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ORIGINAL CONTRIBUTION

Investigating Efficiencies in Financial Markets and the Spillover Effects of COVID-19: Evidence from the Most Affected Countries

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Abstract— This study examines the volatility transmission of COVID-19 to different financial markets, specifically oil, gold, Bitcoin, and the stock market, in the countries with the highest number of coronavirus-infected cases reported. The sample includes China, Italy, the U.K., and the U.S., and the sample period is January 2, 2020, to June 30, 2020. The garch-in-mean test has been utilized to examine the volatility transmission, and the results show that COVID-19 negatively affects the gold returns in China, Italy, and the U.S. The spillover transmission of the pandemic has also extended to the stock markets in China, Italy, and the U.S., negatively affecting returns. The spillover to the oil market is positive and only significant for the U.K. In cryptocurrencies, Bitcoin returns are negatively affected as a response to the volatility spillover in the U.K. Market efficiency has also been investigated in the aforementioned financial markets through the Jarque-Bera statistic, autocorrelation test, unit root tests, and multiple variance ratio test. Most of the tests reflect the inefficiency in almost all of the markets of the selected sample. Most of the markets have proven to be inefficient. The findings have significant implications for market participants and policymakers in understanding how sensitive financial markets are to the pandemic, which will help develop appropriate and required response mechanisms.

Index Terms— Market efficiency, Financial markets, Stock markets, COVID-19

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Introduction

The mechanisms of information transmission across national and international markets have significance for theory and practice. When the economy is in crisis, the impact of volatility spillover among different markets is more pronounced, which may reduce the benefits associated with diverse investment strategies. The quality and speed of information transmission mechanisms have improved with advancements in technologies, which highlights the interconnectedness of financial markets across the globe. Research work on asset allocation, market efficiency, and the contagion effect has investigated the spillover effects. Apart from reducing the benefits associated with diversifying the portfolio, how the spillover affects the relevant connected markets will help in the behavior prediction of different markets. The relevance of investigating volatility spillover is never any less as the nature of volatility changes over time (Jam, Donia, Raja, & Ling, 2017; Yarovaya, Brzeszczyński, & Lau, 2016).

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The pandemic of COVID-19 has drastically affected the lives of everyone. It wouldn't be untrue to say that it has caused serious ramifications for the economic dynamics of the entire world. Considering its gravity and prevalence these days, its direct and indirect effects may not be entirely realized. However, an attempt to quantify its consequences that have already unfolded and are yet to unfold wouldn't be irrelevant to academics, researchers, and policymakers.

Initially, China was identified as the epicenter of COVID-19, which later spread across the world through the movement of the people. This spread has prompted the organizations to implement work-from-home policies to limit the exposure, which aggressively affected the air travel industry as flights were canceled, the sports industry as international and national events got delayed/canceled, and the entertainment industry. Perception of the effects of this pandemic to be area-specific, similar to the crisis of 2008, has later been proved inaccurate as the spread of it across the globe has been highlighted. The deleterious effects of this have been reported in economies, along with the spillover effects in the demand and supply shocks of almost every human endeavor.

Different researchers recently discussed the economic implications of pandemics and other infectious diseases prior to the onset of COVID-19. Fan, Jamison, and Summers (2018) cited the predictions of losses that can be expected as a result of pandemics. Bloom, Cadarette, and Sevilla (2018) highlighted the negative effects of epidemics with regard to their policy and managerial implications. With the world turning into a global village, the impact can be seen in the spread, control, and geographical areas of infectious diseases. Evidence on the effects of epidemics, costs, uncertainty, and risk associated with them, as well as mitigation strategies, has also been provided by Haacker (2004) and Hoffman and Silverberg (2018). A comparison of the effects of these pandemics with COVID-19 has been done by Correia, Luck, and Verner (2022), Eichengreen (2020), and Ma et al. (2020). Haacker (2004) has illustrated the economic costs associated with the HIV/AIDS pandemic, and its impact on development has been shown in the work of Santaeulalia-Llopis (2008).

After the onset of COVID-19, the global economy is leaning toward recession. Previous studies have reported different causes of recession. The 1997 Asian financial crisis was caused by the collapse of Thailand's local currency, Baht, which triggered a contagion effect that spread through many Asian markets (Radelet & Sachs, 1998). Its effect has been observed by comparing it to the recession of 2008, which has been thoroughly investigated in contagion and spillover effects and the interconnectedness of the financial markets (Bekiros, 2014; Yarovaya et al., 2016). The Great Recession of 2008, which started in the U.S. and later became global, was primarily caused by the financial industry's deregulation, mainly in the form of subprime mortgage lending (Allen & Carletti, 2010). The Greece crisis in 2010, which lasted longer than the recession of 2008, was mainly caused by the rigidity in the monetary policy and structural weaknesses (Rady, 2012). This recession is a novel cause, as is the pandemic.

The banking sector has witnessed a rise in non-performing loans after the onset of COVID-19. Due to reduced demand in small and medium enterprises, the number of non-performing loans increased. Exposure to credit risk is also heightened, especially for the financial institutions in the private sector (Parkin, 2020). Banks' profits were reduced due to lesser fees collected as a result of a reduction in ATM cards, machines, and transactions. Many venture capitalists became conservative in the issuance of new equity, reducing the financing for FinTech businesses (Ozili & Arun, 2023).

Markets respond quickly to natural disasters. Customers are more likely to shift to alternate airline companies followed by an air crash disaster (Bosch, Eckard, & Singal, 1998).

The impact of COVID-19 is more pronounced for the entire airline industry (Asadi, Moradi, & Ghorjizadeh, 2021; Goodell, 2020). Loss of airline industries are estimated to be around $113billion had the pandemic of COVID-19 is not readily controlled as per the International Air Transportation Association. This has some serious consequences for the tourism industry as the travelers spend billions per year. Sudden surge in cancellation of different events, flights and accommodations is seen estimating around $200 billion in China.

This study is an attempt to explore what a pandemic, specifically COVID-19, would entail for the economies of the countries that have been affected by it the most. Although determining exact impact of the pandemic would be nascent in any area but the pertinence of its ravages in such a short time period had strengthened the need and few researchers have made their attempts.

This study shows how factors, that are not purely economic and financial, have implications that may cause a ripple effect in economies and financial markets across the globe in unmatched ways. This study encourages the academics to incorporate health aspects in testing the resilience of the financial markets and modifying the econometric models to account for such black swan events. This study specifically examines how the spread of the COVID-19 lead to spillover into different financial markets of the countries that are affected by it the most. Also, it determines the efficiency of the markets during the ongoing spread of the pandemic.

The COVID-19 exhibited itself as a highly contagious pandemic in terms of its spread and its economic and financial impact has triggered uncertainty around the globe. The plunge in demand for food items especially in Italy, Germany and the U.K. has triggered volatility in prices. The volatility in financial market prices has also surged (Albulescu, 2020). Comparison of COVID-19 has been made with the financial crisis of 2008 in terms of its spillover and interconnectedness. Some experts have compared its effects with the previous global wars (Sharif, Aloui, & Yarovaya, 2020). The closest and most accurate comparisons made are with natural disasters and other epidemics and pandemics of similar kind (Correia et al., 2022). Although some studies have been made in few countries on the impact of it on economies and financial markets, however the authors are skeptical regarding the accuracy of the findings due to the shorter time frame of data and sample size (Zeren & Hizarci, 2020). COVID-19 is a cause of systematic risk (Albulescu, 2020; Margaretha & Suryana, 2023), hence its importance in studying the ramifications on related financial markets cannot be overemphasized especially in countries which are affected by it the most.

The urgent need for new research regarding the impact of COVID-19 on international economies and financial markets has been addressed by many researchers. Pandemic of COVID-19 is a cause of systematic risk and hence there is a need for investigating its effects on financial markets. Future research must investigate its impact on different economic variables (Akash, Khan, & Shear, 2023; Sharif et al., 2020). However, Zeren and Hizarci (2020) investigated the impact of COVID-19 on the stock markets of a few selected countries. Authors are skeptical regarding the clear effects of COVID-19 on the financial markets and economies due to the shorter time frame of the data. The authors suggest that future studies must incorporate more economic variables and a larger data set. Corbet, Hou, Hu, Oxley, and Xu (2021) investigated the volatility spillover of COVID-19 on the financial markets, specifically cryptocurrency, future markets of oil and gold, and energy and agricultural markets in China as the epicenter. Later, the U.S. was named as the new epicenter of COVID-19. The deleterious effects of COVID-19 have rapidly been observed across different countries in an exponential manner. It would be relevant to study its effects in countries that have been affected in a manner similar to China's.

This paper contributes to the new emerging literature that studies the financial impact of COVID-19 (Conlon & McGee, 2020; Corbet, Hou, Hu, & Oxley, 2020; Corbet et al., 2021; Goodell, 2020; Sharif et al., 2020) specifically countries that have reported the highest number of cases.

Literature Review

The impact of COVID-19 on one industry that is then transmitted to the financial industry can be gauged by comparing the deleterious effects of disasters and pandemics of similar kind that specifically affect one market, but its spillover effects to other markets are more general (Goodell, 2020). Recent work that has addressed the deleterious effects of pandemics on the health sector is by Fan et al. (2018), who mentioned the absence of readiness in case of an outbreak due to overstretched facilities might be of great concern in terms of the physical and financial loss. Similar concerns are highlighted in the study of Bloom et al. (2018) regarding the negative impact of economic variables disrupting the natural flow of activities and the lack of preparedness to respond with the appropriate measures. The possible collapse of developing countries' banking sector is more likely as the effects of pandemics gain momentum (Lagoarde-Segot & Leoni, 2013). Reduction in consumption behavior as a permanent change has been observed, followed by HIV/AIDS prevalence Haacker (2004). This reduced demand poses a larger threat, especially for small businesses in the economy.

COVID-19 has transmitted shock waves in financial and commodity markets (Albulescu, 2020). Considering the relevance, few researchers quickly responded to the need for new research studying the effects of COVID-19. The smooth flow of the supply chain has been disrupted across the globe as the demand for offerings has reduced, which is followed by the shutting down of many factories in China, being the world's largest exporter. In an attempt to contain the spread of COVID-19, many organizations issued and implemented stay-at-home policies, which might be the lead domino in the onset of recession in many international markets and eventually in global markets (Greeley, 2020).

The consequences of COVID-19 on the economy have been termed 'Coronanomics' by Eichengreen (2020), while others have labeled it as a "Black Swan" event (Petro, 2020). With the world previously turned into a global village, its impact has done the opposite: imposing lockdowns within and between countries, disrupting the smooth flow of resources, and shutting down businesses, some temporary and some permanent (Barua, 2020). A brief review of the effects of COVID-19 has also been presented by Goodell (2020). There are huge economic costs followed by the onset of epidemics and pandemics. Corbet et al. (2020) showed that after the onset of the pandemic, firms, as a consequence of being named "corona," exhibited negative returns on an hourly basis and high volatility in volumes and returns. On the basis of flight to safety, cryptocurrency, specifically Bitcoin and gold, have been investigated as a "safe haven" after the spread of COVID-19, and results show no significant impact (Corbet et al., 2021). Herding behavior in the cryptocurrency markets has been dependent on the rise and fall of the markets; however, the dependency has not strengthened during the pandemic (Yarovaya, Matkovskyy, & Jalan, 2021).

Theory of market efficiency

The theory of market efficiency postulates that the price of the financial asset is reflected in its fundamental value and noise. The fundamental value is subjected to change as a result of different factors which may contribute to volatility. If there exists a relationship between different types of financial assets, then the transmission of volatility as simultaneous changes in volatility from one asset to the other is also related. Noise may also be a cause of volatility in a financial asset, which, if it spills over, may drive the price away from the fundamental value, thus reducing efficiency. Market efficiency shows how accurately asset price absorbs and reflects all the relevant information. An inefficient market is a result of market participants' psychological profiles, the psychology of the markets, and asymmetries pertaining to information, among many others. In such markets, prices of the financial assets are random and cannot be predicted.

As per the Efficient Market Hypothesis (EMH), if the market fully reflects the available information, it is said to be efficient (Fama, 1970). EMH can be further classified into three forms: weak form, semi-strong form, and strong form. The widely studied form in the literature is a weak form, which assumes that prices follow a random walk and abnormal returns cannot be made based on past information. As per Fama (1991) work, the weak form must also incorporate the predicting variables in the information set, which explain the future return. If the information set is expanded to include all publicly available information, it becomes a semi-strong form of market efficiency. If private information is also included in the information set which explains future returns, it becomes strong form market efficiency (Fama, 1970, 1991).

The absence of volatility spillover can be regarded as evidence of rapid and efficient information transmission. Studying the linkages between markets and the volatility spillover have important implications for investors in their portfolio diversification. If the markets are not highly correlated then investors can earn abnormal returns by constructing a diversified portfolio provided the prices of assets are uncorrelated.

Theories of behavioral finance imply that when the economy is going down, market participants' reactions to bad news are more pronounced and strong than to good news due to increased uncertainty and lack of confidence in the market (Du, 2021). These asymmetric responses contradict the theory of efficient markets but are supported by behavioral finance arguments.

Volatility has been considered a better proxy of information by (Clark, 1973) and (Tauchen & Pitts, 1983). The effects of COVID-19 on different economies and financial markets is due to its contagion effects (Corbet et al., 2021).

This study will also examine the efficiency of different financial markets. Specifically, a weak form of market efficiency is examined in different financial markets amidst COVID-19. Weak forms reflect a random walk where errors are identically and independently distributed (Kim & Shamsuddin, 2008). The response of market participants to COVID-19 may be different due to the difference in expectations and perceptions of risk (Sharif et al., 2020). Risk-averse investors quickly react to bad news, which triggers short selling of the financial assets, whereas long-term investors may perceive the situations as favorable disguised buying opportunities, thus affecting market efficiency (Chakrabarty, De, Gunasekaran, & Dubey, 2015).

COVID-19 has increased uncertainty in the economy to unequaled levels (Sharif et al., 2020). The rationality of investors is bound by their cognitive abilities and available resources at hand (Simon, 1997); it wouldn't be incorrect to assume that due to the lack of comprehensive information that accurately depicts the consequences of the pandemic and lack of sophisticated forecasting models that incorporate such black swan events (Yarovaya et al., 2021), the irrationality of the investors would prevail which may create noise in the financial markets disrupting its efficiency.

COVID-19 and stock market

COVID-19 spread has been one of the forceful factors significantly affecting the stock market (Sharif et al., 2020). Anticipation of government support for the operationality of the business may be perceived as a positive signal by the market participants, encouraging them to invest in the stock market (Sharif et al., 2020). Equity prices globally have been reduced by 10% (Barua, 2020). A major trend in financial markets has been negative globally. The plunge of the indices has been unparalleled since the depression of 1929.

COVID-19 and oil

The beginning of 2020 witnessed a price war of oil between two major oil suppliers, Russia and Saudi Arabia. The situation was exacerbated by the reduced demand for oil induced by the spread of COVID-19. As the movement of transported goods and people restricted, demand for air travel fuel reduced, further reducing the price of oil. Later, the increase in Saudi Arabia's oil supply, without the increased demand, created a snowball effect. The revenues of oil-dependent countries plummeted, widening the current account deficit and further worsening the balance of payment. This called for the revision of the yearly budgets of many countries that are no longer useful in depicting the prevalent accurate picture of the economy. Demand for loans from international lenders like the World Bank and IMF to fund the budget deficits heightened (Ozili & Arun, 2023). COVID-19 resulted in financial market volatility and negatively affected oil prices (Albulescu, 2020). Oil prices plummeted sharply by 30% two months after the spread of the pandemic in China, which is the largest reduction after the Gulf War (Sharif et al., 2020). Volatility in the prices of gold, silver, crude oil, copper, and natural gas has been observed as a result of the pandemic, with crude oil exhibiting a sharp decline (Barua, 2020).

COVID-19 and bitcoin

Proponents of traditional finance advocate the rationality and informed approach of investors in decision-making. However, some researchers contradict these claims by proposing that irrationality often drives investors' decisions, which leads to noise in the financial markets (Shleifer & Summers, 1990). The latter phenomenon is more true in the case of relatively new, immature financial markets (such as cryptocurrencies) and also when uncertainty is high in the markets (such as during the pandemic). Researcher established that including cryptocurrency in the portfolio maximizes benefits. However, if there is a volatility spillover due to COVID-19 in the cryptocurrency market, the potential benefits from cryptocurrency inclusion are less likely. The significance of Bitcoin as a safe haven or hedge was established by Conlon and McGee (2020) during the bear market as a result of the pandemic.

COVID-19 and gold

Commodity markets have shown their sensitivity to economic factors, demand, and supply political events (Wang, Wei, & Wu, 2011), and pandemics.

The fall in gold prices after the pandemic is less compared to other financial markets. However, an upward trend has been witnessed in February. When the economy is in turmoil, investors rush toward gold, considering it a safe haven because of its lack of or negative correlation with other assets losing value (Nguyen, Bhatti, Komorníková, & Komorník, 2016). Financial crises negatively affect investment strategies and reduce the benefits associated with portfolio diversification. Reduction in stock prices during the recession of 2007 has been witnessed. However, gold prices have shown an upward trend. This reflects investors' preference for gold in times of economic uncertainty and downturn (Beckmann, Berger, & Czudaj, 2015). Baur and Lucey (2010) also found gold a hedge against stocks when market conditions are extreme.

Based on the arguments presented, the following hypotheses are proposed:

Hypothesis 1: The impact of COVID-19 will be significant on the stock market.

Hypothesis 2: The impact of COVID-19 will be significant on oil prices.

Hypothesis 3: The impact of COVID-19 will be significant on cryptocurrency, specifically Bitcoin.

Hypothesis 4: The impact of COVID-19 will be significant on Gold prices.

Research Methodology

Time period

The sample period of the current study is from January 2, 2020, to June 30, 2020.

Data and methodology

Countries included in the sample are China, Italy, the U.K., and the U.S., which are among the most affected countries, as reported by WHO. Daily observations of infected COVID-19 cases have been taken in China, Italy, the U.K., and the U.S. Oil prices have been measured as West Texas Intermediate (WTI) benchmark crude oil price in the local currencies of the selected countries (Renminbi for China, Euro for Italy, Pound for the U.K. and U.S. dollar for the U.K.). Stock market indices of the selected countries are taken. Specifically, the SSE Composite Index for China, FTSE MIB for Italy, FTSE100 for the U.K., and Dow Jones 30 for the U.S. Gold prices have been measured in the local currencies of the selected countries. Bitcoin price has also been converted into the local currencies of the selected countries. Data was collected from January 2, 2020, to June 30, 2020. Natural logarithms have been taken from the entire series.

Econometric model

Volatility is modeled through GARCH-in-mean, which allows the conditional mean to depend on conditional variance. If the volatility or conditional variance reflects the risk, then the conditional variance will influence the conditional mean of the dependent variable. Two staged GARCH in the mean model have been estimated. In the first stage, the return series of bitcoin is modeled as:

$$CovidR_{\mathrm{j,t}} = \lambda_0 + \lambda_1 CovidR_{\mathrm{j},t-1} + \lambda_2\,\mathrm{V_{j,t}} + \lambda_3 \varepsilon_{\mathrm{j},t-1} + \varepsilon_{j,t}, \varepsilon_{j,\mathrm{t}} \sim \mathrm{N}\left(0,\ \mathrm{V_{j,t}}\right)$$

$$\mathrm{V_{j,t}} = \psi_0 + \psi_1\,\mathrm{V}_{\mathrm{j},t-1} + \psi_2 \varepsilon^2{}_{\mathrm{j,t-1}}$$

Where CovidR is daily rate of corona virus cases at time t and εj,t is the residual which is normally distributed with mean zero, time varying conditional variance Vj,t. To adjust the possibility of serial correlation in mean equation, it is structured by inclusion of ARIMA (1,1) or MA (1) model.

Mean and volatility spillover effects across financial markets are estimated by attaining the standardized residuals and it square divided by variance series in the first stage, and then putting the obtained values into the mean and volatility equations of FRM returns as follows:

$$\mathrm{FMRm,t} = \lambda_0 + \lambda_1 \mathrm{FMRm}, t-1 + \lambda_2\,\mathrm{Vm}, t + \lambda_3 \varepsilon \mathrm{m}, t-1 + \gamma_1 \xi_{j,t} + \xi_{m,t}, \xi_{\mathrm{m},t}\ \mathrm{N}\left(0,\ \mathrm{Vm}, t\right)$$

$$\mathrm{V}m\mathrm{t} = \psi_0 + \psi_1 \mathrm{zj}, t-1 + \psi_2 \varepsilon^2 \mathrm{m,t}-1 + \gamma_2 \mathrm{e}^2{}_{\mathrm{it}}$$

Where FMRm,t refers to financial market returns, specifically oil returns, gold returns, stock market index returns, and bitcoin returns of the countries included at time t, εj,t is the standardized residual series to capture the impact of Covid-19 on the returns of different financial variables. To check the volatility spillover effect, e2 j,t is included as an exogenous variable, which is the square of the standardized residuals over variance series and is included in the conditional volatility equation. εm,t is calculated as (εj,t / Vj,t ·05). zj,t-1 and ε2 m,t-1 is the ARCH and GARCH term, which reflects the dependence of variance on the past values of shocks as captured by lagged squared residuals and on past values of itself as captured by lagged variance terms.

Results and Discussion

Table I
Descriptive statistics

U.S.			
	Mean	Maximum	Minimum
COVID-19	709364.4	2590552	0.0000
Stock Market Index	25612.65	29551.42	18591.93
Oil Price	38.14422	63.27000	10.01000
Bitcoin Price	8499.780	10312.12	4970.79
Gold Price	1617.902	1730.42	1471.21
U.K			
	Mean	Maximum	Minimum
COVID-19	105530.3	311965.0	0.00000
Stock Market Index	6435.830	7674.560	4993.890
Oil Price	258.2007	441.3715	31.91971
Bitcoin Price	6744.776	8173.200	4050.000
Gold Price	10986.42	12319.74	1361.689
China			
	Mean	Maximum	Minimum
COVID-19	65503.04	84780.00	27.00000
Stock Market Index	2928.653	3438.610	2660.170
Oil Price	30.03473	48.17651	8.116108
Bitcoin Price	61397.98	74642.820	35885.42
Gold Price	1285.539	1430.31	1145.334
Italy			
	Mean	Maximum	Minimum
COVID-19	110948.3	240436	0.000000
Stock Market Index	19934.12	25477.55	14894.44
Oil Price	34.51187	56.50011	9.249240
Bitcoin Price	7705.143	9577.000	4424.900
Gold Price	1466.758	1575.268	1354.087

According to results table (I), sample data has the following characteristics. The mean value for COVID-19 cases is 709364 for the U.S., 105530 for the U.K., 65503 for China, and 110948 for Italy. Whereas the maximum value for COVID-19 cases is 2590552 for the U.S., 311965 for the U.K., 84780 for China, and 24 0436 for Italy. While the minimum value is 0 for all countries. The stock market index mean value is 6414 for the U.K., 25612.65 for the U.S., 2928.653 for China, and 19934.12 for Italy. Maximum/minimum values for the stock market index are 29551.42/18591.93 for the U.S., 7674/4993 for the U.K., 3438/2660 for China, and 25477/14894 for Italy.

The mean value for U.S. oil prices is 38.14422, whereas the maximum/minimum value is 63.27000/10.01000. For the U.K., the mean value of oil price is 258.2007, whereas the maximum/minimum value is 441.3715/31.91971. For China, 30.03473 is the mean value for the oil price, whereas the maximum/minimum value is 48.17651/8.116108. For Italy 34.81187 is the mean value for oil price, whereas maximum/minimum value is 56.50011/9.249240.

Mean values for Bitcoin price are 8499.780, 6744.776, 61397.98, 9577 and 9577 for the U.S., U.K., China and Italy respectively. Maximum and minimum values for U.S. are 10312.12 and 4970.790, for UK 8173.200 and 4050 are Bitcoin's maximum and minimum values, for China 74642.82 and 35885.42 4050 are Bitcoin's maximum and minimum values, and for Italy 9577 and 4424.900 4050 are Bitcoin's maximum and minimum values.

The mean value of the gold price is 1617.902, whereas the maximum value is 1730.420, and the minimum value is 1471.210 for the U.S. The Mean value of Gold price for the U.K. is 10986.42, whereas the maximum value is 12319.74, and the minimum value is 1361.689. For China and Italy, the values of gold prices are 1285.539 and 1466.758, respectively. The maximum values are 74642.82 and 9577, and the minimum Values are 1145.334 and 1354.087 for China and Italy, respectively.

Spillover results

The volatility in Bitcoin's return today is significantly affected by its past returns. According to table II the GARCH term is significant and positive which shows that volatility in today's Bitcoin return is affected by past volatility. However, the impact of mean and volatility spillover is found to be insignificant from the rise in COVID-19 cases to Bitcoin. The GARCH term significance in the case of Chinese gold returns reflects volatility persistence in today's gold returns. The negative coefficient of gold return in volatility spillover suggests that as the number of cases reported increases, demand for gold increases, thus increasing its price and decreasing its returns. Mean spillover is found to be insignificant in the case of gold returns. The volatility of oil returns is unaffected by past behavior. Also, the mean and volatility spillover from COVID-19 cases is found to be insignificant in China. The conditional mean of China's stock market index depends on its conditional volatility, as shown by the significant conditional variance. The ARCH and GARCH terms are also positively significant, which shows that past index behavior positively contributes to the volatility of current period returns. The significant volatility spillover has been found from the rise in COVID-19 cases to the stock market index in China.

Table II
Results of Garch-in-mean for China

Country: China					
Parameters	ChCovR	ChBitR	ChGR	ChOR	ChIndexR
λ0	-0.002415 (0.0000)	0.024228 (0.6692)	0.001410 (0.9070)	0.009670 (0.9395)	0.033868** (0.0051)
λ1	0.93448*** (0.000)	-0.44313* (0.0768)	-0.561919 (0.8739)	0.559964 (0.8466)	-0.387564 (0.7108)
λ2	1.51729*** (0.0000)	-10.72718 (0.2106)	-0.092799 (0.9978)	-0.715326 (0.9168)	-2.588669*** (0.0000)
λ3	-0.48347*** (0.0000)	0.067706 (0.8044)	0.528616 (0.8836)	-0.544882 (0.8522)	0.172869 (0.8517)
γ1		0.001030 (0.8735)	-0.000584 (0.8708)	-0.002009 (0.9432)	0.000682 (0.9243)
ψ0	4.11E-08 0.0036	0.002119 (0.0984)	0.000120 (0.2439)	0.006564 (0.4069)	0.000186*** (0.0000)
ψ1	1.57634*** (0.0000)	0.150000 (0.1337)	0.150000 (0.4051)	0.150000 (0.4996)	0.150000** (0.0084)
ψ2	0.20069*** (0.0000)	0.6000*** (0.0037)	0.600000* (0.0776)	0.600000 (0.2170)	0.600000*** (0.0000)
γ2		-7.52E-12 (0.4642)	-3.88E-13*** (0.0000)	-1.85E-11 (0.5476)	-2.08E-11*** (0.0000)

Table III shows the volatility in Italy's current Bitcoin return, which is significantly affected by past shocks in Bitcoin's current returns. However, the mean and volatility spillover is insignificant from the COVID-19 cases reported in Italy to Bitcoin. The volatility spillover from the COVID-19 cases reported to Italy's gold returns and stock market index is found to be highly significant and negative. The mean and volatility spillover from COVID-19 cases reported in Italy to the oil market has been found to be insignificant.

Table III
Results of Garch-in-mean for Italy

Country: Italy					
Parameters	ItCovR	ItBitR	ItGR	ItOR	ItIndR
λ0	-0.0002*** (0.0000)	0.017336 (0.8076)	-0.000496 (0.9736)	0.022214 (0.7718)	0.011696 (0.7581)
λ1	1.16900 (0.00)***	-0.504273 (0.5209)	-0.023857 (0.9945)	0.400313 (0.9339)	0.075082 (0.7763)
λ2	-0.02061 (0.0478)	-8.669132 (0.3875)	8.484135 (0.8170)	-2.156908 (0.5870)	-14.08700 (0.4181)
λ3	-0.2099*** (0.0000)	0.147587 (0.8646)	-0.023857 (0.9942)	-0.385904 (0.9360)	-0.308909 (0.3802)
γ1		-0.006946 (0.5162)	6.78E-05 (0.9839)	0.012587 (0.5716)	0.002961 (0.6882)
ψ0	6.83E-08 (0.1174)	0.002658 (0.0931)	0.000136 (0.2665)	0.006367 (0.3479)	0.000812 (0.3257)
ψ1	5.82010*** (0.0000)	0.150000 (0.3377)	0.15000 (0.5106)	0.150000 (0.4120)	0.150000 (0.4783)
ψ2	0.02401 (0.0534)	0.60000** (0.0134)	0.60000 (0.1142)	0.600000 (0.1522)	0.600000 (0.1378)
γ2		-1.13E-10 (0.4826)	-5.30E-12*** (0.0000)	-2.45E10 (0.5093)	-3.59E-11*** (0.0000)

The volatility in current Bitcoin and gold's return in the U.K. is significantly affected by its past variance. The volatility spillover is found to be highly significant from the number of COVID-19 cases reported to the Bitcoin returns but insignificant in the case of gold returns. The ARCH and GARCH (table IV) are also found to be highly significant and positive in the case of oil returns of the U.K., which shows that volatility in today's oil returns is affected by past shocks, and variance and cumulative of both is closer to 1, which indicates volatility persistence is of long term. The volatility spillover from the number of COVID-19 cases reported to the oil returns is also significant, which reflects the plunge in oil prices in the U.K. during the pandemic. The U.K. stock market index conditional mean is significantly affected by its past volatility. Also, past shocks in the stock market index return positively contribute to the volatility in current U.K. stock market returns.

Table IV
Results of Garch-in-mean for U.K

Country: U.K					
Parameters	UkCovR	UkBitR	UkGR	UkOR	UkIndR
λ0	0.00039 (0.6694)	0.012570 (0.8746)	-0.000698 (0.7191)	-0.003171 (0.4884)	0.000971 (0.3165)
λ1	1.0157*** (0.0000)	-0.458927 (0.5830)	-0.676618 (0.6564)	-1.364084 (0.6953)	-0.148881 (0.8847)
λ2	0.10854 (0.7106)	-6.338101 (0.6085)	19.50258 (0.3925)	-0.311693 (0.8413)	-10.16957 (0.3529)
λ3	-0.05312 (0.6544)	0.159177 (0.8580)	0.666005 (0.6611)	1.323468 (0.7019)	0.049004 (0.9624)
γ1		-0.004124 (0.7502)	-0.001065 (0.3109)	0.001997 (0.7469)	-0.002349*** (0.0000)
ψ0	8.40E-07 (0.3020)	0.00247** (0.2318)	6.41E-06* (0.0788)	6.08E-05 (0.0878)	-3.64E-06*** (0.0000)
ψ1	1.044*** (0.0000)	0.150000 (0.3658)	0.007849 (0.0311)	0.232934** (0.0351)	0.232811** (0.0075)
ψ2	0.5544*** (0.0000)	0.600000* (0.0604)	0.877634*** (0.0000)	0.691950*** (0.0000)	0.773905*** (0.0000)
γ2		-2.06E-09*** (0.0006)	-6.616E-12 (0.7241)	1.12E-08** (0.0301)	3.18E-10 (0.2554)

According to (table V) results, the conditional mean of U.S. Bitcoin's return depends on its conditional variance as shown by the significant conditional variance term of the mean equation. Also, past volatility in Bitcoin's price significantly contributes to the volatility in Bitcoin's current returns. The significant ARCH and GARCH terms signify that Bitcoin's current return volatility is explained by its past returns and shocks. The U.S. oil returns are significantly affected by its past returns and shocks, as shown by the significant ARCH and GARCH terms. This volatility persistence is long-term as, cumulatively, both ARCH and GARCH terms are closer to 1. Results (table IV) also show that volatility in current U.S. gold returns is explained by the past shocks in the gold prices. The volatility spillover from the number of COVID-19 cases reported in the U.S. to the gold market is found to be highly significant and negative. The conditional mean of U.S. index stock returns is dependent upon its past volatility. The volatility in U.S. returns is significantly affected by its past volatility. The volatility from COVID-19 cases has also been found to contribute significantly to the volatility in U.S. index stock returns, establishing the spillover effect.

However, the mean and volatility spillover are found to be insignificant from the number of COVID-19 cases reported in the U.S. to Bitcoin and oil.

Table V
Results of Garch-in-mean for USA

Country: USA					
Parameters	UsCovR	UsBitR	UsGR	UsOR	UsIndR
λ0	-0.00046 (0.2955)	0.03063** (0.0042)	0.000175 (0.9189)	0.008299 (0.4688)	0.00058 (0.8978)
λ1	1.0351*** (0.0000)	-0.144043 (0.2328)	0.318932 (0.9218)	2.047940 (0.3490)	0.178853 (0.5919)
λ2	-0.06334 (0.6785)	-9.86791** (0.0324)	2.428530 (0.91889)	-1.624555 (0.2688)	0.93906 (0.9037)
λ3	-0.341*** (0.0007)	-0.18036** (0.0033)	-0.315758 (0.9246)	-1.985690 (0.3664)	-0.621234* (0.0869)
γ1		-0.000374 (0.9115)	0.000162 (0.9502)	-0.000596 (0.9151)	5.91E-05 (0.9776)
ψ0	-3.37E-07 (0.0028)	0.00049** (0.0379)	0.000131** (0.0325)	5.41E-05* (0.0540)	0.0002*** (0.0000)
ψ1	0.2296*** (0.0000)	0.14842** (0.0310)	0.15000 (0.4766)	0.306489** (0.0077)	0.150007 (0.1173)
ψ2	0.932*** (0.0000)	0.59944*** (0.0001)	0.6000** (0.0125)	0.707000*** (0.0000)	0.6000*** (0.0000)
γ2		-3.10E-10 (0.4826)	-1.56E-10*** (0.0000)	1.04E-09 (0.2547)	-3.01E-1**** (0.0000)

The volatility spillover of COVID-19 to oil prices has only been found significant in the case of the U.K. This spillover transmission is positive. This may be explained by the reduced demand due to restrictions on travel, imports, and exports and reduced growth in the economic output in affected countries. The time span of the sample period is too small to conceptualize the impact on long-term prices of the oil markets in the selected countries. The effect of the volatility on the stock market has been found to be significant for China, Italy, and the U.S. The stock market returns declined with the rise in the confirmed cases. Similar results were reported by Ashraf (2020). Adverse effects on the returns could be explained by reduced liquidity during the pandemic as investors lose confidence in the markets and market sentiment is negative during times of uncertainty. The volatility transmission to gold markets is also significant. Gold returns were also negatively affected by the pandemic, specifically in China, Italy, and the U.S. Such returns could be explained by the flight-to-safe phenomenon. Baele, Bekaert, Inghelbrecht, and Wei (2020) also established that some commodities prices have abnormal negative returns during the flight to safety episodes. The spillover effects of COVID-19 also transmitted to Bitcoin for the U.K. This may also be explained by the flight to safety phenomenon, as the market dynamics are uncertain, and investors may consider Bitcoin a safe haven. Similar reasons were reported by Corbet et al. (2020).

Market efficiency tests

Jarque-Bera test

Table VI
Results of Jarque-Bera test China

	INDEX	OILR	BITR	GPR
Jarque-Bera	392.9627	11643.64	6665.587	7.258039
Probability	0.000000	0.000000	0.000000	0.026542

Table VII
Results of Jarque-Bera test Italy

	INDEX	OILR	BITR	GPR
Jarque-Bera	1296.454	11791.89	2891.350	21.70809
Probability	0.000000	0.000000	0.000000	0.00000

Table VIII
Results of Jarque-Bera test U.K

	INDEX	OILR	BITR	GPR
Jarque-Bera	132.9494	11762.51	4660.146	52.93283
Probability	0.000000	0.000000	0.000000	0.00000

Table IX
Results of Jarque-Bera test USA

	INDEX	OILR	BITR	GPR
Jarque-Bera	191.6703	11762.51	4660.146	52.93283
Probability	0.000000	0.000000	0.000000	0.00000

The significance of Jarque-Bera value tables VI, VII, VIII, and IX with a probability of less than 5% led us to the rejection of the null hypothesis, which assumes the normality of the residuals. It indicates that returns of stock market index, oil, gold, and gold prices are not random and exhibit inefficiency.

Autocorrelation test

Table X
Results of autocorrelation test China

	INDEXR			OILR			BITR			GR		
Lags	AC	Q-Stat	Prob	AC	Q-Stat	Prob	AC	Q-Stat	Prob	AC	Q-Stat	Prob
1	0.043	0.2510	0.616	-0.451	28.012	0.000	-0.202	5.6287	0.018	0.138	2.6268	0.105
2	0.088	1.3331	0.513	0.023	28.086	0.000	0.157	9.0764	0.011	0.116	4.4943	0.106
3	0.137	3.9497	0.267	-0.011	28.103	0.000	-0.098	10.422	0.015	0.186	9.3426	0.025
4	-0.122	6.0630	0.194	0.120	30.147	0.000	0.140	13.184	0.010	-0.049	9.6848	0.046
5	0.038	6.2709	0.281	0.001	30.147	0.000	-0.140	15.961	0.007	-0.152	12.951	0.024
6	0.010	6.2840	0.392	-0.092	31.350	0.000	-0.058	16.441	0.012	-0.029	13.068	0.042
7	-0.050	6.6418	0.467	0.054	31.764	0.000	-0.039	16.660	0.020	-0.164	16.944	0.018
8	0.031	6.7841	0.560	-0.010	31.777	0.000	0.103	18.205	0.020	-0.200	22.785	0.004
9	-0.038	6.9998	0.637	0.049	32.126	0.000	-0.051	18.591	0.029	0.048	23.126	0.006
10	-0.057	7.4737	0.680	-0.001	32.126	0.000	0.163	22.532	0.013	-0.122	25.345	0.005

Table XI
Results of autocorrelation test Italy

	INDEXR			OILR			BITR			GR		
Lags	AC	Q-Stat	Prob	AC	Q-Stat	Prob	AC	Q-Stat	Prob	AC	Q-Stat	Prob
1	-0.102	1.4454	0.229	-0.452	28.150	0.000	-0.197	5.3821	0.020	0.042	0.2402	0.624
2	0.222	8.3112	0.016	0.033	28.305	0.000	0.163	9.0656	0.011	0.016	0.2751	0.872
3	0.117	10.244	0.017	-0.016	28.340	0.000	-0.131	11.456	0.009	0.170	4.3302	0.228
4	0.029	10.360	0.035	0.120	30.386	0.000	0.168	15.435	0.004	-0.105	5.8768	0.209
5	0.108	12.030	0.034	0.006	30.392	0.000	-0.153	18.765	0.002	-0.183	10.618	0.060
6	-0.131	14.475	0.025	-0.093	31.624	0.000	-0.059	19.258	0.004	-0.017	10.657	0.100
7	0.143	17.417	0.015	0.055	32.065	0.000	-0.066	19.891	0.006	-0.096	11.984	0.101
8	-0.161	21.193	0.007	-0.011	32.082	0.000	0.092	21.132	0.007	-0.177	16.561	0.035
9	0.065	21.815	0.009	0.050	32.456	0.000	-0.009	21.143	0.012	0.010	16.576	0.056
10	0.054	22.239	0.014	-0.004	32.459	0.000	0.173	25.574	0.004	-0.065	17.193	0.070

Table XII
Results of autocorrelation test U.K

	INDEXR			OILR			BITR			GR		
Lags	AC	Q-Stat	Prob	AC	Q-Stat	Prob	AC	Q-Stat	Prob	AC	Q-Stat	Prob
1	-0.059	0.4744	0.491	-0.186	4.7958	0.029	-0.217	6.5020	0.011	-0.004	0.0021	0.964
2	0.035	0.6464	0.724	-0.002	4.7964	0.091	0.171	10.583	0.005	-0.004	0.0047	0.998
3	0.013	0.6698	0.880	-0.014	4.8258	0.185	-0.144	13.508	0.004	-0.018	0.0488	0.997
4	0.080	1.5697	0.814	0.039	5.0405	0.283	0.169	17.522	0.002	-0.003	0.0504	1.000
5	0.087	2.6412	0.755	0.016	5.0777	0.406	-0.174	21.831	0.001	-0.001	0.0506	1.000
6	-0.232	10.333	0.111	-0.047	5.3916	0.495	-0.070	22.541	0.001	-0.001	0.0509	1.000
7	0.279	21.566	0.003	0.014	5.4204	0.609	-0.083	23.533	0.001	0.001	0.0510	1.000
8	-0.145	24.624	0.002	0.001	5.4206	0.712	0.085	24.591	0.002	-0.001	0.0511	1.000
9	0.067	25.279	0.003	0.009	5.4313	0.795	-0.028	24.706	0.003	-0.002	0.0520	1.000
10	0.034	25.447	0.005	-0.008	5.4400	0.860	0.190	30.051	0.001	0.005	0.0561	1.000

Table XIII
Results of autocorrelation test USA

	INDEXR			OILR			BITR			GR		
Lags	AC	Q-Stat	Prob	AC	Q-Stat	Prob	AC	Q-Stat	Prob	AC	Q-Stat	Prob
1	-0.059	0.4744	0.491	-0.443	27.041	0.000	-0.157	3.4071	0.065	-0.006	0.0043	0.948
2	0.035	0.6464	0.724	0.027	27.142	0.000	0.138	6.0570	0.048	0.021	0.0654	0.968
3	0.013	0.6698	0.880	-0.017	27.181	0.000	-0.125	8.2559	0.041	0.197	5.5091	0.138
4	0.080	1.5697	0.814	0.122	29.276	0.000	0.163	12.007	0.017	-0.085	6.5214	0.163
5	0.087	2.6412	0.755	0.010	29.290	0.000	-0.152	15.302	0.009	-0.115	8.4105	0.135
6	-0.232	10.333	0.111	-0.097	30.626	0.000	-0.049	15.640	0.016	-0.027	8.5142	0.203
7	0.279	21.566	0.003	0.056	31.075	0.000	-0.063	16.214	0.023	-0.131	11.012	0.138
8	-0.145	24.624	0.002	-0.003	31.076	0.000	0.089	17.378	0.026	-0.193	16.441	0.036
9	0.067	25.279	0.003	0.046	31.391	0.000	-0.014	17.407	0.043	0.069	17.148	0.046
10	0.034	25.447	0.005	0.003	31.392	0.001	0.143	20.451	0.025	-0.125	19.475	0.035

If the *p*-value of the *Q*-statistic is less than 0.05, then the historical returns can be used to predict future returns, and it shows that a weak form of market efficiency does not hold. According to above (table X), in the case of oil and bitcoin returns, weak form market efficiency does not exist. *p* value of gold price returns are significant from 3rd lag and show absence of weak form efficiency onwards. For all lags of index returns, insignificant *p*-values reflect weak form efficiency. According to Table XI, market inefficiency is reflected in the 2nd lag in the case of index return and from the 8th lag in the case of gold returns. For U.K., market inefficiency is reflected at 1st and 2nd lag for oil returns and from 7th lag onwards in case of index return. The insignificant *p*-value in case of gold returns reflect market follow a random walk (Table XII). The results of autocorrelation test (table XIII) indicate that no autocorrelation exists in returns up to 6th lags for index and up to 7th lag for gold but from 7th and 8th lag onwards for index and gold, the returns reflects inefficiency. In case of oil and Bitcoin returns, results show autocorrelation exists up to 10 lags as shown by the significant *p*-value. As per the results, oil and Bitcoin returns don't follow a random walk.

ADF and P.P. test

Table XIV
Results of ADF and P.P. test China

INDEX			BITR		
	I-Statistic	Prob.		*t*-Statistic	Prob.
ADF test statistic	-10.98981	0.0000	ADF test statistic	-14.12136	0.0000
Critical values: At 1% level	-3.479656		Critical values: At 1% level	-3.479656	
At 5% level	-2.883073		At 5% level	-2.883073	
PP test statistic	-10.98872	0.0000	PP test statistic	-13.94865	0.0000
Critical values: At 1% level	-3.479656		Critical values: At 1% level	-3.479656	
At 5% level	-2.883073		At 5% level	-2.883073	
OILR			GR		
ADF test statistic	-12.21911	0.0000	ADF test statistic	-10.08749	0.0000
Critical values: At 1% level	-3.480038		Critical values: At 1% level	-3.479656	
At 5% level	-2.883239		At 5% level	-2.883073	
PP test statistic	-20.32426	0.0000	PP test statistic	-10.21656	0.0000
Critical values: At 1% level	-3.479656		Critical values: At 1% level	-3.479656	
At 5% level	-2.883073		At 5% level	-2.883073	

Table XV
Results of ADF and P.P. test Italy

INDEX			BITR		
	t-Statistic	Prob.		*t*-Statistic	Prob
ADF test statistic	-12.18356	0.0000	ADF test statistic	-14.07194	0.0000
Critical values: At 1% level	-3.479656		Critical values: At 1% level	-3.479656	
At 5% level	-2.883073		At 5% level	-2.883073	
PP test statistic	-12.79842	0.0000	PP test statistic	-13.91528	0.0000
Critical values: At 1% level	-3.479656		Critical values: At 1% level	-3.479656	
At 5% level	-2.883073		At 5% level	-2.883073	
OILR			GR		
ADF test statistic	-12.07557	0.0000	ADF test statistic	-11.06101	0.0000
Critical values: At 1% level	-3.480038		Critical values: At 1% level	-3.479656	
At 5% level	-2.883239		At 5% level	-2.883073	
PP test statistic	-20.14979	0.0000	PP test statistic	-11.05949	0.0000
Critical values: At 1% level	-3.479656		Critical values: At 1% level	-3.479656	
At 5% level	-2.883073		At 5% level	-2.883073	

Table XVI
Results of ADF and P.P. test U.K

INDEX			BITR		
	t-Statistic	Prob.		*t*-Statistic	Prob
ADF test statistic	-12.18356	0.0000	ADF test statistic	-14.35933	0.0000
Critical values: At 1% level	-3.479656		Critical values: At 1% level	-3.479656	
At 5% level	-2.883073		At 5% level	-2.883073	
PP test statistic	-12.16773	0.0000	PP test statistic	-14.18893	0.0000
Critical values: At 1% level	-3.479656		Critical values: At 1% level	-3.479656	
At 5% level	-2.883073		At 5% level	-2.883073	
OILR			GR		
ADF test statistic	-13.87421	0.0000	ADF test statistic	-11.53453	0.0000
Critical values: At 1% level	-3.479656		Critical values: At 1% level	-3.479656	
At 5% level	-2.883073		At 5% level	-2.883073	
PP test statistic	-13.88328	0.0000	PP test statistic	-11.53452	0.0000
Critical values: At 1% level	-3.479656		Critical values: At 1% level	-3.479656	
At 5% level	-2.883073		At 5% level	-2.883073	

Table XVII
Results of ADF and P.P. test USA

INDEX			BITR		
	t-Statistic	Prob.		*t*-Statistic	Prob
ADF test statistic	-12.18356	0.0000	ADF test statistic	-13.49342	0.0000
Critical values: At 1% level	-3.479656		Critical values: At 1% level	-3.479656	
At 5% level	-2.883073		At 5% level	-2.883073	
PP test statistic	-12.16773	0.0000	PP test statistic	-13.39651	0.0000
Critical values: At 1% level	-3.479656		Critical values: At 1% level	-3.479656	
At 5% level	-2.883073		At 5% level	-2.883073	
OILR			GR		
ADF test statistic	-11.98680	0.0000	ADF test statistic	-11.59448	0.0000
Critical values: At 1% level	-3.480038		Critical values: At 1% level	-3.479656	
At 5% level	-2.883239		At 5% level	-2.883073	
PP test statistic	-19.87481	0.0000	PP test statistic	-11.60636	0.0000
Critical values: At 1% level	-3.479656		Critical values: At 1% level	-3.479656	
At 5% level	-2.883073		At 5% level	-2.883073	

Unit roots tests specifically Augmented Dicky Fuller Test and Phillips-Pearson test have been utilized to check the stationarity in data which is a necessary condition for random walk. If there exists a unit root in return series then the data is said to be stationary and follows a random walk. As per the results (table XIV), the returns of index, bitcoin, oil and gold are found to be stationary at order I (0) at 1% and 5% level of significance. The significance of p-value in all the return series in table XV led to the rejection of null hypothesis which assumes existence of a unit root. ADF and P.P. test have significant p-value for all return series at order I (0) and significance level 1% and 5 %, confirming market inefficiency. According to table XVI, ADF and P.P. test have significant p-value for all return series at order I (0) and significance level 1% and 5 %, confirming market inefficiency. For USA, ADF and P.P. test have significant p-value for all return series at order I (0) and significance level 1% and 5 %, confirming market inefficiency (Table XVII).

Multiple variance ratio tests

Table XVIII
Results of multiple variance ratio test China

	GR		INDEX		OILR		BITR	
q	Var.(q)	Z*(q)	Var.(q)	Z*(q)	Var. (q)	Z*(q)	Var. (q)	Z*(q)
2	0.518205	-4.327100*	0.480758	-3.624036*	0.341883	-1.561121	0.354668	-2.175082*
4	0.315498	-3.228698*	0.290386	-3.028645*	0.158599	-1.289687	0.186376	-1.754824
8	0.187153	-2.449779*	0.128584	-2.763596*	0.096803	-1.147351	0.102694	-1.501828
12	0.095332	-2.178415*	0.102161	-2.417860*	0.075077	-1.098285	0.086784	-1.363602
24	0.073703	-1.611027	0.046393	-1.891931	0.042439	-1.044296	0.050533	-1.225545
36	0.051853	-1.395877	0.033643	-1.580842	0.035707	-1.000455	0.041239	-1.155035

Table XIX
Results of multiple variance ratio test Italy

	GR		INDEX		OILR		BITR	
q	Var.(q)	Z*(q)	Var.(q)	Z*(q)	Var. (q)	Z*(q)	Var. (q)	Z*(q)
2	0.520386	-4.217607*	0.358069	-2.463446*	0.337982	-1.564432	0.353327	-2.476053*
4	0.299978	-3.308867*	0.230090	-1.786296	0.158475	-1.284693	0.180753	-1.972552*
8	0.165643	-2.580145*	0.145651	-1.498367	0.096866	-1.142162	0.104346	-1.589545
12	0.099131	-2.222926*	0.080932	-1.423545	0.075279	-1.093185	0.086685	-1.402388
24	0.071517	-1.626843	0.051132	-1.221353	0.042986	-1.039547	0.052258	-1.207628
36	0.041708	-1.393782	0.040757	-1.121262	0.035668	-0.997591	0.041639	-1.120348

Table XX
Results of multiple variance ratio test U.K

	GR		INDEX		OILR		BITR	
q	Var. (q)	Z*(q)	Var.(q)	Z*(q)	Var.(q)	Z*(q)	Var. (q)	Z*(q)
2	0.507755	-0.989113	0.461873	-3.624573*	0.428650	-1.736939	0.344025	-2.690147*
4	0.261420	-0.989346	0.225879	-2.921286*	0.211837	-1.577342	0.177664	-2.095291*
8	0.070162	-1.067466	0.149322	-2.084399*	0.082220	-1.551534	0.103480	-1.647093
12	0.049618	-1.041384	0.089562	-1.798629	0.060022	-1.502375	0.085029	-1.436995
24	0.030429	-1.016069	0.054986	-1.370861	0.036618	-1.444345	0.051335	-1.220833
36	0.025608	-1.006416	0.042901	-1.204056	0.030177	-1.408839	0.040709	-1.128305

Table XXI
Results of multiple variance ratio test USA

	GR		INDEX		OILR		BITR	
q	Var.(q)	Z*(q)	Var.(q)	Z*(q)	Var. (q)	Z*(q)	Var. (q)	Z*(q)
2	0.493189	-4.062812*	0.461873	-3.624573*	0.342366	-1.551229	0.376689	-2.340364*
4	0.280502	-3.125476*	0.225879	-2.921286*	0.159207	-1.281342	0.188139	-1.938032*
8	0.159957	-2.405788*	0.149322	-2.084399*	0.096676	-1.140025	0.108330	-1.597091
12	0.091047	-2.076567*	0.089562	-1.798629*	0.075849	-1.089757	0.088391	-1.425331
24	0.070617	-1.507864	0.054986	-1.370861	0.042951	-1.036479	0.053383	-1.240047
36	0.042123	-1.300418	0.042901	-1.204056	0.035821	-0.994798	0.043210	-1.152583

The significance of V.R. test statistics table XIII for z (q) from period 2 to 12 for gold returns, for period 2 in case of index return, from period 2 to 4 in case of Bitcoin returns exhibit market inefficiency. The insignificance of V.R. test statistics for z (q) from period 24 to 36 in case of gold returns, from period 4 to 36 in case of index returns, from period 2 to 36 in case of oil return and from period 8 to 36 in case of Bitcoin returns reflect market efficiency. According to above table XIX in case of gold and index returns, the standardized V.R. test statistics for z (q) is significant from period 2 to 12 which reflects the inefficiency in gold and index returns. Whereas for oil and bitcoin returns, the insignificance of standardized V.R. test statistics for z (q) for all periods except for period 2 of oil returns reflect efficiency. The standardized V.R. test statistics for z (q) is significant from period 2 to 8 in case of index returns and from period 2 to 4 for Bitcoin returns. At all other periods, the significance reflects market efficiency (Table XX). Whereas for gold and oil returns, markets are efficient and follow a random walk. Table XXI indicates in case of gold and index returns, the standardized V.R. test statistics for z (q) is significant from period 2 to 12 which reflects the inefficiency in returns and exhibition of random walk. Inefficiency in Bitcoin return is only exhibited at period 2 and 4. Otherwise, markets reflect weak form efficiency and random walk behavior. Results are consistent with previous studies such as inefficiency in stock markets of some European countries during the COVID-19 has also been reported by Aslam, Mohti, and Ferreira (2020). Inefficiency in different cryptocurrencies has also been reported by Mnif, Jarboui, and Mouakhar (2020) after the onset of COVID-19.

Table XXII
Summary of weak form market efficiency

	China			
	Stock Market	Oil	Gold	Bitcoin
J.B. Test	NO	NO	NO	NO
Autocorrelation	YES	NO	NO	NO
ADF	NO	NO	NO	NO
PP	NO	NO	NO	NO
Variance Ratio Test	NO	YES	NO	YES
	Italy			
	Stock Market	Oil	Gold	Bitcoin
J.B. Test	NO	NO	NO	NO
Autocorrelation	YES	NO	NO	NO
ADF	NO	NO	NO	NO
PP	NO	NO	NO	NO
Variance Ratio Test	YES	YES	NO	YES

*

Table XXIII
Cont.....

	U.K			
	Stock Market	Oil	Gold	Bitcoin
J.B. Test	NO	NO	NO	NO
Autocorrelation	NO	YES	YES	YES
ADF	NO	NO	NO	NO
PP	NO	NO	NO	NO
Variance Ratio Test	NO	YES	YES	YES
	U.S			
	Stock Market	Oil	Gold	Bitcoin
J.B. Test	NO	NO	NO	NO
Autocorrelation	YES	NO	YES	NO
ADF	NO	NO	NO	NO
PP	NO	NO	NO	NO
Variance Ratio Test	NO	YES	NO	YES

Conclusion

The havoc that COVID-19 has caused for the globe is yet to be exactly determined. Particularly, financial markets have negatively responded in most cases. This study investigated the volatility spillover transmission from COVID-19 to financial markets specifically on Bitcoin return, oil returns, gold return and stock market returns in countries that are among the most affected mainly China, Italy, U.S. and U.K. Also, these markets have been tested for weak form efficiency. Data has been collected from January 2, 2020 to June 30, 2020. To study the volatility spillover, a Garch-in-mean test has been applied. Weak form market efficiency has been tested through Jarque-Bera statistic, autocorrelation test, unit root tests and multiple variance ratio test. Results show that COVID-19 negatively affects the gold returns in China, Italy and the U.S. The spillover transmission of the pandemic is also extended to the stock markets in China, Italy and U.S. negatively affecting the returns. The spillover to the oil market is positive and only significant for the U.K. In the cryptocurrencies, Bitcoin returns are negatively affected as a response to the volatility spillover in the U.K. Almost all financial markets that have been investigated exhibit inefficiency during the sample period which will help in the prediction of future prices based on historical prices. This provides opportunities for market participants to exploit the inefficiencies in the market, which may even lead to speculation. The findings have significant implications for market participants and policy makers in understanding how sensitive financial markets are to the pandemic which will help in developing appropriate and required response mechanisms.

Limitations and future research directions

Current study only included the top five most affected countries on the basis of the COVID-19 cases reported. Future studies must bifurcate the developed, developing, and underdeveloped countries stu,dy the impact of COVID-19 on different financial variables, and compare the findings as the impact and response mechanisms for countries may be different. The comparative analysis may help in better response mechanisms for the future pandemics to come. This study investigated the impact on few financial markets specifically oil, Bitcoin, stock market index and gold. Future study must incorporate more economic and financial variables to understand the broader picture and linkages between them. The time span in this study is relatively short to accurately understand the economic and financial implications for different economies. The actual duration of the COVID-19 is uncertain as of now as so is the impact it has on different variables. Future studies must expand the time duration and study the pre and post impact of COVID-19. This study utilized Garch-in-mean technique to study the mean and volatility spillover in different financial markets. Future studies must utilize more sophisticated techniques to study the effects.

Practical Implications

This study has noteworthy implications for policymakers and market participants. The spillover effect of COVID-19 on different financial markets of countries where most cases have been reported have found to be significant. COVID-19 has exacerbated the oil crises which had been looming prior to the outbreak by imposition of travel restrictions and reduced demands for goods across countries. This will significantly affect oil importing and exporting countries, corporations associated with oil production, exploration and distribution, corporations in transportation industries, financial assets, securities and derivatives sensitive to oil price changes. However, the volatility spillover of COVID-19 had been found to be insignificant for all the selected countries except for the U.K.

Investors may have perceived the risk associated with COVID-19 as systematic because the volatility spillover has been significant to the stock markets in China, and Italy. Government and policy makers must respond with an economic strategy that facilitates smooth functioning and operationalization of the stock markets and restores investors' confidence in the market. Personalized relevant strategies and risk management by professional asset managers and investors must also be adopted in response to dealing with the volatility in the stock market associated with the spread of the pandemic.

The spillover effect to the gold market has found to be significant in China, Italy and the U.S. Ehsan (2020) also reported that the gold prices will be affected in the short run during the spread of the pandemic. Results reflect investors' preference toward gold during times of heightened uncertainty.

The absence of volatility spillover to Bitcoin during the pandemic for the selected countries except the U.K. highlights its diversification and risk management benefits. Cryptocurrencies have been identified as a new asset class in the financial world which provides diversification opportunities for investors due to their lower correlation and higher returns compared to other financial assets (Vardar & Aydogan, 2019). The growth in the cryptocurrency markets has been rapid in the past decade. However, due to its unregulated nature and absence of government support in some countries for cryptocurrencies, vulnerabilities exist in the financial system. Policy makers and regulators must enforce regulation mechanisms and closely monitor its behavior for transmission mechanisms to other markets and economies. As the results of one economy cannot be generalized to other economies.

Also, it has been established that during the span of the pandemic, most markets have shown inefficiencies which may allow market participants to exploit inefficiencies and earn abnormal returns based on historical data. Markets must be regulated by the concerned authorities.

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