the rejection of H_o at 0.05 level. ** indicates the Eigen value.				

The results of the co-integration test are interpreted on the basis of two Likelihood ratio(LR) statistics, namely, the Trace test and the Maximum Eigen value test.

The hypotheses of co-integration test to determine the number of co-integrating equations are,

H_0: $r = r_o$ (None – no cointegration)

H_1: $r_o < r < k$ (There exists 'r' number of co-integrating equations)

in which, **'k'** represents the number of variables.

The hypothesis is evaluated sequentially starting from none and proceeding to 'k' in unit steps until a position is reached, where H_0 cannot be rejected. H_0 is rejected if the trace or Eigen value is greater than the critical value or the probability is less than 0.05 level.

The results from the Trace test and Maximum Eigen value illustrates that there are 4 co-integrating equations in the dataset, which means, the stock markets of all BRICS countries are not co-integrated.

4.3 Spill-over Index

Spill-over is the transmission of volatility induced by one variable in to another variable that is supposed to be cointegrated. The spill-over effect occurs when one or more markets are interlinked. The spill-over index measures the percentage of forecast error variance caused by own and other variables. We construct spill-over index for the return and volatility series of the stock indices of BRICS countries.

We follow the step wise conceptual process to model return and volatility spill-over for the BRICS countries. The procedural steps involved are as follows

Step 1: Check whether the historical series of return is stationary using Augmented Dickey Fuller test

Step 2: Run unrestricted Vector Auto Regression to estimate the optimum lag structure (p)

Step 3: The number of co-integrating equations (r) are determined using Johansen co-integration test at (p) lags.

Step 4: Apply the decision rule to choose between Vector Auto Regression (VAR) and Vector Error Correction Model (VECM). If there is no co-integration among the taken variables, VAR model is employed and if there is at least one co-integration VECM model is applied.

Step 4: Estimate the parameters of VECM model taking (p-1) lag.

Step 5: Forecast 10 days ahead variance decomposition for return and volatility.

Step 6: Perform diagnostics test to check for model accuracy.

Step 7: Construct the spill-over index separately for the series of return and volatility of BRICS countries.

Table 8: Co-integrating Equation-1 Estimates for BRICS

Co-integrating Equation:	**Co-integrating Equation-1**
BRAZIL (-1)	1.000000
CHINA (-1)	0.433086
	(0.28014)
	[1.54597]
INDIA (-1)	-1.376559
	(0.20824)
	[-6.61057]
RUSSIA (-1)	0.057908
	(0.27777)
	[0.20848]
SOUTH AFRICA (-1)	-0.953077
	(0.28116)

	[-3.38981]
C	-0.00062

Table 9: Vector Error Correction Model Estimates durimg Pre-Covid

Error Correction	**D (BRAZIL)**	**D (CHINA)**	**D (INDIA)**	**D (RUSSIA)**	**D (SOUTH AFRICA)**
Co-integration Equation-1	-0.395501	0.101721	0.554222	-0.096401	0.178448
	(0.10519)	(0.07693)	(0.08765)	(0.07579)	(0.09800)
	[-3.75975]	[1.32223]	[6.32285]	[-1.27199]	[1.82091]
D (BRAZIL (-1))	-0.409289	0.043968	-0.4247	0.075278	-0.04086
	(0.10964)	(0.08018)	(0.09136)	(0.07899)	(0.10214)
	[-3.73306]	[0.54835]	[-4.64876]	[0.95300]	[-0.40002]
D (BRAZIL (-2))	-0.259977	0.080231	-0.25274	0.115828	-0.00293
	(0.09228)	(0.06749)	(0.07689)	(0.06648)	(0.08597)
	[-2.81726]	[1.18883]	[-3.28691]	[1.74220]	[-0.03406]
D (CHINA (-1))	0.137956	-0.78622	-0.10959	-0.009726	0.037276
	(0.13689)	(0.10011)	(0.11407)	(0.09862)	(0.12753)
	[1.00779]	[-7.85339]	[-0.96076]	[-0.09862]	[0.29230]
D (CHINA (-2))	0.100252	-0.25081	0.175291	0.089235	0.056490
	(0.13107)	(0.09585)	(0.10921)	(0.09443)	(0.12210)
	[0.76490]	[-2.61661]	[1.60504]	[0.94501]	[0.46264]
D (INDIA (-1))	-0.418271	0.139297	-0.04008	-0.160791	0.169895
	(0.13125)	(0.09599)	(0.10937)	(0.09456)	(0.12228)

	[-3.18671]	[1.45115]	[-0.36646]	[-1.70035]	[1.38941]
D (INDIA (-2))	-0.18192	0.123368	0.050395	-0.138815	0.214075
	(0.10549)	(0.07715)	(0.08790)	(0.07600)	(0.09827)
	[-1.72457]	[1.59916]	[0.57334]	[-1.82655]	[2.17837]
D (RUSSIA (-1))	0.170126	-0.03454	-0.08596	-0.607724	0.042351
	(0.12911)	(0.09442)	(0.10759)	(0.09302)	(0.12028)
	[1.31764]	[-0.36581]	[-0.79901]	[-6.53320]	[0.35210]
D (RUSSIA (-2))	-0.006564	0.050701	-0.11373	-0.420387	0.060721
	(0.13025)	(0.09525)	(0.10853)	(0.09384)	(0.12134)
	[-0.05040]	[0.53228]	[-1.04793]	[-4.47999]	[0.50043]
D (SOUTH AFRICA (-1))	-0.252271	0.178062	0.516566	-0.09279	-0.59673
	(0.12571)	(0.09193)	(0.10475)	(0.09057)	(0.11711)
	[-2.00679]	[1.93683]	[4.93149]	[-1.02454]	[-5.09539]
D (SOUTH AFRICA (-2))	-0.197958	0.051934	0.348716	-0.027366	-0.39336
	(0.11116)	(0.08129)	(0.09262)	(0.08008)	(0.10355)
	[-1.78090]	[0.63885]	[3.76490]	[-0.34171]	[-3.79857]
C	-9.20E-05	-4.21E-05	-5.01E-05	-4.89E-05	2.14E-06
	(0.00102)	(0.00075)	(0.00085)	(0.00073)	(0.00095)
	[-0.09020]	[-0.05651]	[-0.05894]	[-0.06655]	[0.00225]

R^2	0.442382	0.437012	0.506681	0.385867	0.394275
Adjusted R^2	0.386620	0.380713	0.457349	0.324453	0.333702

Sum of squared residuals	0.013947	0.007459	0.009684	0.007239	0.012105
S.E. Equation	0.011260	0.008235	0.009383	0.008112	0.010490
F-statistics	7.933425	7.762374	10.27085	6.283108	6.509141
Log likelihood	380.5574	418.7295	402.8106	420.5572	389.1996
AIC	-6.041924	-6.6677	-6.40673	-6.697659	-6.1836
Schwarz Criterion (SC)	-5.766119	-6.39189	-6.13093	-6.421853	-5.9078
Mean dependent	-7.43E-05	-8.86E-05	-2.18E-05	-6.02E-06	-1.04E-05
S.D. dependent	0.014377	0.010464	0.012737	0.009870	0.012851

Determinant residual co-variance (dof adj.)	**3.27E-21**
Determinant residual co-variance	1.95E-21
Log likelihood	2043.372
AIC	-32.4323
SC	-30.9384

Table 10: Vector Error Correction Model Estimates durimg Post-Covid

	BRAZIL_ POST COVID	CHINA_ POST COVID	INDIA_ POST COVID	RUSSIA_ POST COVID	SOUTH AFRICA_ POST COVID
BRAZIL_ POST COVID(-1)	-0.127184	0.002220	0.225859	0.254440	0.160155
	(0.18319)	(0.05945)	(0.11002)	(0.09633)	(0.10521)
	[-0.69428]	[0.03734]	[2.05281]	[2.64129]	[1.52229]
BRAZIL_ POST COVID(-2)	0.095148	-0.021798	0.110702	0.067423	0.183878
	(0.18556)	(0.06022)	(0.11145)	(0.09758)	(0.10657)
	[0.51277]	[-0.36198]	[0.99332]	[0.69097]	[1.72547]
CHINA_ POST COVID(-1)	0.118174	0.021081	0.122977	0.043403	0.060706
	(0.38673)	(0.12550)	(0.23227)	(0.20336)	(0.22210)
	[0.30558]	[0.16797]	[0.52946]	[0.21343]	[0.27333]
CHINA_ POST COVID(-2)	-0.267957	-0.152994	-0.084482	-0.215919	-0.250909

	(0.38271)	(0.12420)	(0.22986)	(0.20125)	(0.21979)
	[-0.70016]	[-1.23184]	[-0.36754]	[-1.07288]	[-1.14157]
INDIA_ POST COVID(-1)	-0.371439	-0.17968	-0.479826	-0.416905	-0.54886
	(0.23258)	(0.07548)	(0.13969)	(0.12230)	(0.13357)
	[-1.59704]	[-2.38055]	[-3.43496]	[-3.40876]	[-4.10909]
INDIA_ POST COVID(-2)	-0.208991	0.093526	-0.055926	-0.158187	-0.058393
	(0.24168)	(0.07843)	(0.14516)	(0.12709)	(0.13880)
	[-0.86473]	[1.19244]	[-0.38528]	[-1.24466]	[-0.42070]
RUSSIA_ POST COVID(-1)	0.454615	0.181459	0.455912	0.265887	0.566470
	(0.28796)	(0.09345)	(0.17295)	(0.15143)	(0.16538)
	[1.57873]	[1.94174]	[2.63606]	[1.75587]	[3.42528]
RUSSIA_ POST COVID(-2)	-0.320181	-0.200874	-0.680584	-0.198887	-0.146399
	(0.29883)	(0.09698)	(0.17948)	(0.15714)	(0.17162)
	[-1.07144]	[-2.07132]	[-3.79196]	[-1.26563]	[-0.85303]
SOUTH AFRICA_ POST COVID(-1)	-0.037499	0.143870	0.014730	-0.198952	-0.111068
	(0.32303)	(0.10483)	(0.19401)	(0.16987)	(0.18552)
	[-0.11608]	[1.37240]	[0.07592]	[-1.17122]	[-0.59869]
SOUTH AFRICA_ POST COVID(-2)	0.604565	0.192597	0.600868	0.491709	0.265639
	(0.31009)	(0.10063)	(0.18624)	(0.16307)	(0.17809)
	[1.94962]	[1.91385]	[3.22624]	[3.01541]	[1.49161]
C	-0.002864	-0.00048	-0.001737	-0.001324	0.000226
	(0.00456)	(0.00148)	(0.00274)	(0.00240)	(0.00262)
	[-0.62838]	[-0.32457]	[-0.63442]	[-0.55234]	[0.08624]

R-squared	**0.148022**	**0.221999**	**0.392250**	**0.298068**	**0.353785**
Adj. R-squared	0.042839	0.125950	0.317219	0.211409	0.274005
Sum sq. resids	0.151797	0.015987	0.054758	0.041976	0.050067
S.E. equation	0.043290	0.014049	0.026000	0.022765	0.024862
F-statistic	1.407283	2.311298	5.227847	3.439573	4.434523

Log likelihood	164.1796	267.7154	211.0826	223.3100	215.2019
Akaike AIC	-3.329992	-5.58077	-4.349621	-4.615435	-4.439173
Schwarz SC	-3.028473	-5.279251	-4.048103	-4.313917	-4.137654
Mean dependent	-0.002075	-0.000347	-0.00154	-0.001171	1.96E-05
S.D. dependent	0.044248	0.015027	0.031466	0.025635	0.029179

Determinant resid covariance (dof adj.)	7.24E-18
Determinant resid covariance	3.83E-18
Log likelihood	1192.074
Akaike information criterion	-24.71899
Schwarz criterion	-23.2114

Table 11: One-Day ahead forecast during Pre-Covid

	Brazil	**China**	**India**	**Russia**	**South Africa**	**Contribution from others**
Brazil	96.20	0.03	1.14	1.83	0.80	3.80
China	4.50	94.87	0.00	0.01	0.62	5.13
India	3.78	1.03	94.96	0.22	0.01	5.04
Russia	6.57	0.96	0.57	91.90	0.00	8.10
South Africa	16.39	8.77	0.36	12.83	61.65	38.35
Contribution to others	31.24	10.79	2.07	14.89	1.43	60.42
Contribution including own	127.44	105.66	97.03	106.79	63.08	500.00
					Spill-over index	12.08%

Table 12: Two-Day ahead forecast during Pre-Covid

	Brazil	**China**	**India**	**Russia**	**South Africa**	**Contribution from others**
Brazil	92.12	0.03	4.93	1.71	1.22	7.89
China	4.68	94.31	0.00	0.21	0.80	5.69
India	7.71	5.94	83.99	0.93	1.44	16.02
Russia	7.27	1.94	0.57	89.93	0.29	10.07
South Africa	18.63	9.05	0.39	13.25	58.70	41.32
Contribution to others	38.29	16.96	5.89	16.10	3.75	80.99
Contribution including own	130.41	111.27	89.88	106.03	62.45	500.04
					Spill-over index	16.20%

Table 13: Three-Day ahead forecast during Pre-Covid

	Brazil	**China**	**India**	**Russia**	**South Africa**	**Contribution from others**
Brazil	86.63	0.12	8.06	1.68	3.50	13.36
China	4.05	94.61	0.42	0.23	0.69	5.39
India	14.93	5.38	69.50	1.26	8.92	30.49
Russia	5.83	1.44	2.67	89.41	0.65	10.59
South Africa	19.18	8.87	1.92	12.57	57.47	42.54
Contribution to others	43.99	15.81	13.07	15.74	13.76	102.37
Contribution including own	130.62	110.42	82.57	105.15	71.23	499.99
					Spill-over index	20.48%

The above tables shows the daily volatility Spill-over index of BRICS stock market. We run the Vector Error correction model and forecast the error variance for 3 days. The error decomposition quantifies the market variability caused by self (respective index) due to shock and the percentage of volatility coming from other indices. The rows in the table indicate the contribution from others, and the column shows contribution to others. The spill-over tables are to be read as (i x j) matrix. . Every ij^{th} value in the matrix shows the contribution of forecast error variance from country j to i for all j ≠ i. For every country in row (i), we estimate the contribution of error variance due to shocks or innovations from other countries by simply adding values of (j), for all j ≠ i. The diagonal values in the matrix for every i=j shows the contribution from own to the forecast variance. The total values in every row excluding j=j shows the contribution of volatility from other countries j_1, j_2 - ---- j_n. The diagonal value shows the contribution from own. The sum of values in every row (i) excluding i=j or the diagonal element in the row shows contribution from others. We then add all i=1…..n to get the total contribution from others. The sum of columns (j) for all j ≠ i provides the contribution of every country to the forecast error variance of other countries. In simple terms, the sum of rows for all j ≠ i highlights the contribution from others. Similarly the sum of columns for all j ≠ i shows the contribution to others. Spill-over index = Contribution from other / Contribution including own. During pre Covid the Spillover index is found to be 12.08 %, 16.20 % and 20.48 % from 1 to 3 days.

Table 14: One-Day ahead forecast during Post-Covid

	Brazil	**China**	**India**	**Russia**	**South Africa**	**Contribution from others**
Brazil	93.74	0.02	3.37	2.86	0.01	6.26
China	12.90	73.58	4.98	6.80	1.74	26.42
India	38.24	3.14	51.82	6.80	0.01	48.19
Russia	35.30	1.96	13.87	47.68	1.21	52.34

South Africa	41.38	3.84	18.04	13.75	23.00	77.01
Contribution to others	127.82	8.96	40.26	30.21	2.97	210.22
Contribution including own	221.56	82.54	92.08	77.89	25.97	500.03
					Spill-over index	42.04%

Table 15: Two-Day ahead forecast during Post-Covid

	Brazil	**China**	**India**	**Russia**	**South Africa**	**Contribution from others**
Brazil	90.12	0.50	3.23	3.50	2.66	9.89
China	12.38	71.42	5.28	7.67	3.25	28.58
India	34.13	2.87	45.96	12.13	4.92	54.05
Russia	32.78	2.28	12.94	45.11	6.89	54.89
South Africa	41.67	5.09	17.06	13.91	22.28	77.73
Contribution to others	120.96	10.74	38.51	37.21	17.72	225.14
Contribution including own	211.08	82.16	84.47	82.32	40.00	500.03
					Spill-over index	45.03%

Table 16: Three-Day ahead forecast during Post-Covid

	Brazil	**China**	**India**	**Russia**	**South Africa**	**Contribution from others**
Brazil	89.08	0.50	3.30	4.43	2.69	10.92
China	12.64	70.32	5.33	8.50	3.21	29.68
India	33.29	2.83	44.80	13.87	5.21	55.20
Russia	31.77	2.23	13.31	46.02	6.67	53.98
South Africa	40.85	5.01	16.92	15.54	21.67	78.32
Contribution to others	118.55	10.57	38.86	42.34	17.78	228.10

Contribution including own	207.63	80.89	83.66	88.36	39.45	499.99
					Spill-over index	45.62%

The above table shows the Spillover index of BRICS post Covid 19. The index ranges between 42 % and 45.62 %. The spillover index has increased form 20 % pre Covid to 45.62 % post Covid 19. The substantial increase in Spillover during post coivd indicates a spike in bilateral and multilateral Spillover across the BRICS nations. The stock makets have become sensitivite to the shocks within the country and also the external shocks leading to increase in Spillover index. The BRICS nations. The Spillover is caused due to the trade relationship among BRICS. The intra trade among the nations contributed 10.61% of global trade in 2017. We found the integrated markets are prone to see increase in volatility due to global shocks.

Conclusion

It is well known that globalization has integrated the world economies. But during shocks or crisis there is a change in the extent of this integration. From the research, we can conclude that the impact of corona has created much volatility in the BRICS stock market and the extent of integration has increased post-covid compared to pre-covid. It suggest that investors deliberating on portfolio diversification should consider this in their asset allocation and the research also helps policymakers to understand how a shock could be transmitted across trading blocs and how a government should act to prevent such down-side effects.

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