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DYNAMICS OF VOLATILITY SPILLOVER AMONG THE US AND EMERGING ASIAN STOCK MARKETS AMID THE COVID-19 PANDEMIC

Mariyam Qadir[1], Dr. Saqib Gulzar[2], Dr. Muhammad Owais[3]

Affiliations:

[1, 2, 3] COMSATS University Islamabad, Wah Campus.

The Corresponding Author's Email:
[1]mariyamqadir30@gmail.com

Abstract

This study examines the dynamics of volatility Spillover among the US and emerging Asian Stock markets (China, Pakistan, India, Malaysia and Korea) amid the COVID-19 pandemic. The analysis used data of daily stock returns and the time period is divided into two phases: pre and during COVID-19. The pre period is from November 1st, 2017 to November 30th, 2019 and during period is from December 1st, 2019 to December 31st, 2021. The pre-period has been taken for comparative purpose. The Spillover index method provided by Diebold and Yilmaz (2012) is use to check these dynamics. The findings indicate the presence of integration and the asymmetric volatility Spillover among these sampled stock markets. The transmission pattern of volatility Spillover is bidirectional. The Korean Composite Stock Price Index (KOSPI) is the only market that transmitted less and also received less volatility Spillover from other stock markets. The US (S&P 500) being highly affected country by pandemic transmitted higher volatility Spillover to others rather than receiving while China being pandemic originating country lies on` a moderate level; not highly affected by others nor affect others. The findings of the present study help investors and portfolio managers to diversify their portfolio accordingly while help policy makers to design strategies to protect their financial markets from future uncertain events. The study have significant implications for risk minimization and portfolio diversification.

Keywords: Volatility Spillover, COVID-19, Portfolio Diversification, Risk Minimization

Introduction

In recent years, the integration of financial markets has increased due to Globalization. The investors are not restricted to domestic markets for diversification of their portfolio. In order to reduce risk and maximize profits investors do diversification on globalized level (Faque & Hacioglu, 2021). We all witness how financial markets are becoming borderless and involving entities from whole world (Paskaleva & Stoykova, 2021). This liberalization of international markets encourage investors to invest across the globe. The ease in investment policies due to elimination of investment's restrictions across the borders

not only raise the number of opportunities but further elevated integration level of stock markets. The higher the degree of integration among stock markets, the more widely it affect the investment decisions of global investors as well the economic policies that usually design for economic stability (Pasha et al., 2019; Siddiqui, 2009). These highly integrated stock markets transmit higher effect of shocks to others and also receive higher from others (Jebran et al., 2017). This shock transmission negates the concept of international portfolio diversification.

The global pandemic of COVID-19 which originated from China rapidly spread across the globe in 2020. This pandemic has severely affected all financial markets of the world leading to an unusual risk level due to which in a very shorter time span investors suffered a lot (Zhang et al., 2020). The countries with higher infection rate observe rapid depreciation in their stock indices. Further the level of uncertainty elevated when the WHO (World Health Organization) declared the COVID-19 as a global pandemic on 11th March 2020. COVID-19 spread ten times more rapidly than Severe Acute Respiratory Syndrome (SARS). The risk of global financial markets has increased in response to COVID-19 pandemic making investments across the globe riskier. Each individual stock market responded in accordance with the situation of pandemic in that country. The higher the number of COVID-19 cases, the more volatile stock market of that country is (Alber, 2020; Asif et al., 2022). This pandemic not only affected the health of people but also decline the growth of economy. The stock markets across the globe linked with economic system either directly or indirectly and due to strong co-integration of these financial markets they bear significant loss. That's why the impact of pandemic on stock markets raise serious questions about the dynamics of stock markets (Mensi et al., 2013). The volatility transmission between stock markets increase due to increase in connection of global markets and financial interdependence across the globe as well.

The emerging Asian stock markets have considered as new economies that can bring change in the world. In the twenty first century it's expected that India and China can transform the economy of the world (Syllignakis & Kouretas, 2011). Among the stock markets of South Asia the Bombay Stock Exchange (B.S.E) is considered as the rapid growing stock exchange. With the market capitalization of $ 3.41 trillion (November 2021) it stands on the ninth position among world's largest stock markets. There are 5439 companies listed on B.S.E. The Pakistan gained much importance in Asia after China Pakistan Economic Corridor (CPEC) and considered as key market both strategically and economically. In 2021, the K.S.E 100 index (Pakistani stock market's proxy) reached to 47,295 points from 28,109 points in 2019 indicating a positive trend (19,186 points) in Pakistani Stock Markets. During pandemic of COVID-19 the NYSE (New York Stock Exchange) lost 4,417 points within one month. The Korean and Malaysian economies have been the part of most emerging economies of Asia during last decade because of financial integration, trade openness, liberalization and more advancement in financial sector (Asif, 2022; Gulzar et al., 2019). Here the strong integration can drastically impact the internationally diversified portfolio.

The purpose of this research is to analyse dynamics of volatility Spillover during COVID-19 on selected Asian stock markets. A detailed literature is available on the influence of COVID-19 on financial markets, for example Ashraf (2020a), Singh et al. (2020), Faque and Hacioglu (2021), Kluwe-Schiavon et al. (2021) and Zhang et al. (2020). Furthermore, in literature the researchers emphasize more on the effect of COVID-19 on stock markets such as in Zeren and HIZARCI (2020), Topcu and Gulal (2020), Liu, Wang, et al. (2020) and Elsayed and Abdelrhim (2020) irrespective of comparison between their origin and

more number of cases. After the World Health Organization declared the COVID-19 as a global pandemic this lead to abnormal market returns and a substantial difference exist between markets return before and after the announcement of pandemic (Asif et al., 2022; Zeren & HIZARCI, 2020). China reported highest market volatility in February of 2020 while lowest in March 2020, on the other hand market volatility of the US increased substantially in March, four times more as compared to February. This fluctuation is moving simultaneously with the number of confirmed cases of COVID-19 in both China and the US. This thing gave clear picture about higher uncertainty and risk in financial markets across the globe (Asif et al., 2022; Zhang et al., 2020). Further the prior literature suggest that these Asian stock markets are connected with major stock markets of the world. So the dynamics of volatility Spillover has been analysed during global pandemic.

In order to attain objectives of this study, the sample comprises of daily stock return data of Chinese stock market (COVID-19 originated from China), daily stock returns of the US stock market (highest number of COVID-19 confirmed cases) and four emerging stock markets of Asia, namely Pakistan, India, Malaysia and Korea. The selected Asian Stock markets are integrated with stock markets of China and the US. Following questions are under consideration in this study: 1) What are the dynamics of time varying average volatility Spillover from the US and China to other emerging Asian stock markets during COVID-19? 2) What is the nature of time-varying and static dynamic asymmetric volatility Spillover from the US and China to other emerging Asian stock markets during COVID-19? The objectives of this study are new in its kinds as its providing dynamics of volatility Spillover. To best of our efforts still there's no other study find that analysed the stock markets during Covid-19 keeping in view the above mentioned research questions.

In the world of finance, the analysis of volatility Spillover dynamics among the connected stock markets is important. The above mentioned research questions help investors, portfolio managers and policy makers. This estimation help portfolio managers and investors in hedging and optimizing their portfolio while help policy makers in designing strategies of risk minimization. The portfolio managers and investors can diversify their portfolio in much better way after knowing the dynamics of volatility Spillover existing among these stock markets. By closely analysing the direction of Spillover the investors not only avoid capital loss but can also earn profit by re-allocating their portfolios. Further the policy makers of these emerging economies can make strategies/ policies to secure their markets from negative ripple effect of any other future uncertain events in these developed economies. Till now, not enough knowledge is available on the dynamics of volatility Spillover of COVID-19. The quantification of interconnectedness existing among these stock markets will help in determining the nature, direction and frequency of any other uncertain event than can occur in future and this can be used by investors and portfolio managers in making secure investment strategies.

Literature Review

Modern Portfolio Theory is the underlying basis of portfolio diversification (Markowitz, 1991). The risks associated with portfolio can be reduce by adding more securities in a well-designed portfolio. This suggests the investor can overcome the risk associated with individual security by internationally diversifying their portfolio (Biswas, 2015). The benefits of internationally diversified portfolio tend to

reduced due to transmission of volatility Spillover from one market to other. This volatility transmission is just in accordance with Meteor Shower hypothesis (Ito et al., 1992), which states the volatility in one market has Spillover effect in other market and it remains continue despite of the fact that market closes. This continuity lead to dynamic volatility Spillover in geographically distant stock markets opening several hours later.

Now a days, the influence of Novel Coronavirus (COVID-19) on stock markets is under consideration. As it's originated from China, which is considered as the hub of foreign investment in Asia so of course here global investors will consider the co-integration before doing investment in Chinese stocks for diversification of their portfolio. The risk of global financial markets has increased in response to pandemic making investment across the globe riskier. Each individual stock market response depends on situation of pandemic in that country. The higher the number of COVID-19 cases, the more volatile stock market of that country is (Faque & Hacioglu, 2021; Zhang et al., 2020). That's why it's important for investors to understand how stock markets collectively behave during pandemic specifically if they want to gain maximum benefit from globally diversified portfolio.

Like SARS, COVID-19 also become the reason of millions of death, but COVID-19 caused 10 times more cases then SARS did in quarter of time (Gates, 2020). AlAli (2020) classified the COVID-19 as a "Black Swan" because it's an uncertain event influencing the world economy badly. A "Black Swan" is define as any uncertain event having these properties: surprise effect, incomputable probabilities and diverse influence (Taleb, 2005). Due to this the financial markets undergo drastic and uncertain changes. These uncertain conditions tend to increase the risks of financial markets, making these markets highly volatile (Zhang et al., 2020). The uncertain conditions of fatal disease reduce the trust of investors on financial markets. Although the direct impact of pandemic on decision making is quite difficult to measure because due to globalization and co-integration of financial markets overall the global investments stood on the verge of risk (Lee & McKibbin, 2004). The COVID-19 has lessened the benefits of globalized diversification due to increased interdependence of stock markets. The earlier the investors understand about changing trends of stock markets during this pandemic, the more it's easier for them to formulate strategies to earn more profits (Azimli, 2020). Globally the effects of COVID-19 crisis on economies are far more than the financial crisis of 2007-2008 (El-Basuon, 2020). Ashraf (2020b) analysed the effect of COVID-19 on stock markets. By using daily data of COVID-19 deaths and cases he confirmed that COVID-19 negatively affected the stock markets. Sadraoui et al. (2021) find the volatility Spillover existing between BRICS stock market, oil prices and natural gas prices. The information of oil market increase the stock market volatility forecast.

The pandemic has negatively affected the oil and gas markets, became highly volatile (Bakas & Triantafyllou, 2020). The rapid spread of COVID-19 has reduced the oil and gas demand due to lockdown and travel restrictions. The effects of uncertain events indicate that higher integration level leads to less benefits from internationally diversified portfolio (Billio et al., 2017). No other pandemic affected the global financial markets like COVID-19 did (Baker et al., 2020). The investors usually have vast knowledge of domestic financial markets and use this knowledge to make decisions regarding investment. The perception of investors about prevailing conditions in home country affects their decisions (Nguyen et al., 2019). The firms who faced pandemic earlier e.g. SARS, are more effective in dealing with COVID-

19 pandemic while the countries widely affected by SARS showed less connectedness as compare to others (Bissoondoyal-Bheenick et al., 2021). The researchers (Ghorbel & Jeribi, 2021) believe that COVID-19 pandemic could generate another financial crisis on a globalized level while other group of researchers believe that if effects of pandemic could not be handle in a proper manner then it lead to more worse impacts as compare to combine effects of SARS, second world war and Global Financial crisis.

The COVID-19 affects are obvious as it leads to high level of unemployment, permanent shut down of firms etc. This pandemic mainly affects the markets of commodities, (specifically gold and petroleum as during this whole period of pandemic these two things undergo rapid fluctuation in their prices), stock markets and the markets made of debt (Evans, 2020). A detailed study done by Goodell (2020), emphasizing the effects occur due to natural disasters on economy such as climate change, epidemics, nuclear wars or local disasters and he proved that COVID-19 causing more financial destructions (negatively influencing stock markets, insurance sector and banks as well) as compare to destructions done by previous disasters. Researchers tried to quantify the expectations of investors about COVID-19 impact on economy via the data from futures and equity markets (Gormsen & Koijen, 2020). For policy makers it's important to analyse the impact of COVID-19 on economy but it's quite challenging because the pandemic spread at rapid pace (Alber, 2020). The stock markets are more sensitive to number of new cases as compare to the number of deaths.

In the above literature, various studies focused on impact of Covid-19 on stock markets (Singh et al.; Zhang et al., 2020). These studies focused on stock markets of developed countries and a little consideration has been given to emerging stock markets, e.g. Liu, Manzoor, et al. (2020) observed the impact of COVID-19 on top 21 indices of developed economies such as UK, Germany, Italy etc. Tsai (2014) analysed the Spillover effect of GFC on developed stock markets (UK, US, Germany, France, and Japan) while, Kim et al. (2015) have focused on the effect of Asian Financial Crisis on emerging economies of the world (Indonesia, Korea, Philippine, Thailand and Taiwan). These studies have underestimated the importance of emerging economies Asian mainly the economies selected for present study (i.e., Pakistan, Malaysia and Korea). Furthermore, various studies have focused on during COVID-19 period (e.g., Ashraf (2020b); Gates (2020); Liu, Manzoor, et al. (2020)). The Volatility Spillover dynamics of COVID-19 on stock markets of have not analysed yet. This study focuses on the volatility Spillover dynamics among US and other emerging Asian stock markets. This study help investors and portfolio managers to design their portfolio in a way to reduce risk at maximum level, while help policy makers to make strategies to protect their stock markets from uncertain events that can happen in future.

Methodology

To analyse the Spillover effect of COVID-19 on stock market following methods will be use: the Spillover Asymmetry Measure (SAM) provided by Baruník et al. (2015), the and Spillover Index Method provided by Diebold and Yilmaz (2009). In past various methods has been used such as unconditional approach of cross market correlation coefficient. If the correlation coefficient increase during the pandemic period according to expectation this indicates a Spillover effect of pandemic while if the magnitude of co-integration is greater than expectation during pandemic period than the effect is contagion effect. The similar approach has been used by Arshanapalli and Doukas (1993) and Lee and Kim (1993) to analyse the

impact of the US market failure happened in 1987 and by Calvo and Reinhart (1996) for the impact of Mexican peso crisis of 1994. There might be the issue of heteroscedasticity in test as it compares the correlation coefficient of sub-samples. Various other researchers also used the different tests of Generalized Auto-Regressive Conditional Heteroscedasticity (G.A.R.C.H.) to analyse the impact of crisis (Bekaert & Harvey, 2003; Gulzar et al., 2019; Le & Tran, 2021). The co-movements of stock market analysed by G.A.R.C.H. and Auto-Regressive Conditional Heteroscedasticity (A.R.C.H.). The results showed the mechanism of covariance and variance transmission among the economies (Kao et al., 2018). Instead of conditional change the researchers were interested in analysing the permanent changes occurred in unconditional variance. This problem has been resolved by using Dynamic Conditional Correlation (D.C.C.) M.G.A.R.C.H. model. The D.C.C. M.G.A.R.C.H model has been developed by Engle (2002) and used by various researchers (Acatrinei et al., 2013; Jones & O'Steen, 2018). This model doesn't require a specific date of contagion occurrence instead of this the model measures the conditional correlation which varies with time. This test usually generate more reliable results and works better in different circumstances (Engle, 2002) while the B.E.K.K parameterisation has been designed by Engle and Kroner (1995) for the bivariate G.A.R.C.H. model and is written as

$$H_t = CC' + DH_{t-1}D' + A(\varepsilon_{t-1}\varepsilon'_{t-1})A'$$

In the above equation H_t is the conditional variance-covariance matrix, C is the constant matrix, D is the conditional variance matrix, A is the matrix of residuals while ε is the vector of residuals and it is normally distributed.

With the passage of time the tools used to find out the contagion effect on interlinked economies. A Spillover index method has been developed by Diebold and Yilmaz (2009) to measure the Spillover effect in equity markets. This method depends on the order of variables which is the biggest flaw of this method. This order dependence issue has been resolved by Diebold and Yilmaz (2012). This new method generate both pairwise and directional Spillover measure along with mean static and dynamic Spillover. The method also analyse the time varying nature and directional Spillover as well. This is the latest techniques to measure the volatility Spillover existing among integrated stock and financial markets.

Spillover Index

The research of volatility Spillover dynamics was improved after Diebold and Yilmaz (2009) designed Spillover index method lies under the VAR framework. The results generated by the Spillover index model was dependent on the order of variables due to Cholesky factorization. In this model of Diebold and Yilmaz (2009) its important to pay attention to order of variables i.e. at first place the significant variable. The Diebold and Yilmaz (2012) modified the existing model as the significant variable is usually unknown in the beginning, So, they improved the model which is independent on the ordering of these variables. The functionality of Diebold and Yilmaz (2009) Spillover index method is limited as it only find out the directional volatility Spillover in total from or to each markets to or from to all other selected markets. It's important to find out each market's directional volatility Spillover to find out which market is net transmitter and net receiver of volatility, by this method the source of volatility Spillover either transmitter or receiver can be easily identified. The Diebold and Yilmaz (2012) VAR method of volatility Spillover estimation is in accordance with Engle III et al. (1988) VAR model. In the method of

Diebold and Yilmaz (2012) the variance decomposition is use for estimating Spillover effects. The find out individual market i volatility Spillover, add the forecasted variance of errors that occur due to any shock that hits the market j, for all i=j, and now add all i= 1,2,…. N. The Diebold and Yilmaz (2012) Spillover index which is independent of the variables order is made by using generalized VAR model of Pesaran and Shin (1998) and Koop et al. (1996). The issues of previous Diebold and Yilmaz (2009) model has been overcome by new model of Diebold and Yilmaz (2012), as this new model also calculates the net directional volatility Spillover. In this study the directional and average volatility Spillover from the US stock market and other emerging Asian stock market is calculated by using Diebold and Yilmaz (2012) Spillover model. Following is the explanation of Spillover index method.

Consider a covariance stationary N-variable VAR (p),

$$y_t=\sum_{i=1}^{p} \varphi_t y_{t-i} + \mu_t \quad (1)$$

In the above equation $y_t = y_{1,t}, y_{2,t}$ and φ is the representation of a 2 × 2 matrix. In this study y considers as a volatility vector of individual selected stock markets. The μ_t is the error term's vector which is identically distributed and independent as well.

$$y_t=\sum_{i=0}^{\infty} A_i \mu_{t-i} \quad (2)$$

The above equation is use to estimate the moving average. The Ai represents the recursion $A_i= \theta_1 A_{i-1} + \theta_2 A_{i-2} + ... + \theta_p C_{i-p}$, of N×N coefficient matrix. The A_0 represents the identity matrix, $A_i=0$ while $i<0$. The cross market Spillover is used to calculate the H-step ahead forecast error variance of y_i occur due to uncertain event in y_j, while $i,j= 1,2, ... N$, while own Spillover is used to calculate the H-step ahead forecast error variance of y_i occur due to uncertain event in y_i, while $i= 1,2, ... N$. The cholesky factorization lead to orthogonality and due to this the resultant variance decomposition depends on the order of variables. The Diebold and Yilmaz (2012) solve this issue by using the generalized VAR methodology of Pesaran and Shin (1998) and Koop et al. (1996). The forecast error variance of H-step ahead (Koop et al., 1996; Pesaran & Shin, 1998) can be computed as follows:

$$\alpha_{ij}^{g}(H) = \frac{\sigma_{ii}^{-1} \sum_{h=0}^{H-1}(e_i' A_h \psi e_i)^2}{\sum_{h=0}^{H-1}(e_i' A_h \psi A_h' e_i)} \quad (3)$$

In the above equation ψ represents the matrix of μ, σ_{ii} represents the standard deviation of errors in equation i while e_i is representing the selection vector having value one as ith element or otherwise zero. The sum of decomposed variance is not equal to 1 because there is no orthogonality in shock face by individual variables.

$$\sum_{j=i}^{N} \alpha_{ij}^{g} \neq 1 \quad (4)$$

The contribution of market's own volatility Spillover is represented by diagonal values of the volatility Spillover index's matrix. The contribution of volatility Spillover from other markets to a market is represented by of-diagonal row values of the volatility Spillover matrix while volatility from a particular market to others markets is represented by of-diagonal column values. The sum of column and rows of matrix normalize every entry of variance decomposition which is computed as follows:

$$\tilde{\alpha}_{ij}^{g}(H) = \frac{\alpha_{ij}^{g}(H)}{\sum_{j=1}^{N} \alpha_{ij}^{g}(H)} \quad (5)$$

While $\sum_{j=1}^{N} \tilde{\alpha}_{ij}^{g}(H) = 1$ and $\sum_{ij=1}^{N} \tilde{\alpha}_{ij}^{g}(H) = N$, the total volatility Spillover computed as follows:

$$TS^{g}(H) = \frac{\sum_{i,j=1}^{N} \tilde{\alpha}_{ij}^{g}(H)}{\sum_{i.j=1}^{N} \tilde{\alpha}_{ij}^{g}(H)} \times 100$$

$$TS^{g}(H) = \frac{\sum_{i,j=1}^{N} \tilde{\alpha}_{ij}^{g}(H)}{N} \times 100 \quad (6)$$

Data

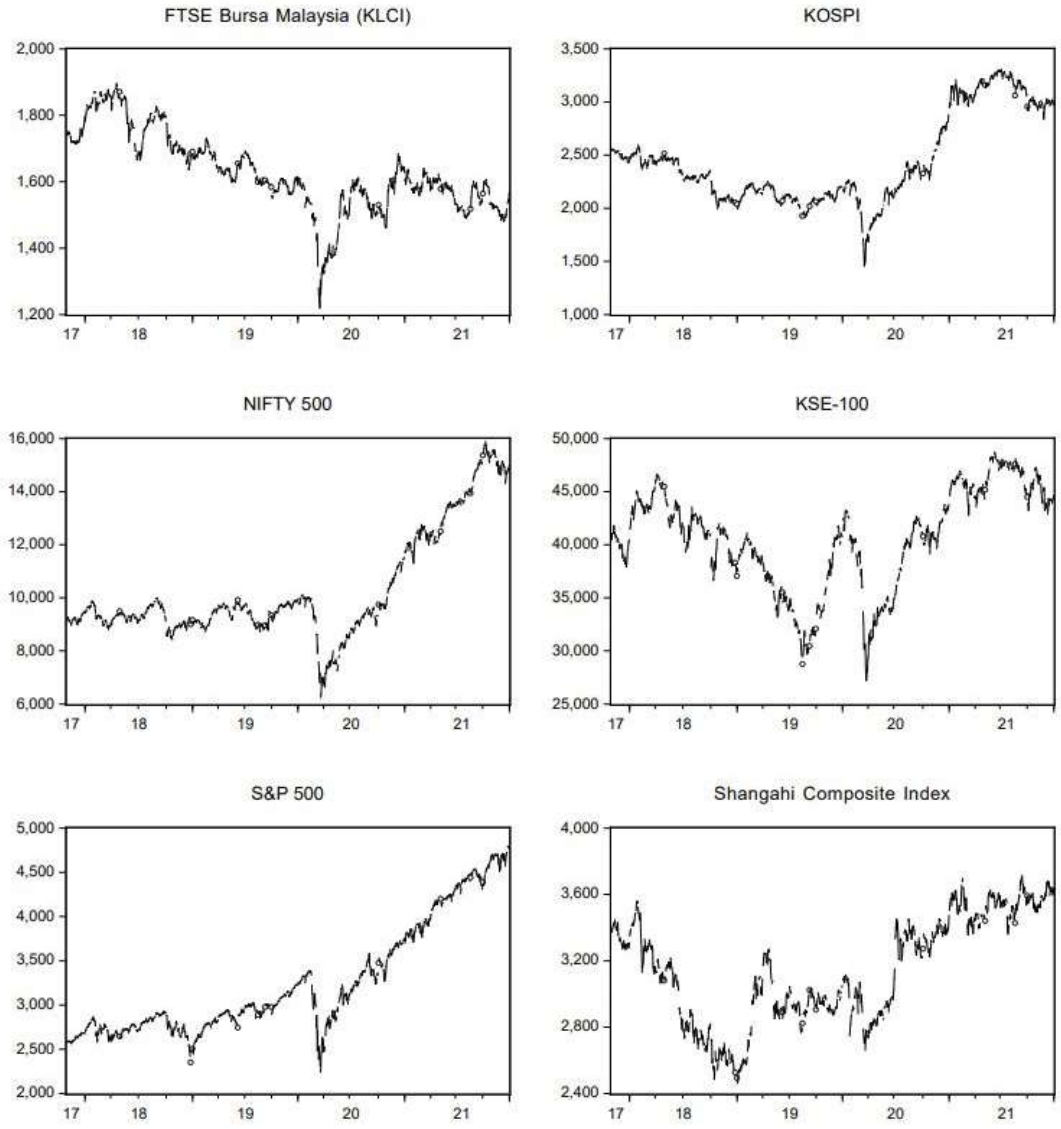
This study is based on the daily data of stock indices of China (S.S.E, Shanghai Stock Exchange) (http://english.sse.com.cn/), United States of America U.S.A (N.Y.S.E, New York Stock Exchange) (http://www.nyse.com/index), Pakistan (K.S.E, Karachi Stock Exchange) (https://www.psx.com.pk/), India (B.S.E, Bombay Stock Exchange) (https://www.bseindia.com/), Malaysia (K.L.S.E, Kuala Lumpur Stock Exchange) (http://www.bursamalaysia.com/market/) and Korea (K.O.S.P.I, Korea Composite Stock Price Index) (http://global.krx.co.kr/main/main.jsp). The data will be taken from November 1st, 2017 to December 30th, 2021. The selected time period has been divided into two parts: pre-pandemic and during COVID-19 pandemic. The pre period for China will be from November 1st, 2017 to November 30th, 2019 and during period will be from December 1st, 2019 to December 31st, 2021 while for the US the pre period will be from November 1st, 2017 to January 12th, 2020 and during period will be from January 13th, 2021 to December 31st, 2021. RATSPro software will be used for the analysis of data.

Analysis and Results

The day to day fluctuation in stock indexes is given in the Figure 1. The graphs are clearly showing higher volatility during Covid-19 period. The stock markets of each country is showing higher fluctuations right from the end of 2019 till the end of sampled period. As depicted in graph each of these stock markets except Shanghai Composite Index (SCI), fall at rapid pace right from the start of pandemic (December, 2019) and then show higher fluctuation level throughout pandemic period. The stock indexes of KOSPI, NIFTY 500, KSE 100 and S&P 500 followed higher trend during sampled period rather than others. Further the change is more elevated during the first quarter of 2020, when WHO declared Covid-19 as global pandemic. The stock markets of the US (S&P 500) showed rapid downfall as it's highly connected with rest of the world, making it more prone to external shocks. Same is the case with India (NIFTY 500). This vulnerability to external shocks make people more reluctant to invest in stock markets or take their money out from these markets.

Figure 1

Fluctuation in Stock Indexes



Volatility Spillover Index

The average volatility Spillover existing between the US and emerging Asian stock markets is presented in Table 1. The Average Volatility Spillover among the US and the emerging Asian stock markets is 22.4% during the sampled period. The highest contribution of own market volatility Spillover is reported by KOSPI (89.54%), with 6.07% contribution to others stock markets from KOSPI while others stock markets contributed 10.45% in its volatility. This indicates that among the whole sample the KOSPI is the highly isolated market and that's why it has least vulnerability to volatility Spillover directed from other stock markets of sample. This isolation and least vulnerability of KOSPI among sampled stock markets suggest that it's significant for international portfolio diversification.

In the sample the NIFTY receive highest volatility Spillover (34.50%) from other stock markets, so NIFTY is highly vulnerable to volatility Spillover directed from others. After NIFTY, KLCI (28.07%) and S&P 500 (24.31%) are more prone to volatility Spillover contribution from others stock markets. The S&P 500 highly contributed (15.89%) in volatility Spillover of NIFTY while the KOSPI contributed the least (1.03%). This indicates that during crisis period S&P 500 highly affected the NIFTY and transmit more volatility to them. This higher impact of S&P 500 on NIFTY indicates it's not suitable to keep stock of these stock markets collective in an internationally diversified portfolio.

The S&P 500 transmitted highest volatility Spillover to other stock markets (40.98%), after this NIFTY (38.10%) and KLCI (23.27%) transmit the high volatility to other stock markets. The S&P 500 transmit highest volatility Spillover to NIFTY (15.89%) and then to KLCI (10.98%). This indicate the US stock market highly transmit the effect of crisis to other stock markets of the sample, indicating it less beneficial to keep shares of the US stock market in a portfolio having shares of Indian and Malaysia or must designed portfolio in some alternative manner.

The KOSPI is least affected by others stock markets (10.45%) while NIFTY is highly affected by others making it more volatile during crisis period as well. The volatility of S&P 500 affected the others volatility the most (40.97%) while KOSPI least affected the other stock markets (6.07%). On average the volatility Spillover is 22.4% across the US and other emerging Asian stock markets and most of the volatility Spillover is due to the US stock market (S&P 500). This presence of high market volatility requires to include shares from other stock markets or to invest in other risk hedging instruments so, that to get and optimal diversified portfolio.

Despite of the fact that COVID-19 originated from China, still SCI (China) transmit less volatility Spillover to other stock markets and also receive less volatility Spillover from others as well. On the other side, the US (S&P 500) reported highest number of confirmed cases and deaths as well, following India (NIFTY) on second number. The S&P 500 (the US) transmit highest volatility Spillover (40.98%) to others indicating that highly affected one (the US) affect the emerging Asian stocks more abruptly as compare to the pandemic originating country (China). Similarly, after the US India is more affected by pandemic but instead of transmitting more volatility Spillover to others stock markets in sample, it become the highest recipient of volatility Spillover (NIFTY 34.50%). The NIFTY receives highest volatility Spillover from S&P 500.

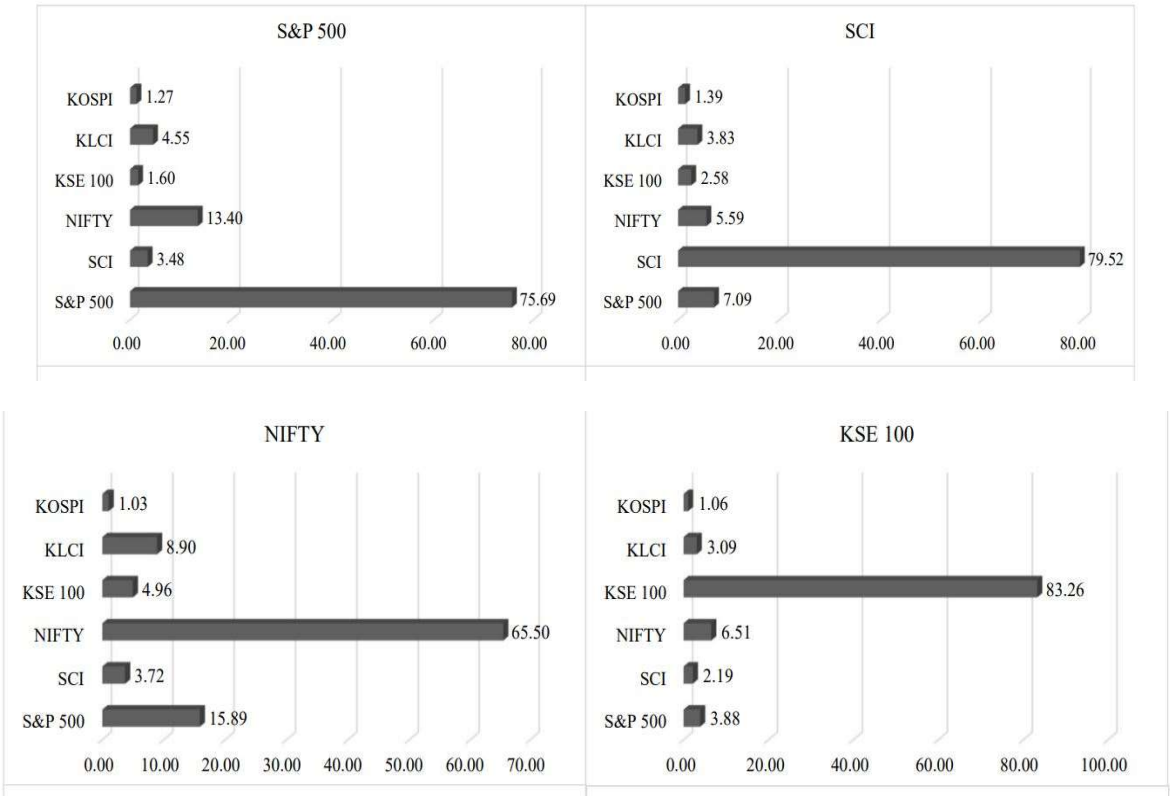
Table 1

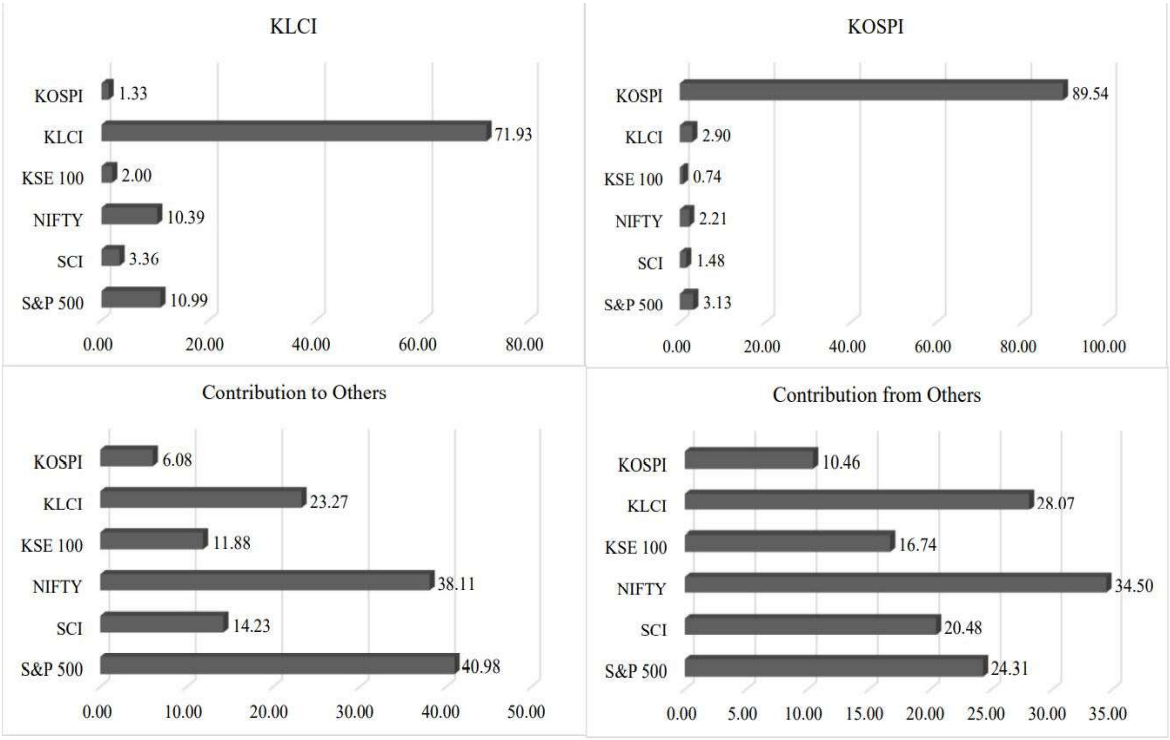
Volatility Spillover Index, US and emerging Asian Stock markets

	S&P 500	SCI	NIFTY	KSE 100	KLCI	KOSPI	Contribution from others
S&P 500	75.6886	3.48357	13.4	1.60424	4.55466	1.26893	24.3114
SCI	7.0913	79.5182	5.59246	2.58433	3.82649	1.38724	20.4818
NIFTY	15.8919	3.71854	65.4992	4.95971	8.90099	1.02961	34.5008
KSE 100	3.88032	2.18743	6.51461	83.2628	3.09201	1.06287	16.7372
KLCI	10.9875	3.36138	10.3932	1.99746	71.9329	1.32759	28.0671
KOSPI	3.12888	1.48391	2.20564	0.737002	2.89985	89.5447	10.4553
Contribution to others	40.9799	14.2348	38.106	11.8827	23.274	6.07623	134.554
Contribution including own	116.668	93.753	103.605	95.1455	95.2069	95.6209	22.4%

Figure 2

Volatility Spillover Index, Graphical Representation





In order to capture the time changing trend of volatility Spillover, a rolling window analysis is use, which involves the 10-step forecast horizons and 200 day window. According to Pesaran and Timmermann (2002) small length of rolling window increase the variance which lead to larger mean square forecasted errors. The length of window must be accurately selected so that it can create a balance between data loss in initial window and increase in variance (Clark & West, 2007; Molodtsova & Papell, 2009). Here in this study a 200-day long rolling window is used to find out the necessary information. This captured information must be enough so that we do not lose necessary information or gather the irrelevant one. In order to check robustness of model, the length of rolling window is changed and the results are robust showing a little sensitivity to the length of rolling window. As the static Spillover index is not able to capture the cyclical patterns of volatility so this issue is resolved by using the rolling window analysis. In Figure 3, the time-varying analysis of volatility Spillover show the response of stock markets to changing pattern in normal days and during Global pandemic of COVID-19. As we already know that the first case of COVID-19 found in china at the end of 2019, so the graph show a sudden increase in volatility Spillover at the end of 2019.

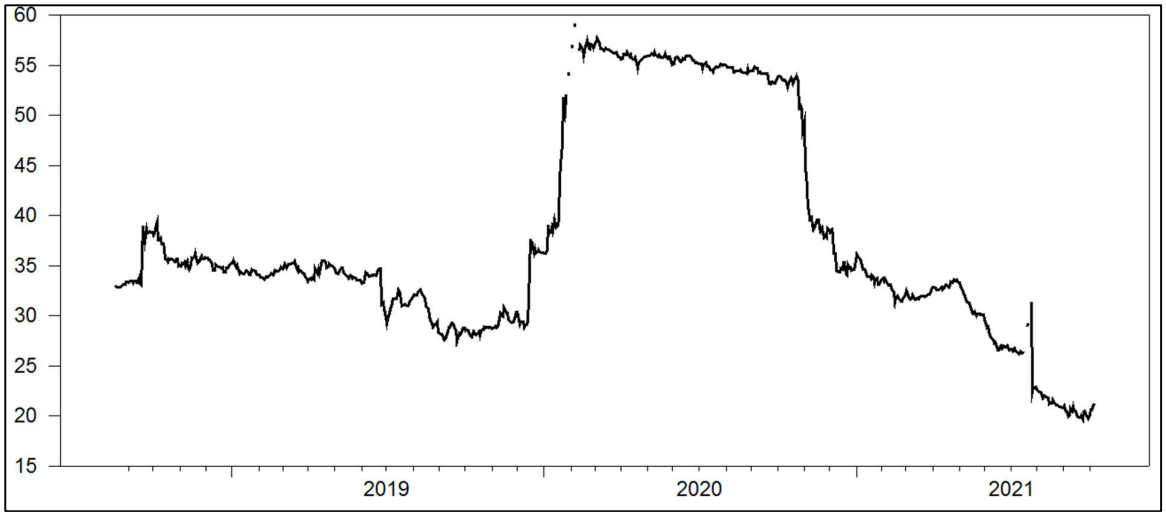
After origination of COVID-19 from china soon it spread to whole world and declare as global pandemic. The volatility Spillover showed a higher trend during first three quarters of 2020 and showed a rapid decline in the last quarter of 2020. The higher trend during 2020 is due to declaration of COVID-19 as global pandemic by WHO. This declaration further elevated uncertainty across the globe. Despite of the fact the governments intervene to mitigate the risks associated with this uncertainty of pandemic, the higher number of cases and deaths added fuel to this fire of uncertainty. The Figure 3 showing higher volatility Spillover during 2020 in a continuous manner depicting the impact of higher uncertainty of Global pandemic on sampled stock markets.

On 16th March 2020, the world reported a rapid shift in COVID-19 percentage confirmed cases and deaths as well. The number of cases increase by 195.11% while the number of deaths increase by 240.19% (WHO, 2020) which further elevated the uncertainty level as shown in Figure 1, which is more steeper during this time. On 23rd November 2020, the cases decrease by -1.75% (WHO, 2020) and in figure 3 this decrease in confirmed cases is indicated by sudden downward trend. Then again in April 2021 there's sudden increase in both confirmed cases and deaths (13.91% and 7.03% respectively). This trend is depicted in figure as graph continuously showing a downward trend and then increase rapidly in April 2021. The Omicron variant of Covid-19 discovered on 25th November 2021 and considered as deadliest variant among all. This variant also spread negative sentiments across the globe and shown in sudden rise in last quarter of 2021.

In the last quarter of 2020, the Pfizer and Moderna vaccines entered in their clinical trial phases and showing some positive response against COVID-19. This positive response after trail phases lead to reduce uncertainty in environment. Then further reduction in volatility Spillover trend is due to approval of full regulatory usage of Pfizer and Moderna in start of 2021 indicating a condition to control COVID-19 to some extent by using vaccine against it. This raise positive sentiments of investors, people and portfolio managers and reduce the ambiguity prevailing among stock markets. Then further in 2021 the trend is continuously decreasing while the two upward shifts are due to sudden increase in Covid-19 cases and discovery of Omicron variant. The decreasing trend is due to the fact that the stock markets of countries under observation started to recover from COVID-19. This recovery reduce the volatility Spillover.

Figure 3

Average Volatility Spillover



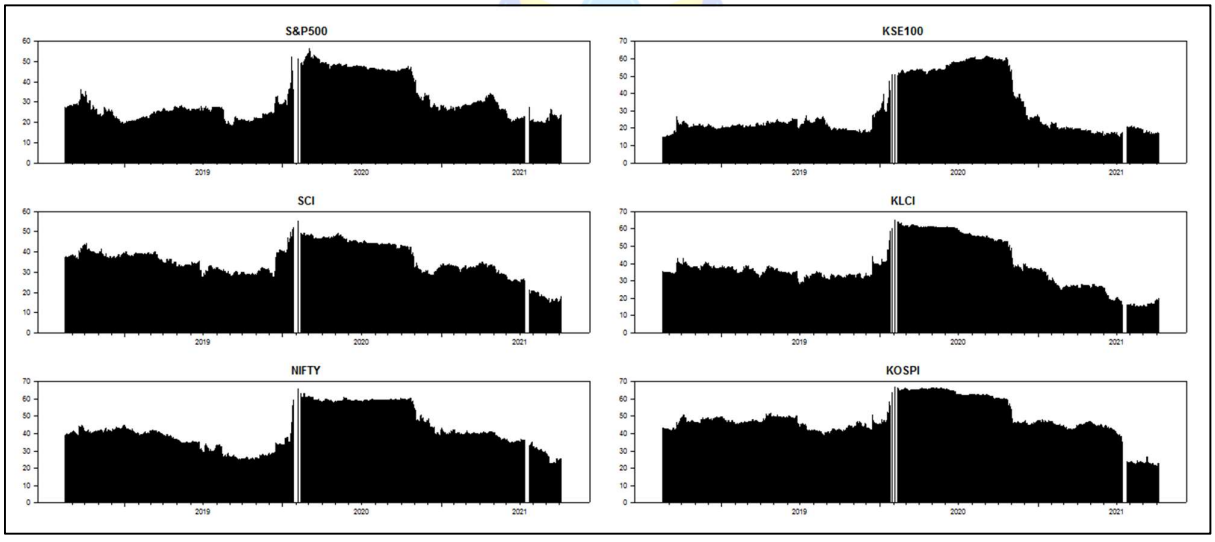
Directional Volatility Spillover

Following is the directional Spillover analysis of the US and emerging Asian stock markets:

The directional volatility Spillover from others to each of the six stock markets is presented in Figure 4. In figure we can observe that each of these stock markets are receiving higher directional Spillover from other stock markets during the peak period of pandemic. Specially, from the end of 2019 to third quarter of 2020. During this turbulent period of COVID-19 pandemic, the S&P 500 suddenly receive higher volatility Spillover from others then receive in a steady manner till the end of third quarter of 2020. This volatility rise suddenly for a shorter time span during 2021 and then fall again. The SCI, NIFTY, KLCI and KOSPI receive higher volatility Spillover during pandemic peak period. The KOSPI receive higher volatility Spillover from others and despite of fall in the last quarter 2020, still it receive higher volatility from others. Like other stock markets, KSE 100 receive high volatility from others stock markets in the start of pandemic period and further elevated in the third quarter of 2020 and then fall substantially. The KSE 100 receive the least volatility Spillover from other from the last quarter of 2020 to the end of sampled period. All of these stock markets receive higher volatility Spillover from others in the beginning of pandemic period then the receiving pattern is different for each of these stock markets.

Figure 4

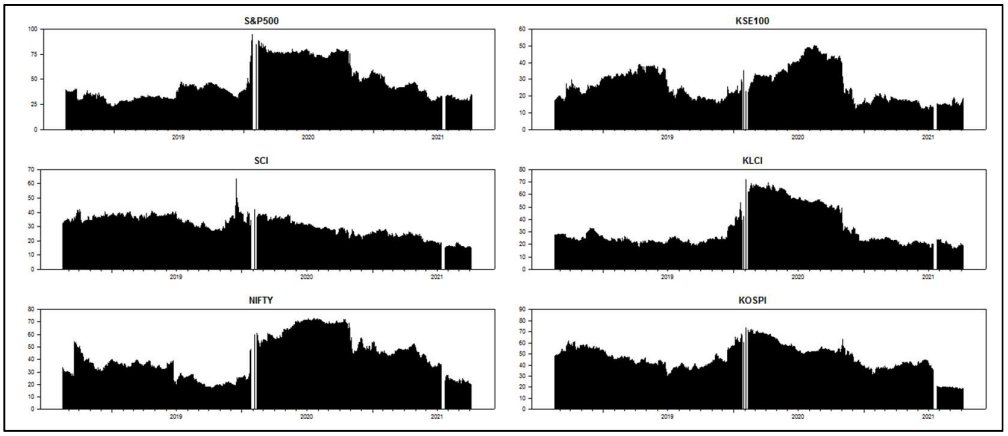
Directional FROM SAM – The US and emerging Asian stock markets$SAM_{2N,i}^{H} \leftarrow \blacksquare$



The directional volatility Spillover TO others from each of the six stock markets is presented in figure 5. Each of these stock markets followed a random transmission pattern to other stock markets. In the start of pandemic period, specifically in first two quarters of 2020 S&P 500, NIFTY, KOSPI, KLCI transmitted highest Spillover to others while KSE 100 transmitted highest Spillover to others after first quarter of 2020 and till the mid of last quarter of 2020. The SCI follows nearly a steady transmission pattern to others. It decreases in steady pattern over the passage of time and then become stationary. The NIFTY transmitted higher volatility to others while SCI transmitted the least. Despite of the fact that pandemic originated from China (SCI) still the transmission of volatility from china to others is static as compare to others in sample. The NIFTY transmitted higher volatility Spillover to others in second and third quarter of 2020.

Figure 5

Directional TO SAM – The US and emerging Asian stock markets $SAM_{2N,i}^{H} \rightarrow \blacksquare$

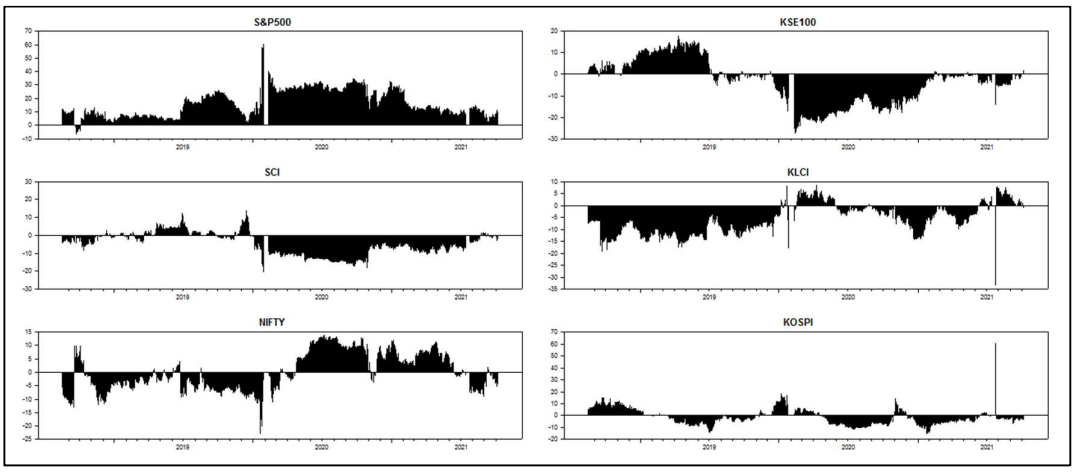


In the net directional Spillover, we check the underlying difference between transfers to others and receive from others. So, whenever the values of stock market plotted above zero then that market is transferring more volatility to others as compare to the volatility receiving. This type of stock market is considered as net Spillover giver while more receiving one or values lying below zero is the net Spillover receiver. The Figure 6 is representing the net volatility Spillover of the stock markets under consideration. The S&P 500 is the net Spillover giver among the whole sample as it transmitted volatility to others and this transmission increase during the peak time of pandemic. The NIFTY was lying under the head of net receiver before pandemic arrives and during the time of pandemic it also transmit higher volatility Spillover to others. On 15th September 2020, India reported highest number of COVID-19 cases, 91,953 while deaths were 1,247. This was highest during third quarter of 2020 as indicated by higher volatility transmission during this period.

The SCI and KSE 100 receives net volatility Spillover throughout their pandemic phase. Before pandemic, the SCI transfers less volatility Spillover or it seems like it's not in connection with the stock markets under consideration. During the start of pandemic, KLCI was the net Spillover giver while from the peak time to further the KLCI became net Spillover receiver. The KOSPI receive more volatility and transfer less to others. On the whole during COVID-19 pandemic, S&P 500 and NIFTY are the net Spillover giver among the sampled stock markets, SCI and KSE 100 are the net Spillover receiver while KLCI and KOSPI followed a mixed trend.

Figure 6

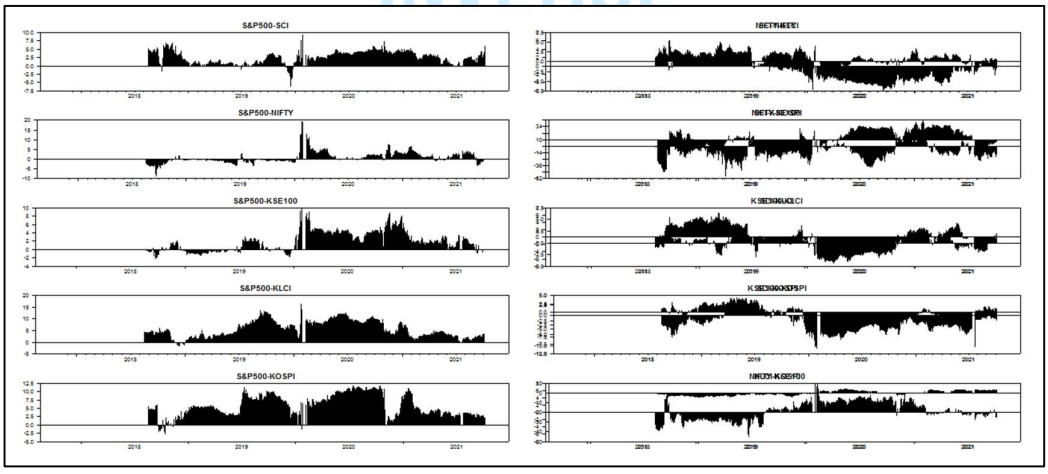
Net Directional Volatility Spillover



The net pair wise volatility Spillover which depicts the dominance and dynamics of stock markets in each pair is depicted in figure 7. As we see in figure, the S&P 500 transfers the volatility to all other stock markets under consideration. Among all the S&P 500 transmitted higher volatility to KLCI and KOSPI. Despite of the fact that the US reported highest number of confirmed cases (75,687 in June 2020), still it acted as volatility transmitter in pair with all sampled stock markets. On the other side KOSPI followed a mixed trend transmitted and received as well.

Figure 7

Net Pair Wise Volatility Spillover



Conclusion

The effect of uncertain events on stock markets, financial co-integration and spillover has been analysed in prior literature. The study contributed in this literature by analysing the dynamics of volatility spillover from the US to emerging Asian Stock markets (China, Pakistan, India, Korea, Malaysia) amid the global pandemic of Covid-19. The Spillover index method designed by Diebold and Yilmaz (2012) is used to analyse the dynamics of volatility spillover during Covid-19 pandemic. The TO and FROM SAM helped in determining the highest volatility transmitter and highest volatility spillover receiver among sampled stock markets. Further the net volatility spillover and directional volatility spillover helped in determining which market is affecting the most as depicted by Spillover index method table.

The Covid-19 leads to financial turmoil across the globe. As the world stock markets are highly integrated we hypothesized that this global pandemic period has volatility Spillover effect on selected stock markets (US, China, India, Pakistan, Korea, Malaysia). The graphs of their daily stock indexes showed that these markets become highly volatile during pandemic period. In the sample, the US (S&P 500) and Indian (NIFTY) stock market is highly connected with rest of the world. Investors across the globe invest in these stock market. These two markets show higher volatility spillover during the sampled period. As these countries are highly affected by pandemic as depicted by more number of confirmed cases and deaths. With each percent increase in confirmed cases and deaths, more volatility is depicted in their stock markets. Despite of the fact that pandemic originated from China, still it transmit and receive less volatility Spillover from other sampled stock markets. The reason is that still China's stock market are not highly integrating with other world markets.

In September 2018, China created partnership with 62 countries. This partnership made the residents of these 62 countries eligible to invest in stock market of China. Still much progress is on its way that will make Chinese Stock markets more integrated with the world. The KOSPI affect itself the most, as investors here feared about their investment and right from the start of Covid-19 pandemic, due to inflationary pressure both local and foreign started to withdraw their money from local stock market i.e. Krafton Inc., KakaoBank Corp., Celltrion Inc., etc have lost their major local shares during 2020. These all things affected the KOSPI market abruptly. Similarly the KSE 100 also affected receive and transmit less volatility Spillover. The major investors in this stock markets are local investors while in the name of foreign investment, 1,886 institutional investors invested in Pakistani stocks. This thing make Pakistani markets less prone to external shocks.

The results of dynamic volatility spillover test depicted the fact of integration and asymmetric transmission pattern of volatility spillover among the sampled stock markets. The time varying patterns showed the response to global pandemic of Covid-19, specifically the confirmed cases and deaths. Then fluctuation occur in volatility transmitting pattern due to omicron variant and clinical trials of Pfizer and Moderna vaccines. The results suggest that despite of the fact that the US reported highest number of cases or most affected by the Covid-19 global pandemic, still it transmitted highest volatility spillover to others rather than receiving. It affect others sampled stock markets the most. After the US, India is widely affected by Covid-19, so with each percent increase in cases there is more volatility in NIFTY. It receive higher volatility Spillover from S&P 500. The China being the originating country less affect others and affected

less by others, or we can say it follow a more static pattern. On the other hand, KOSPI affected by itself the most rather than affecting others and being affected by others. The results are just in accordance with Meteor shower hypothesis. Each of these markets have some different trading days and despite of their closure on some days still they transmit volatility Spillover to these connected markets. It doesn't matter whatever their geographical location or when they are opening still they are either receiving or transmitting volatility Spillover to other stock markets in sample.

The investors if want to acquire maximum benefits from international portfolio diversification specifically from stock markets can design portfolio in a way by keeping stocks of transmitter, receiver and static in an appropriate manner. This will secure them by negative effects of any other upcoming financial turmoil. Further can in order to mitigate risk they can design portfolio by investing in other investment assets as well. The investors and portfolio managers have significant implications for the diversification of their portfolio and minimization of risks as well. Investors in international stock markets can invest in stocks of KOSPI for hedging purpose as it's the only market transmit less and also receive less volatility Spillover from others. So, investing in KOSPI's stock can be a safer side for risk minimization associated with any uncertain events which lead to volatility Spillover transmission. Along with investing in stock markets, investors and portfolio managers can invest in other instruments to mitigate risks associated with international portfolio diversification. The policy makers can get the idea of highly volatile markets and can design strategies to secure their markets from any other upcoming uncertain event. Further the strategies can be designed to attract maximum number of international investors i.e. KSE 100 index has privileged to show secure investment environment for foreign individual investors to attract maximum investment not only from institutional investors but also from individual investors as well.

The present study also provides some basis for future research. The researchers can also use tail-dependence approach of Diebold-Yilmaz to find out the connectedness existing in these stock markets. Other economic variables can also be incorporated to analyse the impact of other factors affecting the portfolio returns. As the present study is conducted on stock market, one can conduct volatility Spillover analysis on currency, bitcoin etc. during pandemic period.

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