Downside risk-return volatilities during Covid 19 outbreak: a comparison across developed and emerging markets

Syed Asim Shah1 · Hassan Raza2 · Aijaz Mustafa Hashmi1

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Abstract
This research study evaluates the impact of the Covid 19 pandemics on the downside risk-return volatilities across the four stock markets of the USA, UK, China, and Pakistan. The pandemic results in severe economic and financial consequences both at micro and macro levels as well as across the stock markets of various countries. The selected stock markets of the USA, UK, Pakistan, and China are significantly affected in terms of both investor risk and return during the pandemic time. The entire period distribution of the risk exhibited the downside risk behavior of both markets and investors’ serious concern regarding their investment strategies. Using high-frequency data from January 2020 to April 2021, the findings of the study reveal more of the downside abnormal returns across both markets. The impact is larger and high in developed markets of USA and UK compared to the emerging markets of China and Pakistan. The outcomes of the various value-at-risk models disclose the higher downside risk implications for all markets, larger for developed countries. Similarly, the three stock markets of the USA, UK, and China were found to be significantly connected during a pandemic. Investors’ reactions were positive and high in case of positive news outbreaks and dwindling in case of negative news and downside impact. The outcomes of the study are useful for investors, portfolio managers, investment advisors, and others to understand the dynamics of the pandemic situation and devise effective strategies to overcome the severities of downside risk.

Keywords Covid 19 · Downside risk · Value at risk (VaR) · Risk simulation · Equity markets

Introduction
The equity markets have always been volatile, and it is exposed to both unsystematic and market risk. On some level, the risk is unavoidable and compulsory to generate substantial profits. However, if it reaches a certain point, it will result in calamity. If the returns are favorable, it is not a major worry; but, if they are negative, it has a significant impact on investors and the economy’s functioning. Researchers have devoted a lot of time and effort to studying stock market behavior, particularly during crises. Stock markets, according to Carp (2012), may impede economic progress because of their market failure susceptibility due to crisis. Health catastrophes are regarded as more significant since they affect both people’s lives and the economy as a whole.

Furthermore, due to the interconnected features of global markets after globalization, Chiang et al. (2007), Sun and Hou (2019), and Morales and Andreoss-O’Callaghan (2012) corroborate that instability in one particular equity market is substantially associated with the instability in other equity markets. As a result, bad news from a foreign market impacts not just that country’s market but also markets in other nations and asset classes. When there is no plan for contingencies, as in the instance of COVID-19, which has left the globe traumatized, it is serious. On December 31, 2019, the first case of COVID-19 was reported in Wuhan, China. The World Health Organization (WHO) declared
it a Public Health Emergency of International Concern on 30 January 2020, even though it was not taken seriously at first. The WHO deemed this to be an urgent global public health emergency with fast increases in infection even after travel prohibitions in China. Happening March 11, 2020, the WHO delayed nearly two consecutive months to designate COVID-19 as a worldwide contagion. This unwelcome and unexpected occurrence has had an impact on every area of the global economy. Because the Republic of China is the world’s leading producer and trader of world crude oil, economists have predicted a slowing of its development (Sohrabi et al. 2020). The condition is rapidly deteriorating, and the deadly sickness had to transmit to the other countries and regions of the world, killing more humans than in China. The governments of the majority of countries impacted by the virus are implementing a variety of steps, including public place lockdowns and closures, compensation for employers, and tax reductions.

In the event of a health-related crisis, the situation becomes much more perilous since the economic activity is halted. As of now (May 2020), it has affected 59, 20, 231 individuals worldwide and claimed the lives of about 362,365 people (Worldometer). Forecasts for employment and gross domestic product (GDP) have reached new lows. Furthermore, financial sector participants are restricting their investments. Agricultural goods have seen a 20% reduction in price (Bhosale 2020, March 19). The British Public Federation on March 20, 2020, expressed worry about a large drop in industrial turnover in the various sectors in the UK. During the H1N1 virus pandemic in Taiwan, 18% of families lost income as a direct consequence of the impact on the education sector (Chen et al. 2011). As a result of the closure of educational institutions due to the COVID-19, country-wise 900 million pupils are tormented released in the report by UNESCO on March 24, 2020. COVID-19 pandemic, according to Nicola et al. (2020), has also resulted in a geopolitical battle over oil output between Russia and OPEC nations. COVID-19, to put it bluntly, has stemmed the world from the impeding dogma of the greatest crises of history.

Based on the frightening cases of the COVID-19, the effects of the previous crisis on the world economy, the devastating repercussions of the COVID-19, and the relevance of stock market indexes to reflect an important economic dimension, we are attempting to conduct a scientific assessment on the stock market indices of the world’s leading economies representing developed and emerging block. Favorable and unfavorable ups and downs in the stock markets are investigated during the period of the COVID-19 era and relative to other time periods with significant stock market volatility using different variants of the augmented value-at-risk models. In addition, our study tried to figure out how different marketplaces interact with one another during pandemic crisis periods. How does the market participant react to downside risk volatilities, and how do they retransform their strategies to safeguard such crises?

**Significance of the study**

The spread of COVID-19 has sparked fear about the global economic outlook, and most economic activities have been halted. As a result, the financial markets were destabilized, with sharp drops. Several stock markets in Asia, Europe, and North America had their greatest declines in history, as well as daily price recoveries that show their rising downside volatility (Rudden 2020). Because it is practically impossible to estimate how long the COVID-19 epidemic will endure, the economic and financial consequences are as difficult to forecast. This disastrous incident has posed unprecedented hurdles to investors and portfolio managers. As a result, they have been compelled to go on an arduous journey toward the adoption of new investing techniques that would, perhaps, boost returns while reducing risk, all while equities remain afflicted by excessive volatility. In reality, the unprecedented health crisis caused by COVID-19 has underlined the necessity for a thorough examination of severe downside movements between global markets to assess their interconnectedness and contagion, as well as to determine the consequences for financial market stability.

Sita and Abdallah (2014), Lien et al. (2018), Jitma neeroj (2018), Kang et al. (2019), and Sun et al. (2020) are only a few examples of research in the finance literature that look at downside risk spillovers in equity markets and compare results before and after chaotic periods. However, the majority of this research look at conditional volatility and correlation, generally adopting a multivariate conditional autoregressive heteroscedastic (GARCH) approach to do so. However, most people overlook significant downside risk volatilities in global stock markets, resulting in an underestimation of downside risk spillovers (Yu et al. 2018). Recent research (e.g., Girardi and Ergün 2013; Adrian and Brunnermeier 2016; Reboredo and Ugolini 2016; Fang et al. 2018; Bouri et al. 2020; Shahzad et al. 2018, 2021) has highlighted the importance of considering tail (extreme downside) risk when analyzing spillover effects between financial markets or institutions. Importantly, there is essentially little information on how the catastrophic COVID-19 epidemic created extraordinary downside movements between the global stock market and the stock markets of the nations most affected by the pandemic, which has crucial implications for stock market stability. Rizwan et al. (2020) analyze how COVID-19 influenced systemic downside risk in the banking sectors of eight of the most COVID-19 afflicted
nations in intriguing research. They detect a considerable rise in systemic risk among the sample nations and identify systemically important financial institutions using the arithmetic mean of value at risk (VaR) and connectivity indicators during COVID-19.

The influence of COVID-19 on dynamic severe downside risk-return volatilities across the top stock markets of the nation’s worst afflicted by the pandemic is highlighted in this research, which builds on Rizwan et al. (2020) analysis. As a result, we investigate whether stock market downside risk-return effects are amplified in these historically extreme market conditions. The COVID-19 pandemic is a rare occurrence that poses a systemic threat (Sharif et al. 2020). Extreme occurrences have been seen in the past to put downward pressure on financial markets and affect downside risk and return expectations (Merkle and Weber 2014; Farhi and Gabaix 2016; Heo et al. 2020). Due to pandemic-related tendencies, numerous hazardous asset classes have seen spells of high volatility. In our study, we use Girardi and Ergün’s (2013) tail-risk interdependence of the “contribution” and “exposure” conditional values at risk (CoVaR) and Adrian and Brunnermeier’s delta (2016) PVar, TVaR, and SVar. These measurements go beyond the unconditional value at risk (VaR), which calculates a country’s greatest loss for a given level of confidence and time frame (Reboredo and Ugolini 2016). VaR, on the other hand, fails to recognize a country as part of a system that may experience instability and introduce new sources of downside risk, particularly during times of crisis (Petrella and colleagues 2019).

On two fronts, we contribute to the scholarly literature. To begin, we examine extreme downside risk-return volatilities in the four leading stock markets in the COVID-19-affected nations. This adds to earlier research that has overlooked the influence of this tragic event on the global stock market’s extreme downside movements causing extreme losses. Market spillovers are higher during bearish conditions than during normal or bullish ones, according to recent studies of, e.g., Aloui et al. (2016), Saeed et al. (2020), and Shahzad et al. (2021). Examining the downside risk volatilities throughout global financial markets, therefore, contributes to a better understanding of information transmission in severe market situations like the COVID-19 era. Second, we use Diebold and Yilmaz’s (2012) connectedness technique to examine the system of connectedness between the VaR series of the sampled stock market indices and the global stock index (2014). Such an analysis captures the system of risk spillovers with a downward risk propensity, which is significant and valuable for the creation of financial stability regulations, as well as investment and hedging methods for the benefit of investors, portfolio managers, and risk managers.

The entire study of ours is organized around five sections. Section one was the introduction and theoretical background, the second section highlights the significance and contribution of the study, the third section elaborates on the review of past studies, and the fourth section reports the research design and methodology to empirical test the main hypothesis. Section five reports the empirical findings of the study, while the last section reports the conclusion, implications, and limitations of the research study.

**Review of empirical studies**

Contingency effects usually decrease prediction and prevention. This involves a comprehensive examination of past occurrences to seek certain patterns or indications for future action. In reaction to contingency, especially negatives, researchers, economists, and market analysts are continually reviewing how the markets and the economy operate. The economic consequences of the contagions and global health diseases are huge, not confined to the affected nations according to Lee and McKibbin (2004). In their research findings, they examined the economic and financial consequences of the SARS disease. In the chemical, building, departmental, food, hotels, textiles, and car industries in Taiwan, there are constant negative returns (Chen et al. 2011). The losses in financial markets equal $2 trillion in equity in DeLisle et al. (2011) almost comparable to the Asian financial crisis. The cost of influenza economics in the USA was estimated by Meltzer et al. (1999) to range from US$73.1 million to US$166.5 million. Blooms et al. (2014) considered the effects of the contagion owing to the conversion of an avian infection strain in human bodies and concluded that the world’s economic development and world commerce fell, respectively, by 0.6 and 14%, based on 20% occurrence rate and 0.5% death rate causing the huge number of causalities in affected areas.

The harmful short-term effects of H1N1 flu from 2009 in Mexico were also reported by Rassy and Smith (2013). The economic cost of McKibbin and Sidorenko (2006) has been forecast as US$300 million to US$4.4 trillion, considering three mild or severe pandemic scenarios. On 28 February 2020, Mike Patton, Senior writer at Forbes, said that the worst-case scenario of Spanish flu was a 21% drop, but in the first half of the year, the swine flu was up by 40%, as the stock had already been undervalued by the worldwide crisis (Patton 2020). However, several researchers did not find particularly severe stock market impacts. The market indexes of three Latin American and Caribbean nations except for Brazil have not shown significant adverse returns during the epidemic of the Zika virus Macciocchi et al. (2016). A similar behavior during the Spanish flu was seen by Velde (2020). The reported downfall was enormous
throughout the period of the worldwide crisis in India, according to Kumar (2020), with the Nifty falling 65% from its high but a widening time horizon. In just a few days, the worldwide epidemic collapsed by 30% and 32% of Indian and US stock markets correspondingly. However, Valigra (2020) declared that the financial markets generally correct themselves following the epidemics, when it referenced S&P 500–18.72% and 35.96%, respectively, of swine influenza, within 6 months and 1 year.

Jenny (2020) adds that during the time of contagion majority community can perform work duties. As a result, the monetary cost of COVID-19 would be considerably higher than the 2008 global crisis, and the Western nations can lose around 15% of their GDP in the near run. The economic costs of the COVID-19 containment approach would, according to Ferguson et al. (2020), be substantial. It is the only way to rescue the world, however. A USD 14 billion quick track funding plan has been agreed upon by the World Bank Group to assist firms and nations react to the Covid-19 spread (Ilyas 2020). Baker et al. (2020) reported around 18 leaps in 22 days were recorded, more jumps than at any other period in history when analyzing the stock market swings via documenting ups and downs in these markets by more than 2.5%. Jordà et al. (2020) specified over a long-term period of eras with declining investment possibilities trails epidemics because of the dread of devaluation, loss of money, and over-capital recovery per unit of enduring labor when examining the influence of pandemics on real interests’ rates. They also anticipated, however, that the outcome might be different this time, as the bulk of those afflicted by the past pandemics are less than 60 years old, and if small interest supports over a longer period of time, it can be useful in helping governments to ease COVID-19 costs. In addition, the epidemic leads to geopolitical warfare between the countries of China and the USA (Hartl et al. 2020). Anil Sarin, the Equities Chief Investing Officer at Centrum Broking, shared his insights on investing strategies, stating that, in addition to market turbulence caused by the raw crude oil mandate, there is a huge disagreement between Saudi Arabia and Russia. As a result, the stock market in the United States has dropped by more than 20%.

The decrease in capital markets was seen by McKibbin and Fernando (2020), demand and other risk factors increase as a result of COVID-19 and investors relocating their money to other assets and areas they believe are safe. Liu et al. (2020) investigated lately the equity markets in COVID-19 nations concerned and established that there were equity markets impacted by the virus substantially and adversely. In addition, it was established that the rates of indexing decreased the most by approximately 0.01 for France, Germany, Russia, Italy, Thailand, the UK, Canada, Japan, the USA, India, Abu Dhabi, and Australia, and those for Singapore, Thailand, Korea, Indonesia, and Hong Kong decreased the highest by 325.245%, 274.619%, 115.163%, 64.345%, 49.086%. The transmission of baffling COVID-19 can be decreased by societal separation, as indicated by Prem et al. (2020); nevertheless, its effects vary across various age categories. Atkeson (2020) further expresses worry that the disease can spread fast throughout the world within less than 18 months if attempts to mitigate the sickness are loosened.

The literature outlines several risk steps, but VaR is one of the finest and most commonly followed since it does not complicate a single measure. It also helps to discover the risk of adverse effects. VaR is the primary measure for calculating the risks of the market (BCBS, 2006). JP Morgan and Reuters created VaR in 1994—risk metrics and successful results were seen. Many other industries started to use their market risk calculation afterwards. As Linsmeier and Pearson (2000) have developed, the emergence of VaR as a risk measure was driven by large fluctuations in important economy-related indicators and the growing usage of derivatives. As to Jorion 1996, p. 911), VaR is able to encapsulate in a single dollar that easily communicated the impacts of leverage, diversification, and probability of unfavorable price shifts. Accordingly, the specified model is the prime measure of downside risk for various groups of statistical continuous distributions, asserted Gaglianone et al. (2011). VaR became more common in the banking sector and was used to calculate the capital adequacy ratio in the context of a risk measure, after the required adoption of VaR by the Basel Committee on Banking Supervision in April 1995. (Jorion 1996). VaR was also proposed by the Securities and Exchange Commission in December 1995 to replace listed US CRPBs. Also, proponents of VaR are Jorion (1996), Uylangco and Li (2016), and Xu et al. (2022), but attentively. Most research with VaR focuses on evaluating the risk of the banking industry and on improving the methodology and back-testing the various models. Swami et al. (2016) are generally underestimated with estimates of VaR foreign exchange in India which have been reached based on traditional standard methods. Sarma et al. (2003) proposed that users select various VaR models depending on distribution for distinct portfolio estimates. Chinhamu et al. (2015) reviewed both short- and long-term trading profits and losses on the Chinese gold market and observed that the precise VaR estimate depends on the adequacy of extreme data exposures.

In recent research, the impacts of COVID-19 on financial markets have been investigated further. Ciner (2021) looks at 4-month stock index data from the start of 2020 to see if the returns can be forecast in such a scenario. The study, which is backed up by the Federal Reserve’s purchase of corporate bonds and related ETFs, reveals that corporate bond ETFs and most industry returns are predictable during COVID-19. Contessi and De Pace (2021) examine the
data in 18 various markets throughout the world to detect
times of modest market volatility. The poll revealed insecu-
ry and a startling shift in the market from China to other
countries, with slow dissemination and a swift collapse.
The impacts of the COVID-19 pandemic on the US VIX
index are demonstrated by Bollain-Parra et al. (2021). The
relationship between COVID-19 news and high volatility
spillover throughout markets is presented by De la Torre-
Torres (2021). De la Torre-Torres (2021) present a new trad-
ing algorithm that outperforms the market during moments
of extreme volatility. COVID-19 influences the volatility of
the Canadian stock market, as shown by Xu et al. (2022).
A few research have also looked at the risk-reward trade-
off. Kusumahadi and Permana (2021), for example, used
the basic equation and the threshold generalized autoregres-
sive conditional heteroskedasticity model to perform their
research. During the pandemic, the stock return was shown
to be strongly connected with volatility, according to the
research. Furthermore, the magnitude of the pandemic is
inversely proportional to the amount of volatility. In addi-
tion, the exchange rate has a negative influence on market
returns. To summarize, all available research overlooks
idiosyncratic volatility and the impact of the COVID-19
disease and a startling shift in the market from China to other
countries, with slow dissemination and a swift collapse.

The COVID-19 predicament and stock market volatil-
ity are being recognized in a growing corpus of literature.
One branch of this research has looked at the influence of
the COVID-19 pandemic on various stock markets (Ashraf
2020; Liu et al. 2020; Okorie and Lin 2021; Zaremba et al.
2020; Zhang et al. 2020). The majority of this research tries
to figure out how COVID-19 affects stock price changes
throughout the world. Nonetheless, since investors perspec-
tives of the stock market have shifted in the aftermath
of the epidemic, more recent research has looked into the
stock market reaction in China (Al-Awadhi et al. 2020; Huo
and Qiu 2020). In addition, Aslam et al. (2020) examined
COVID-19’s impact on European stock market indexes.
In the COVID-19 circumstance, however, the impact of
daily news on confirmed illness and mortality cases in the
US demonstrated the stock market’s informational effi-
ciency (Albulescu 2021; Mazur et al. 2021a, b; Wagner
2020). Although multiple types of research have found that
COVID-19 has a major influence on the stock market, the
experimental results are mixed. Furthermore, the majority
of studies on stock market reaction during COVID-19 have
focused solely on stock index predictions or changes in trade
volume and investor expectations. However, empirical evi-
dence of COVID-19’s influence on the downside risk and
underlying return across the various region is limited to date.

After studying and recognizing the pertinent empirical
literature and the severity of pandemic impact on equity
markets, our study aims to analyze the dynamics of the
stock market in emerging and developed economies world-
wide in terms of downside risk-return volatilities. Because
it is widely utilized for market downside risk assessment,
VaR and its variant models were used to study the down-
side risk dynamics of selected markets. Our study answers
the following research questions:

What is the impact of the Covid-19 pandemic on the
downside risk volatilities of the selected markets? How
will markets react? Which market is more exposed relative
to other markets?

Research design and methodology

Our study draws the comparison of assessing the down-
side risk and relative returns across four countries during
the pandemic period. We have selected the Pakistan, US,
UK, and China stock markets as these countries are sig-
ificantly dazzled by the COVID-19 shocks and are the
leading nations in the comparison of risk-return volatilities
with worldwide partners. The stock indexes undertaken for
the empirical analysis are KSE-100-Pakistan, S&P 500-
USA, FTSE-UK, and SSE-China. According to Pearce
(1983), stock price disparities can be anticipated to affect
collective expenditure and, hence, economic direction.
Therefore, in our study, we have regarded stock market
indices as a major economic indicator. The selected econo-
 mies are the world’s top economies, with COVID-19 creat-
ing significant downside volatilities across these markets.
We used high-frequency data from January 2020 to April
2021 to analyze the impact of the Covid 19 pandemic on
the downside risk patterns across these markets. These
downside risk volatilities result in a significant worth of
losses for investors and impact the economies on a larger
scale. Since the Covid-19 is not yet over, the data and
results may be obsolete if there is a change in the pattern
of illness. However, from 1 January 2020 to April 2021,
we use a limited data period as a Covid-19 period. This
is because, in October 2019, the first official Covid-19
case was recorded. Secondly, we examine upside volatility
and downside volatility for chosen economies during the
Covid-19 pandemic. This time period was selected based
on data availability and homogeneity across the sample
economies. Various econometric techniques were applied
to calculate and analyze the downside risk volatilities
including, VaR models, risk simulations, and trend analy-
sis. The purpose is to study whether the pandemic has
significant implications for various investors, managers,
and policymakers to hedge and overcome negative out-
comes due to downside risk caused by the pandemic. Data
were obtained from the different national and international
market indexes’ official websites including data stream and
yahoo finance. Additional information about Covid-19 was obtained from the different nations’ Ministry of Health repositories of the concerned nations.

**Computation of return volatility**

We begin our analysis with the calculation of return volatility for each market during the pandemic, and the findings exhibit the significant downside volatilities that indicate the presence of a larger downside risk. However, we present both positive as well as overall trends relative to negative trends exhibiting the presence of downside risk due to pandemics across all four selected markets. Figs. 1, 2, and 3 below provide the return volatilities of the selected markets over the sample timeframe.

**Modeling return volatilities**

**Parametric value at risk (PVaR)**

In the first variant of the VaR model, we estimated VaR in the first step, for all selected markets and also the total time to observe the downside risk. Throughout a given period, the value at risk approach (VaR) is a standard method of counting the biggest probable loss. Variance–covariance method (parametrical VaR) or parametric value at risk (PVaR) are the most used way of VaR. The returns should be independent and distributed identically in accordance with this technique based on the premise of normal distribution. The parametric value at risk (PVaR) is specified as
VaR_p = \mu - z^{-1}\sigma

The terms \mu and \sigma represent the arithmetic mean (AM) and deviation around the mean (SD) of the selected time series based on the 99% interval level, whereas \( z^{-1} \) measures the converse of the properties of the given function based on the normal distribution.

**Student T-value at risk (TVaR)**

In the second variant, we estimated the TVaR to observe more the deep fluctuations in the returns during the pandemic to observe the downside volatilities. However, as the return series is generally observed to have tall peaks and even tails, and meanwhile the sampling size of the regime is limited, our study has additionally calculated VaR to incorporate more tail events. The properties of TVaR are defined as

\[
\text{VaRST} = \sqrt{v-1(v-2)} t^2 ((1-\alpha)\sigma - h\mu)
\]

In the given equation, \text{VaRST} denotes the TVaR, and the term \( v \) describes the degrees of freedom for the Student’s \( t \)-distribution.

**Monte Carlo simulation**

Simulation generally offers the proper path in case the given data set is not identically distributed (Uylangco and Li 2016). To perform robustness measures and check the conduction of the VaR model, our study applied the Monte Carlo simulation for the entire sample period of the study. The specified model is

\[
l_{t+1} = l_{t}\exp\left[\left(\text{rf} - \frac{\sigma^2}{2\sigma_y}\right)\right]
\]

In the given equation, \( l_t \) denotes the current price of the given stock at time period \( t \), the term \( \text{rf} \) is the measure of the risk-free rate of return, \( \sigma \) measures the standard deviation of the targeted index returns, and \( \sigma_y \) represents the normally distributed random variable consisting of 0 mean and unit standard deviation. In this study, we adopted the arithmetic variate method of Boyle (1977) and employed techniques of variance reduction to decrease simulation errors. We have generated 100,000 simulated equity prices randomly to experiment with the test of VaR to examine the risk volatilities on different returns.

**Isolation of positive and negative returns**

In our study analysis, the description of the volatility indicates that the anticipated return has deviated. The difference might be favorable or negative. Investors are worried that their investment value is being lost as it produces negative volatility. But both the favorable instability and the unfavorable instability in our study design were considered. In analyzing each country’s benchmark returns, we have built two distinct clusters. One group is divided by positive returns, while the other is divided by negative returns. We tried, using the following formula, to determine the maximum gains measured by (MPG) and maximum potential losses measured by (MPL) for both groups:

\[
\text{MPGorMPL} = \mu \pm 2.33 \sigma \times \text{af}
\]

\[
\text{af} = \sqrt{v^{-1}(v-2)} T^{-1}(\alpha, v) N^{-1}(\alpha)
\]

In the given equations, \( \sigma \) and \( \mu \) represent the standard deviation and mean at a 99% significance level, the term \( v \) describes the student’s distribution number of degrees of freedom, and the symbol \( N^{-1} \) is the converse function of the entail \( t \)-distribution. Our study also estimated peaks and dips in the case of positive and negative clusters, by calculating the returns smaller than the MPG and MPL.

**Back-testing**

For the purpose of back-testing, Kupiec’s test is utilized. The second term for the test Kupiec likelihood ratio (LR) is the POF test ratio which indicates the percentage of failures. Escanciano and Olmo (2010) described back-testing as the procedure in which the actual trading outcome is compared relative to the model produced risk metrics. The test of Kupiec evaluates the loss frequency above the value of VaR. As to Chinhamu et al. (2015, p. 113), the ensuing technique contains in its calculation the number of times the rates of failure measured decline under (in long-standing spots) or over (for short-standing spots). The testing null hypothesis measures the expected fraction of violations relatively equivalent to \( \alpha \). If the number of observations is \( N \), the number of violations is \( \alpha \), and the resulting assurance interval is \( \alpha \); then the estimated POF is \( \rho \), and it would be specified as \( \alpha = \rho = V/N \). The LR is calculated as follows:

\[
LR_\rho = 2\ln\left[\frac{1 - \alpha^N - V^\alpha V}{1 - \left(\frac{\alpha}{N}\right)^N - \left(\frac{V}{N}\right)^V}\right]
\]

In the specified equation, the term in the upper division entails the maximum likelihood of the realized outcomes according to the non-alternate hypothesis, and the term in the lower division entails the maximal likelihood of the
realized ratio as per the alternate hypothesis reported in the study of Patra and Padhi (2015).

We quantify and compute the PVaR, TVaR, and SVaR to estimate the magnitude of losses owing to downside volatilities after separating the positive and negative returns due to pandemic disruption. When compared to bivariate dynamic condition correlation GARCH models, one of the main advantages of these dynamic variants of VaR models, along with back-testing through the Kupiec likelihood ratio (LR), is their ability to evaluate extreme downside risk volatilities between markets during radical negative and positive price movements. Because of its potential to assess high negative risk and return volatilities during pandemic times rather than the median state, these variations of VaR models reveal themselves as a crucial methodological feature of our study (Adrian & Brunnermeier 2016; Lee and Long 2009; Samarakoon, 2011). Since our research covers the COVID-19 period and aims to determine the relationship between pandemic conditions and downside risk-return volatilities, we used a variety of value at risk models (VaR) to measure extreme losses in the US, UK, Pakistan, and Chinese equity markets during a distressing period. Due to the varied driving variables of the downside risk spillovers, the systemic risk may be asymmetric. We quantify the upside and downside risk-return volatilities as the dynamics exigent to calculate equities market losses for this purpose. The applied model consists of novel and dynamic approaches that have been used widely in a variety of developing and developed market environments likewise used in the work by Yang, Chen, and Xie (2018) and Sun et al. (2020).

Discussion of empirical findings

Beginning our analysis with the estimation of downside exposure, Table 1 displays the findings of the risk estimation models based on PVaR, TVaR, and SVaR of the equity market earnings of four economies. Among four selected markets, S&P-USA reports the highest risk, FTSE-UK the second highest, KSE-Pakistan third highest, and SSE-China the lowest among four markets. Except for the USA, the other three markets exhibit the downside risk between 4 and 12%, but the S&P-USA risk stands at 14.336%, 8.962%, and 8.677% according to SVaR, TVaR, and PVaR reported values. The S&P index representing the US equity platform turns out to be the highest downside risk market for investors relative to the others during the pandemic time period. But, although COVID-19 originated in China, it is extremely unusual to discover the SSE Chinese equity market is so robust and less obstructed. That might be why international leaders accuse China of having launched a biological war. But China’s excellent pandemic management approach might be the explanation behindhand by the lesser influence of COVID-19 on the Chinese equity market.

While risk measure (VaR) is viewed as the systematic model to estimate the market risk, the real risk still exceeds the expected 1% chance (when counting VaR in 99% significance level). The results are therefore extremely useful for back-test. In the initial analysis, we compute the number of VaR breaches. The lower the infringement, the better the estimate. We count the infringement if the index return is lower than the VaR estimate. In addition, standard Kupiec’s LR correspondingly shows the exactness of the method. According to the findings of the Kupiec’s test reported in the Table 2 below, the different variants of VaR models were constructed to be correct over the targeted sample period. Among these models, SVaR stands to be the utmost correct model. Since the distribution of the returns stream is not quite normal and the LR of Kupiec is lower for SVaR in every system, SVaR might stand as the best model. According to Koutmos and Booth, COVID-19 has an asymmetric influence on volatility spillovers, with positive news having a lower impact on volatility than negative news during this systemic event (1995). The findings of our study are consistent with Das and Rout (2020) and Li (2021) reporting the significant influence of the Covid-19 epidemic on the equity market exposure exhibiting the downside risk volatilities.

Violations against overall simulated VaR

In this phase of the study, we compute the SVaR violations of each market from SVaR throughout the whole time period.

### Table 1  Downside risk based on various models

|                  | KSE-Pakistan | S&P-USA | FTSE-UK | SSE-China |
|------------------|--------------|---------|---------|-----------|
| Mean             | −0.160       | −0.134  | −0.242  | −0.173    |
| SD               | 1.970        | 1.980   | 2.899   | 1.988     |
| PVaR             | −4.980       | −8.677  | −6.899  | −4.122    |
| TVaR             | −5.113       | −8.962  | −7.133  | −4.872    |
| SVaR             | −5.344       | −14.336 | −12.248 | −5.016    |

### Table 2  Violations from VaR Models

|                  | KSE-Pakistan | S&P USA | FTSE UK | SSE China |
|------------------|--------------|---------|---------|-----------|
| ViolPVaR         | 1            | 3       | 2       | 2         |
| ViolTVaR         | 1            | 3       | 2       | 2         |
| ViolSVaR         | 0            | 0       | 0       | 0         |
| %ViolPVaR        | 1.171        | 3.445   | 2.338   | 3.016     |
| %ViolTVaR        | 1.171        | 3.445   | 2.338   | 3.016     |
| %ViolSVaR        | 0            | 0       | 0       | 0         |

KUPIECPVaR     | 0.040**      | 3.887**  | 1.899** | 3.098**   |
KUPIECTVaR      | 0.040**      | 3.887**  | 1.899** | 3.098**   |
KUPIECSVaR      | 0**          | 0**      | 0**     | 0**       |

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This is done to evaluate the period of highest volatility over the four identified stock markets. The greater the violation proportion, the greater the risk. It is evident in Table 3 that the percentage of violations is highest in the USA market, second highest in the UK market, and Pakistan and China markets exhibit the same quantity of violations. The data suggest the gravity of the COVID-19 phase in a time that is so high around the globe. But China’s case is startling. Similarly, in the case of the Pakistani market, the dazzling effect of the pandemic is not so severe, and downside risk volatilities appear to be low at peak relative to the USA and UK stock markets.

### Positive and negative return spillovers

In this section of the study, we segregate the returns into negative and positive chunks for in-depth analysis to see separate volatilities resulting in both upside and downside risk. The findings reported in the table below indicate more negative returns than positive returns during the pandemic period, which means the investors were exposed to more of the downside risk in that time period than the upside risk. The likelihood of earning more of the losses is higher in the pandemic period. Pakistan and China had the highest MPG in the case of the positive return regime, and the USA and UK had the highest MPL in the negative return regime. These findings indicate the presence of more downside risk volatilities for the USA and UK stock markets relative to Pakistan and China stock markets during the pandemic time period. The jumps and percentage of jumps were also highest in the case of US and UK stock markets than in the other two markets. This concludes the presence of higher downside risk for US and UK investors relative to Pakistan and China investors in line with Zhang et al. (2020). The asymmetry parameter’s coefficients were negative and statistically significant in all-stock market returns, indicating that bad news has a stronger impact on stock markets than positive news. The presence of the leverage effect was demonstrated by the asymmetry of shocks, proving that stock market volatility did not respond to equally positive and negative shocks of similar size. Because the COVID-19 was deemed negative news, it had an impact on the selected stock markets’ results. The importance of negative shock persistence, also known as volatility asymmetry, suggests that investors were more sensitive to bad news than good news, implying the presence of an asymmetric volatility spillover mechanism. This conclusion corroborated the findings of Yong and Laing (2021), Choi and Jung (2021), and Yousfi et al. (2021). Finally, the results of the asymmetric estimators in the model accurately reflect the investor’s worry hypothesis about losses owing to downward movements (Tables 4 and 5).

### Market integration and interdependence

Since the markets are connected in the era of globalization, it is extremely necessary to verify before the planning of investments the association between the different markets since it gives a view of the strategy of diversification. The connection between the four countries’ stock markets is reported in the correlation matrix below. The correlation matrix exhibits a significant positive correlation among the four markets. The stock returns of the USA were highly and significantly associated with UK and China and the UK with China. The returns of the Pakistan market are insignificant and minimally correlated with the other three markets of the USA, UK, and China. These findings indicate the market interdependence among the USA, UK, and China exists and prevail during the period of the risk of the pandemic that largely affects the other nations and related stakeholders.

The collective findings of the study corroborate that the adverse news-induced volatility dominates the downside risk-return volatility in global stock markets. Risk on the downside is more likely to spread throughout global stock markets. And this is consistent with the financial contagion effect, which refers to the spread of market disturbances, mostly on the downside, from one country to the next, a process observed through co-movements in various economic and financial factors causing ultimate downside risk volatilities associated with negative returns consistent with the study of the financial contagion effect (Dornbusch et al. 2000). Due to the massive impact of the COVID-19

| Table 3 Violation from simulated VaR model |
|--------------------------------------------|
|                       KSE-Pakistan | S&P-USA | FTSE-UK | SSE-China |
| Viol          | 2.000    | 13.000  | 8.000    | 2.000     |
| %Viol        | 2.118    | 15.337  | 8.449    | 2.997     |

| Table 4 Summary of positive return |
|------------------------------------|
|                                 | KSE-Pakistan | S&P-USA | FTSE-UK | SSE-China |
| Mean                      | 1.482        | 0.788   | 0.977   | 1.299     |
| SD                        | 0.893        | 0.522   | 0.858   | 0.944     |
| MPG                      | 4.031        | 1.811   | 2.663   | 3.778     |
| Jumps                             | 2            | 1       | 2       | 2         |
| % Jumps                        | 1.997        | 0.564   | 1.616   | 1.595     |

| Table 5 Summary of negative returns |
|-------------------------------------|
|                                 | KSE-Pakistan | S&P-USA | FTSE-UK | SSE-China |
| Mean                      | –1.447      | –3.779  | –2.337  | –1.994    |
| SD                        | 1.399       | 3.006   | 1.877   | 1.587     |
| MPL                      | –6.001      | –11.770 | –7.988  | –6.117    |
| Jumps                             | 5           | 16      | 15      | 7         |
| % Jumps                        | 12.033      | 33.772  | 34.556  | 12.887    |
pandemic on the global economy, global stock markets are more vulnerable to negative risk during the coronavirus recession, according to this conclusion. Global stock markets became extraordinarily volatile when the COVID-19 pandemic hit, and the degree of volatility split across global stock markets is at an all-time high. The stock markets of the UK, Canada, and the USA split a significant amount of danger to global stock markets. And developing markets (China’s, India’s, and Brazil’s stock markets) were the principal risk receivers, taking on a significant amount of risk from developed markets. Furthermore, during the 2020 stock market crisis, downside risk dominated the volatility spillover (Table 6).

The findings of the study also suggest that global stock markets are closely integrated, that risk from one stock market is transferred to all other nations, and that established markets, not developing markets, are the primary risk senders. This finding just reveals that, on average, the relationship between China’s stock market and worldwide stock markets was rather weak over the study period for the Chinese stock market. Specifically, throughout the sample period, the stock markets of the USA and the UK are the greatest net risk senders, have a significant impact on global stock markets, and are closely linked. USA, UK, and Pakistan’s stock market is the world’s highest net risk receiver, highly susceptible to global shocks but with insufficient effect on global stock markets. This means that the financial contagion effect on global stock markets is dominated by downside risk. Except for China, the degree distribution of the positive and negative from indexes is substantially narrower than that of the positive and negative to indexes. This discovery shows that global stock markets are interconnected and that both positive and negative volatility in one stock market is communicated to all other stock markets. Furthermore, industrialized markets are more vulnerable to market downturns than emerging ones. This finding corroborated the findings of Yong and Laing (2021), Choi and Jung (2021), and Yousfi et al. (2021).

### Conclusion and implications

The global community has reached an era in which human beings fear talking, working, eating, and not talking to each other. In this study, the influence of COVID-19 on equity market indexes of four economies, using VAR models, has been tested and analyzed. The findings of the study show that the volatility of stock markets was considerably affected by COVID-19. It is noted that in the COVID-19 era, the MPL of all four countries was the greatest in such a short time. This makes the situation far more frightening than the other financial crises of different time periods. Relative to China and Pakistan, the VaR from the regime was likewise the greatest in the USA and UK which is very unanticipated because the disease began in the state itself. In this system, particularly in Pakistan and China, violation of the MPL has also been most serious but less relative to the USA and UK. In addition, in the COVID-19 era, the market correlation is likewise the greatest except in Pakistan. But a sigh of relief may be raised because the markets also showed a favorable return if the administration tried certain political steps to deal with the problem. The investor’s community nevertheless usually risks being ignorant, and our research study has also demonstrated that the recipient reacts to bad news rather than to favorable news. This also indicates the herding behavior in addition to the serious reaction toward risk volatilities.

The impact of this form of the pandemic is difficult to predict, as vaccination is in process with different variants of the virus still emerging, so it is still not foreseeable. The drawback of our analysis is that the stock market behavior may alter if the pace of the epidemic changes or if a treatment may be found. Therefore, our study mainly examined the short-term influence based on highly frequency data. Investors and regulators would be helped to foresee the potential of risk in similar conditions by knowing the short period fluctuations of the stock market. The implications of these research findings for investors and politicians are significant. The importance of dynamic asymmetric (downside) risk-return volatilities in portfolio diversification and asset allocation is critical for investors. Investors might have a better understanding of the markets by identifying positive and negative risks. Investors might get more insight into monitoring and analyzing changes across global markets and developing optimum trading strategies by discovering dynamic downside risk-return spillovers.

Policymakers may use the conclusions of this research to limit contagion risk and protect financial stability. Downside risks return spillover assessment aids in identifying the global stock market’s interconnected network and classifying risk transmitters and receivers. The downside volatilities also reveal when and where these risk categories change.

### Table 6  Correlation matrix

|                  | KSE-Pakistan | S&P-USA | FTSE-UK   | SSE-China   |
|------------------|--------------|---------|-----------|-------------|
| KSE-Pakistan     | 1.000        |         |           |             |
| S&P-USA          | 0.049        | 1.000   |           |             |
| FTSE-UK          | 0.053        | 0.776***| 1.000     |             |
| SSE-China        | 0.337***     | 0.484***| 0.396***  | 1.000       |

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Changes in network connectivity may be considered by policymakers when designing and formulating macroprudential and financial regulatory regulations. Policymakers might strengthen the macro-prudential monitoring mechanism for risk transmitters to prevent the spread of hazards, particularly downside risks. Risk receiver policymakers might utilize the dynamic linked network to detect and comprehend the primary sources of negative risks and establish defensive plans and timely target tactics to defend against contagion risks from other markets. Furthermore, the financial globalization process connects the financial markets of developed and emerging nations, with the results indicating that emerging markets are the primary risk receivers. Emerging-market policymakers should increase the efficiency and stability of financial markets even further, as well as take actions to limit their sensitivity to external shocks developed markets. Furthermore, the research outcomes enable equity market contestants from many regions of the globe to structure their asset management strategies by monitoring and therefore diversifying their portfolios by the degree and directions of the connection between different markets. Government and regulators can also, after thorough observation, adopt actions to improve investor confidence.

Author contribution SAS: idea conception, initial data gathering, theoretical background, problem statement, and write up; AMH: research design, data collection, and proof review. HR: data analysis and interpretation.

Data availability The data has been collected from a secondary open-source database. The data is available to everyone and is free for use and does not require any consent. The researchers provide consent for its use for future references with proper citations. Also, the data analyzed can be provided upon request.

Declarations

Ethics approval It is solemnly declared that the research does not violate any ethical standards of any sort concerning the involvement of research participants, data collection, research write-up, acknowledgement of sources, and other areas of concern in the ethical domain.

Consent to participate The data has been collected from a secondary open-source database. The data is available to everyone and is free for use and does not require any consent. The researchers provide consent for its use for future references with proper citations.

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