Guo *Financial Innovation* (2024) 10:58
https://doi.org/10.1186/s40854-023-00514-1

Financial Innovation

RESEARCH

Open Access

Exploring Bitcoin dynamics against the backdrop of COVID-19: an investigation of major global events

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Abstract

COVID-19 has significantly influenced global financial markets, including Bitcoin. Recent studies have focused on investigating the first wave of the COVID-19 outbreak and accounting for market changes, which were mostly due to the pandemic. This research not only analyzes the contagion effects of COVID-19 but also considers aftermath events beyond the first pandemic wave to examine spillovers of Bitcoin. The study employs Diebold and Yilmaz's method to explore the static and dynamic spillovers of the selected variables and identifies several major global events, including crypto-specific affairs, macroeconomic policies, and geopolitical conflicts, to explain the new market dynamics of Bitcoin using network analysis. The findings identify a few high-contagion periods related to Bitcoin. The paper also found that Bitcoin is more likely to produce extreme returns and is more connected to other markets. Contagion effects "from" and "to" other markets are asymmetrical in terms of arrival time and market response. Bitcoin is more likely to be affected by other markets in extreme situations and receives spillovers from them sooner than it transmits spillovers to others. In the context of various global events, impacts arising from developed countries are stronger. China still has some impact on cryptocurrency markets, but they are waning. Bitcoin is thus not a safe haven from the shocks of global events, but can sometimes work as a hedge or diversifier. The results offer alternative explanations for Bitcoin's different market dynamics and enrich our understanding of Bitcoin's safe haven, hedge, and diversifier properties within a diversified portfolio.

Keywords: Bitcoin, Contagion, COVID-19, Network analysis, Geopolitics

JEL Classification: G01, G15

Introduction

COVID-19 is an important global phenomenon. The pandemic generated shocks more rapidly and deeply than any other economic downturn, leading many economies into recession within a short period. Its economic and social impacts have been massive, including impacts on banking and insurance, governments and the general public, and financial markets (Goodell 2020). Repeated spikes in cases have made economic recovery unexpectedly slow and challenging. The International Monetary Fund has repeatedly reported lower growth rates of the world economy, from 4.9% (October 2021) to 4.4%

(January 2022) and then to 3.6% (April 2022). Although some countries declared that COVID-19 is no longer a "socially critical disease," its impacts on the economy and society are proving long-lasting.

The impact on financial markets has likewise been enduring and complex. Numerous studies have investigated the changing dynamics. During the pandemic, global markets became more closely connected and also more susceptible to external shocks (OECD 2020). Cases of infection are considered the main factor impeding financial activities, and high numbers of reported deaths are likely to negatively impact financial development (Anser et al. 2021). With cases on the rise globally, financial markets have experienced substantial increases in risk levels (Zhang et al. 2020; So et al. 2021; Liu et al. 2022) and a heightened contagion effect across assets (Akhtaruzzaman et al. 2020; Alqaralleh and Canepa 2021; Le et al. 2021; Belhassine and Karamti 2021). Equity markets responded negatively to the total number of confirmed COVID-19 cases, with stronger volatility and negative returns (Al-Awadhi et al. 2020; Liu et al. 2020; Ashraf 2020; Xu 2021). Commodities have been previously identified as having hedging properties during major crises (Ayadi et al. 2021); however, they also experienced huge declines and high volatilities at the beginning of the pandemic (Ezeaku et al. 2021). In particular, crude oil experienced extreme highs and lows, spiking to a crisis level. Even gold, the traditional safe-haven asset, lost its status during the pandemic (Cheema et al. 2022).

In terms of the cryptocurrency market, some studies examined the impact of the first wave of the outbreak in early 2020. Demir et al. (2020) investigated the relationship between reported COVID-19 cases/deaths and Bitcoin, with results showing that cryptocurrency values had negative relationships with the number of cases in the early days of the pandemic, but later turned positive. The COVID-19 outbreak adversely affected the efficiency of leading cryptocurrencies, with Bitcoin and Ethereum being the hardest hit (Naeem et al. 2021). The total spillover index of the cryptocurrency markets abruptly intensified following the outbreak, especially in the high-volatility regime (Shahzad et al. 2021). Al-Shboul et al. (2022) adopted the quantile vector auto-regressive (QVAR) approach to analyze the return spillovers of 5 different cryptocurrencies before and after the outbreak, with results showing that Bitcoin lost its property as a hedge during the pandemic. The market structure of cryptocurrency communities also evolved after the crisis (Assaf et al. 2023). Some other studies investigated the relationships and contagions between cryptocurrencies and equity markets (Conlon and McGee 2020; Conlon et al. 2020; Corbet et al. 2021; Belhassine and Karamti 2021), bond markets (Le et al. 2021; Karim et al. 2022), commodity markets (Mo et al. 2022), gold (Kumar and Padakandla 2022), and foreign currency markets (Umar and Gubareva 2020; Aharon et al. 2021; Umar et al. 2021a; Elsayed et al. 2022). The results show mixed performance for Bitcoin; however, they all confirm the new Bitcoin dynamics within the context of COVID-19.

A few studies have identified the dynamic roles of cryptocurrencies in the pre- and early COVID-19 periods. However, with the rapidly changing circumstances, both the world in general and cryptocurrency markets specifically continue to experience dramatic shifts and turbulence. Examples include unconventional monetary policies, presidential elections, the current situation in Russia and Ukraine, and new cryptocurrency regulations. This paper argues that, first, only a limited number of studies integrate these events to investigate the safe haven, hedging, and diversifying capabilities of cryptocurrencies after the early shocks of COVID-19. Most studies place greater emphasis on the first wave of early outbreaks. Now, however, more up-to-date knowledge of later shocks and other effects merit our attention in this post pandemic era. Second, many studies imply that the pandemic was exclusively responsible for the increased level of market risk and contagion. This view ignores other factors that might have contributed to the changing relationships between the different markets after the early outbreak. Third, current studies focus on contagion and spillover effects either within different cryptocurrencies or a specific asset class and cryptocurrency markets (for example, equity markets and cryptocurrencies, commodity markets and cryptocurrencies, or foreign exchange markets and cryptocurrencies). However, studies examining multiple asset classes within a single portfolio are lacking. This is particularly important for understanding the current financial properties of cryptocurrencies.

To address these gaps, this study investigates the contagion effects between Bitcoin and other markets by integrating the aftermath events that could potentially have impacted the cryptocurrency market during the pandemic. Thus, the research questions are as follows: (1) Whether Bitcoin can still act as a safe haven, hedge, or diversifier during the COVID-19 crisis? (2) How did Bitcoin react to upcoming events within the context of COVID-19? Therefore, this study first employs Diebold and Yilmaz's (2012) approach to investigate the spillovers between Bitcoin and an additional eight major markets before and during the COVID-19 period. The study further identifies several global events to explain the above changes, and employs network analysis to describe the reactions between Bitcoin and other assets. This study focused on three representative periods and events after the immediate shock of COVID-19 in early 2020.

The contributions of this study are as follows: First, it enriches the understanding of cryptocurrencies and their relationships with other global markets during the COVID-19 period. Little is known about how the long-term effects of COVID-19 have persisted. This study not only examines the COVID-19 crisis directly, but also considers emerging global events in the context of COVID-19. Second, our analysis contributes to an understanding of the dynamic role of cryptocurrencies as financial assets. We compare the static and dynamic contagion effects between Bitcoin and a wide portfolio of assets before and during the pandemic. The analysis produced several interesting findings on Bitcoin dynamics and enriches knowledge of the diversifier, hedge, and safe-haven properties of Bitcoin. Third, this study offers alternative explanations for the different contagion patterns of Bitcoin. Most studies do not venture past the level of capturing the facts and features of these changing relationships before and during COVID-19. By considering the aftermath events of COVID-19, this study advances towards identifying the factors contributing to the new patterns.

The remainder of this paper is organized as follows. The *Literature Review* section describes the three strands of literature related to this study. The *Data* section presents the data considered in this study, including an explanation of it, the sample period, and sources. The *Methodology* section presents the main research methods used in this study, namely Diebold and Yilmaz's (2012) model and network analysis. The *Empirical Results* section presents the results of the study. Economic and policy implications are covered in the *Discussion* section, and the *Conclusion* summarizes the main findings.

Literature review

Three strands of literature are related to this study. The first concerns how contagion is understood and the transmission mechanism of its effects. There are multiple perspectives on contagion. Pericoli and Sbracia (2003) offer five different definitions for it. The first is a significant increase in the probability of a crisis in one country conditional on a crisis in another. The second is the volatility spillover of asset prices from one market to another. The third and fourth concern the co-movement of asset prices and quantities across markets. The fifth is understood as the intensified or changed transmission channels after a shock. These definitions have been widely acknowledged and referenced in the literature. In this study, Diebold and Yilmaz's (2012) approach is applied to measure the co-movement across different assets, which falls into the third and fourth definitions.

According to the literature, contagion emerges from the following three sources: (1) Fundamental changes in the macroeconomic environment (Forbes and Rigobon 2002; Haile and Pozo 2008), including changes in monetary policy, industrial shifts, economic slowdowns, etc. (2) Investment behavior (Dornbusch et al. 2000). In behavioral finance, investment decisions of market participants can be influenced by the choices of other actors. Investment behavior can impact market sentiment and further accelerate contagion. Examples include herding behavior and bank runs. This is particularly evident in cryptocurrency markets. (3) Physical exposure (Kyle and Xiong 2001; Jokipii and Lucey 2007), where a shock in one market causes instability in others, regardless of the underlying fundamentals (Kyle and Xiong 2001). Extreme crises or events, such as the 2008 financial crisis and the COVID-19 crisis, can cause huge capital outflows from the market.

Different sources of contagion should not be considered in isolation. Alqaralleh and Canepa (2021) distinguish between two source of contagion during the COVID-19 pandemic: fundamental and investor behavior-based contagions. Yarovaya et al. (2022a) constructed a four-level contagion transmission framework that includes different contagion sources. The first is the catalyst, a specific event that triggers contagion in financial markets—in this study, the COVID-19 outbreak. This information then reaches the media. Media attention refers to people's engagement with various types of media. The public then begins spreading information about the catalyst, which may trigger the second level of contagion. This channel plays a key role in forming expectations, public opinions, and pressure for government action. Herding behavior is linked to this level. The third level is contagion in financial markets. Financial markets are believed to be more sensitive to news and information and respond faster. The fourth level of contagion involves macroeconomic fundamentals. At this stage, the determinants of the contagion effect are traditional economic indicators and financial policies.

The second strand of related research examines how cryptocurrency markets react to different events. Many studies have examined the relationships between cryptocurrencies and major global events, with the exception of the COVID-19 crisis. These events can be categorized into two types, as follows.

The first are exogenous, such as political and geopolitical events and macroeconomic factors. Geopolitical risks were found to contribute to most of the risk premia and volatility of Bitcoin. Geopolitical risks and uncertainties in global and United States (US) economic policy have been shown to have greater impacts during negative economic conditions (Al Mamun et al. 2020). By analyzing the time-varying interrelationship between geopolitical events and Bitcoin prices, the results show that Bitcoin can work as a key indicator to reflect and provide a contingency for financial risks related to geopolitical events in some cases (Su et al. 2020). During positive events, Bitcoin can be used as a hedge or safe haven to avoid policy uncertainties; however, this is not always the case in negative situations (Qin et al. 2021a). There is strong interconnectedness between monetary policies in the US and Europe and cryptocurrencies. Compared with traditional monetary policies, cryptocurrency return spillovers are only slightly higher when unconventional monetary policies are in effect, but the composition of the spillover effect changes substantially (Elsayed et al. 2022).

Second, cryptocurrency-specific events, including new policies and regulations, security issues, and other updates related to cryptocurrency development. Tighter regulations and greater government involvement have been found to lower cryptocurrency prices and produce abnormal returns (Hashemi Joo et al. 2020; Shanaev et al. 2020; Chokor and Alfieri 2021). Among regulations, anti-money and issuance regulations have the greatest and most consistent impact (Shanaev et al. 2020). Uncertainties related to Chinese policies and regulations also exert significant influence on cryptocurrencies (Borri and Shakhnov 2019; Cheng and Yen 2020). Cryptocurrency exchange hacks impact the volatility of the Bitcoin market (Lyócsa et al. 2020) and significantly strengthen cross-market linkages between cryptocurrencies (Caporale et al. 2021).

Together with the contagion mechanisms and reactions of the cryptocurrency market to events, this study argues that in an examination of the contagion aspects of the cryptocurrency market during the COVID-19 period, a single catalyst—say the direct exposures to the crash of the early COVID-19 outbreak—does not adequately explain the phenomenon. External events and cryptocurrency-specific affairs can influence the safe haven, hedging, and diversifier properties of Bitcoin. Therefore, this study argues that we should consider not only the COVID-19 crisis but also different global events to examine and explain the dynamics of the Bitcoin market.

The third strand focuses on the interrelationships between cryptocurrencies and other assets. Before COVID-19, Bitcoin was widely investigated for its diversifier, hedge, and safe haven properties with various assets. Bouri et al. (2017) explore the dynamic conditional correlation between Bitcoin and major global equity markets, the bond index, the commodity index, oil, and gold. Their results show that Bitcoin cannot be regarded as a weak or strong safe haven against extreme movements of any asset. Bitcoin is a strong hedge for the commodity index and a useful hedge for the Chinese market. Umar et al. (2021b) find that the cryptocurrency market appears to have been less integrated with the technology sector and structurally less exposed to systemic risk before COVID-19; thus, cryptocurrencies can diversify the technology sector. Cryptocurrencies are isolated from mainstream assets but carry idiosyncratic risks. There are periodic, short-term, and increasing spillovers between Bitcoin and the VIX (Volatility Index), foreign exchanges, the GSCI (Goldman Sachs Commodity Index), and gold during sudden shocks (Corbet et al. 2018). Bitcoin also has certain hedging capabilities for oil prices on downward, normal, and upward trends in oil prices. Chan et al. (2019) select different frequency data to investigate whether Bitcoin can diversify risk in the European, Chinese, Canadian, Japanese, and US equity markets. Their findings show that monthly data on Bitcoin returns exhibit strong hedging properties for all markets. Numerous studies have also compared Bitcoin to gold. For instance, Dyhrberg (2016) used the GARCH (generalized autoregressive conditional heteroskedasticity) model to explore the hedging capabilities of Bitcoin. He concluded that Bitcoin shares some similarities with gold and the US dollar (USD). Bitcoin retains hedging capabilities and reacts symmetrically to good and bad news, but also behaves like a currency in response to US federal rate changes. Selmi et al. (2018) find that Bitcoin shares similarities with gold. Investors tend to choose Bitcoin and gold during bear markets when there are economic downturns, geopolitical events, and financial stress.

During COVID-19, some studies explored the dynamic relationships between Bitcoin and various markets, with results demonstrating Bitcoin's diverse performance. Corbet et al. (2020a) find that Bitcoin was not a good hedge for the Chinese market during the early outbreak of COVID-19, from January to February 2020. Contagion effects between developed markets—such as the European and US markets—and Bitcoin intensified during the first wave of COVID-19 (Guo et al. 2021). There is a "phase transition" of cryptocurrencies from being a hedge for traditional markets to becoming part of the global market, which is substantially coupled with traditional financial instruments (Wątorek et al. 2021). Meanwhile, Kwapień et al. (2021) find that cryptocurrencies, even in the COVID-19 crisis, are more independent from other markets than such markets are independent of each other. The hedging effects of cryptocurrencies on commodities increased after the initial COVID-19 shocks (Mo et al. 2022). Bitcoin is most affected by the Swiss franc, and cryptocurrencies have an inflation hedging function towards the Chinese yuan (Elsayed et al. 2022). Karim et al. (2022) find that the bond market can serve as an effective hedge and safe haven for cryptocurrencies. If we consider a lengthier period rather than focusing exclusively on the early pandemic shocks, the study shows that Bitcoin returns recovered by April 2020 and remained resistant to further shocks (Marobhe 2022). The second lockdown in Europe in November 2020 had a greater impact on volatility spillovers of cryptocurrency returns and persisted longer than the initial COVID-19 outbreak in February 2020 (Özdemir 2022). In the long term, Bitcoin has safe haven properties for NASDAQ and EURO STOXX (Kumar and Padakandla 2022). Karamti and Belhassine (2022) find that US market fears spread to other markets and drive the long-term dynamics of other markets, whereas gold, the Chinese market, and cryptocurrencies are exceptions that can work as safe havens for US market portfolios.

The above analysis shows that Bitcoin has been tested for its safe haven, hedge, and diversifier properties against equity, commodities, bonds, and currencies, and it has also been compared with gold. The literature reveals several portfolio implications. This study further extends the analysis by considering a wide spectrum of assets to analyze the contagion effects of Bitcoin in the context of COVID-19. Based on existing empirical analyses, this study selected nine variables (US market, European market, Chinese market, USD, gold, commodity market, bond market, and market fear), including Bitcoin. Apart from the empirical relationships between Bitcoin and the selected variables, these were chosen for two additional reasons. First, they are closely related to COVID-19. China was the first country to identify COVID-19 cases, and Europe was hit by COVID-19 in the next wave followed by the US. These three regions represented the early COVID-19 outbreaks and a large proportion of global equity markets. Second, diversified asset classes enable a better portfolio analysis. This study attempts to include not only equity markets but also other assets that have been previously examined. The selected variables are representative of different asset classes.

Data

The sample period was January 1, 2018 to April 30, 2022 and was selected for the following reasons. First, we selected the starting point immediately after the Bitcoin peak, at a time when it exhibited relatively mature features. The cryptocurrency market began reaching maturity in mid-2017 (Drożdż et al. 2018), and thus including any earlier data will skew the results. Second, the sample pre-COVID-19 and COVID-19 periods are comparable in length, offering more comprehensible results for the two sub-periods.

Furthermore, the sample was divided into sub-periods: pre-COVID-19 and mid-COVID-19. The World Health Organization (WHO) received its first coronavirus case report on December 31, 2019. Although the WHO announced the world pandemic on March 11, 2020, COVID-19 had begun spreading globally at the beginning of 2020. Therefore, data on the pre-COVID-19 crisis period covers 2018 and 2019, and subsequent data belongs to the COVID-19 period.

Nine variables were selected to examine the interrelationships in this study based on daily data, namely: Bitcoin (Bitcoin price-btc), the US market (MSCI_USA index-usa), the European market (MSCI_EUROPE index-eu), the Chinese market (Shanghai composite index-cn), the USD (traditional US Dollar Index-usd), gold (COMEX gold future price-gold), the commodity market (GSCI index-gsci), market fear (VIX-vix), and the bond market (Vanguard Total Bond Market Index Fund Admiral Shares-bond). Bitcoin and gold prices are referenced in USD. This study uses the rate of change for the VIX data and the log returns for the rest of the market for further analysis. The analysis disconsidered data missing due to holiday differences. Commodity and bond data were collected from the website Investing.com, and additional data were collected from the Wind database.

Methodology

Contagion measurements

This study uses Diebold and Yilmaz's (2012) approach to investigate spillover effects between Bitcoin and other markets. This model was selected for the following reasons: First, this method solves the order-dependency issue of Cholesky factorization in variance decomposition (Diebold and Yilmaz 2009, 2012). Second, this method provides a useful tool for analyzing directional spillovers, which better illustrates contagion effects between Bitcoin and other markets and offers rich data for visualizing contagion. Third, this approach indicates both static and dynamic spillovers of different markets, and is particularly useful for comparing the changing relationships between Bitcoin and other markets before and during the COVID-19 shocks. Fourth, this method can assess the bidirectional spillovers of different assets. This bidirectional analysis provides an approximate "input–output" decomposition of the spillover index, which can clarify the Bitcoin bidirectional spillover effects with various other markets. Fifth, this approach has been widely employed empirically in cross-sectional assets and market analyses. For example, the spillover between global equity markets (eg. Corbet et al. 2021), bond markets (eg. Rout and Mallick 2022), the cryptocurrency market, and currency markets (eg. Aharon et al. 2021). Spillovers across different assets are vital in this analysis.

The N-variable VAR(p) is given as

$$y_t = \sum\nolimits_{i=1}^{p} \phi_i y_{t-i} + \varepsilon_t \tag{1}$$

where $\varepsilon \sim (0, \Sigma)$ is a vector of independently and identically distributed disturbances.

The moving average equation is

$$y_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i} \tag{2}$$

where $N \times N$ coefficient matrices of A_i follow the recursive pattern of $A_i = \phi_1 A_{i-1} + \phi_2 A_{i-2} + \cdots + \phi_p A_{p-1}$, where A_0 is an $N \times N$ identity matrix and $A_i = 0$ for $i < 0$.

The model calculates the generalized h-step-ahead forecast error variance decompositions by $\theta_{ij}^{g}(H)$. For $H = 1, 2, 3, \ldots$, there is

$$\theta_{i \leftarrow j}^{g}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e_i A_h \sum e_j)^2}{\sum_{h=0}^{H-1} (e_i A_h \sum A'_h e_i)} \tag{3}$$

where $\theta_{i \leftarrow j}^{g}(H)$ represents the risk spillover of asset j to asset i, Σ is the variance matrix for the error vector ε, σ_{jj} is the standard deviation of the error term of asset j, and e_i and e_j are an $N \times 1$ selection vector with one as the i th element and zeros otherwise. The shocks to each variable are not orthogonalized; therefore, the sum of the element's contributions in each column is not necessarily equal to one. To facilitate comparison, the normalized variance decomposition matrix is given as follows

$$\widetilde{\theta}_{i \leftarrow j}^{g}(H) = \frac{\theta_{ij}^{g}(H)}{\sum_{j=1}^{H} \theta_{ij}^{g}(H)} \tag{4}$$

where $\sum_{i,j=1}^{N} \widetilde{\theta}_{ij}^{g}(H) = N$ and $\sum_{j=1}^{N} \widetilde{\theta}_{ij}^{g}(H) = 1$.

Directional spillover from market i to market j is denoted by

$$S_{\bullet i}^{g}(H) = \frac{\sum_{j=1, i \neq j}^{N} \widetilde{\theta}_{ji}^{g}(H)}{\sum_{i,j=1}^{N} \widetilde{\theta}_{ji}^{g}(H)} \times 100 = \frac{\sum_{j=1, i \neq j}^{N} \widetilde{\theta}_{ji}^{g}(H)}{N} \times 100 \tag{5}$$

The spillover to market i from market j is denoted by

$$S_{i \bullet}^{g}(H) = \frac{\sum_{j=1, i \neq j}^{N} \widetilde{\theta}_{ij}^{g}(H)}{\sum_{i,j=1}^{N} \widetilde{\theta}_{ij}^{g}(H)} \times 100 = \frac{\sum_{j=1, i \neq j}^{N} \widetilde{\theta}_{ij}^{g}(H)}{N} \times 100 \tag{6}$$

Then the net spillover is equal to

$$S_{i}^{g}(H) = S_{\bullet i}^{g}(H) - S_{i \bullet}^{g}(H) \tag{7}$$

This study uses net pairwise spillover to build contagion networks to illustrate the relationships between different assets. The net pairwise spillover describes the net contagion contribution of two markets or assets.

The net pairwise spillover is

$$S_{ij}^{g}(H) = \left(\frac{\widetilde{\theta}_{ji}^{g}(H)}{\sum_{i,k=1}^{H} \widetilde{\theta}_{ik}^{g}(H)} - \frac{\widetilde{\theta}_{ij}^{g}(H)}{\sum_{j,k=1}^{H} \widetilde{\theta}_{jk}^{g}(H)} \right) \times 100 = \left(\frac{\widetilde{\theta}_{ji}^{g}(H) - \widetilde{\theta}_{ij}^{g}(H)}{N}\right) \times 100 \quad (8)$$

Network analysis

Network theory is widely used in the research on financial contagion and market connectedness research (eg. Diebold et al. 2014; Gai and Kapadia 2010; Georg 2013; Martínez-Jaramillo et al. 2010) as well as in recent studies related to COVID-19 (eg. Vidal-Tomás 2021; Le et al. 2021). This method allows the different financial linkages between various assets to be mapped and visualized, and also facilitates comparison of different contagion effects after the occurrence of different global events.

In financial contagion network analysis, each financial market represents a node, and the interconnections between different markets are defined using links. These links are directed and weighted to reflect the exposure of each institution (Gai and Kapadia 2010). Degree measurements were used to build the network. The degree of a node is the number of links to other nodes.

$$d_i = \sum_{j=1}^{n} a_{ij} = \sum_{i=1}^{n} a_{ji} \quad (9)$$

In-degree measures the number of links pointing to a node. For node i, if node j has a directional link to node i, then a_{ij} equals 1.

$$d_{in}(i) = \sum_{j=1}^{n} a_{ij} \quad (10)$$

Out-degree measures the number of links pointing out from a node. For node i, if node i has a directional link to node j, then a_{ji} equals 1.

$$d_{out}(i) = \sum_{i=1}^{n} a_{ji} \quad (11)$$

This study uses network analysis to depict contagion networks. Nine assets are denoted by nine nodes, and the node size is the out-degree value of the asset. A larger node indicates that the market transmits more spillovers. In this study, the edges were weighted based on the net spillovers of the two markets, derived from Diebold and Yilmaz's (2012) method. Edge thickness and color denotes the degree of net contagion from node assets to other assets.

Empirical results

Descriptive statistics

Table 1 Presents the descriptive statistics for the full sample and each sub-period. The basic features of many financial assets changed during the COVID-19 shocks, and early research showed that different assets exhibited higher volatility during the COVID-19 crisis (Guo et al. 2021). However, new data shows that average returns on most assets have increased. Moreover, Bitcoin returns changed from negative to positive. Loose monetary policy initiatives aim to stimulate the economy, ultimately contributing to the rapid growth of financial markets, including cryptocurrency markets. While Bitcoin price volatility is slightly higher than before, the skewness and kurtosis of equity markets and Bitcoin changed significantly, indicating a higher possibility of extreme returns and fat-tailed features during COVID-19.

Table 1 Descriptive statistics for (log) return, nine asset classes

	Mean	Std. Dev	Skew	Kurtosis	ADF test
Panel A: full sample					
btc	0.000932	0.048649	− 0.885240	10.188540	− 9.1411***
us	0.000423	0.013915	− 0.995605	15.577220	− 9.2363***
eu	0.000112	0.011538	− 1.292708	17.170820	− 8.8277***
cn	− 0.000093	0.012117	− 0.469962	5.304945	− 9.5523***
usd	0.000110	0.003822	0.190840	1.947285	− 10.3840***
gold	0.000367	0.009787	− 0.258182	4.865910	− 10.5840***
gsci	0.000528	0.016347	1.348802	10.597990	− 9.7886***
vix	0.000210	0.000537	0.521173	0.629370	− 10.9210***
bond	− 0.000065	0.002693	− 0.692585	5.216177	− 9.9907***
Panel B: before COVID-19					
btc	− 0.001558	0.047334	− 0.317903	3.314795	− 6.5311***
us	0.000386	0.009665	− 0.621286	3.487669	− 7.1710***
eu	0.000094	0.007677	− 0.706400	1.973553	− 6.8404***
cn	− 0.000198	0.012164	− 0.354504	3.060114	− 6.2799***
usd	0.000103	0.003464	0.277556	1.307824	− 7.7866***
gold	0.000301	0.007086	0.331822	2.148386	− 7.2293***
gsci	− 0.000031	0.011923	− 0.103379	4.938443	− 7.2721***
vix	0.000730	0.090801	1.834414	11.351360	− 8.1663***
bond	0.000064	0.002006	− 0.073448	1.401370	− 6.5526***
Panel C: after COVID-19					
btc	0.003083	0.049700	− 1.322494	15.239945	− 6.5505***
us	0.000455	0.016750	− 0.964824	12.880542	− 6.4260***
eu	0.000128	0.014053	− 1.236761	13.711700	− 6.2660***
cn	− 0.000002	0.012088	− 0.570128	7.270436	− 7.5310***
usd	0.000115	0.004110	0.141370	2.020966	− 7.3924***
gold	0.000424	0.011633	− 0.360716	3.742168	− 7.8111***
gsci	0.001011	0.019372	− 1.536551	9.015542	− 7.0030***
vix	0.001624	0.090390	1.242735	4.326018	− 7.1915***
bond	0.000176	0.003167	0.714678	4.287886	− 8.0265***

This table presents the summary statistics for the full sample period as well as the sample periods before and during COVID-19. The statistics include the mean (Mean), standard deviation (Std. Dev), skewness (Skew), kurtosis (Kurtosis), and ADF test results. Lag selection in ADF test is based on Akaike Information Criterion (AIC). ***Denotes 1% level of significance

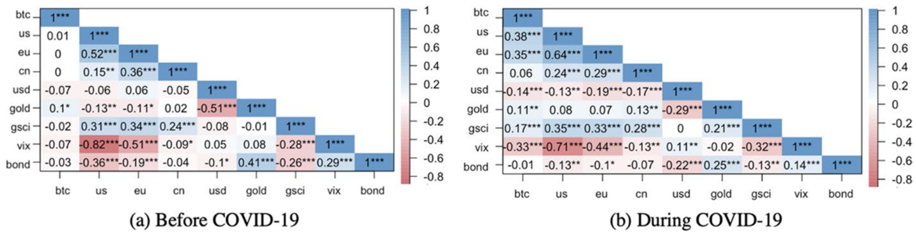


Fig. 1 Correlation matrices, nine asset classes. *Note*: This figure shows the unconditional correlation matrices of the variables. Panel **A** shows the correlation of nine assets before COVID-19 and Panel **B** presents the correlation of nine assets during COVID-19. The correlation matrices are calculated based on Spearman's method. *** Denotes 1% level of significance; ** denotes 5% level of significance; * denotes 10% level of significance

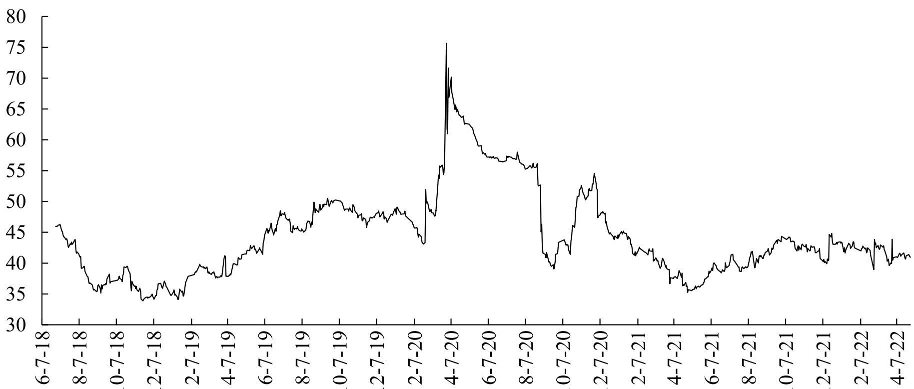


Fig. 2 Contagion Level for Full Sample, nine asset classes. *Note*: This figure shows the dynamic spillovers for all variables over the full sample period. The y-axis represents the total percentage of contagion levels. Figure 2 uses a 100-day rolling window and a 10-day forecast horizon. The following two figures use the same parameters. Using other rolling windows and forecast horizons only makes the pattern more or less smooth than that in Fig. 2, without impacting the outcomes or conclusions of this study

The unconditional correlation matrices (Fig. 1) demonstrate that Bitcoin only shows significant negative correlations with gold, indicating its property as a safe haven or hedge for most assets before COVID-19. These findings resonate with existing research that indicates Bitcoin was relatively independent of major financial markets (Corbet et al. 2018; Ji et al. 2018). During COVID-19, different assets became more interconnected. Bitcoin likewise has become less independent from most assets and is most strongly correlated with the US and European markets. The VIX is an inverse indicator; therefore, a negative correlation means that Bitcoin prices increase when the market fears drop. In the Chinese and bond markets, Bitcoin can work as a diversifier. Although Bitcoin is quoted in USD, this does not fully explain the correlation changes between equity markets and the USD with Bitcoin. Bitcoin became a stronger safe haven and hedge against the USD during the COVID-19 pandemic.

Contagion effects for all assets

For an overall understanding of the dynamic evolutions and contagion effects of the various assets, this section presents an average contagion-level analysis for the full sample period (Fig. 2). Before COVID-19, the impact of one asset on others ranged from ~30–50%, with an average contagion level of 35.04%. Statistical results also show that

Bitcoin received less contagion from other markets before the pandemic. The diagonal number shows that the directional spillovers of Bitcoin are 97.08%, explained by its own shocks. Developed markets and VIX have a larger impact on each other than on other assets. Gold and the USD also have interrelated contagion effects, and gold receives stronger spillover effects from the USD.

Based on the quantile level of spillover, we define four different intervals to better convey the risk level and explain the interrelationships between different assets and Bitcoin. When the contagion level was below 0.5 quantiles, the transmission risk was low. When between 0.5 and 0.75 quantiles, here defined it as medium. If over 0.75 quantiles, it was considered high, with values over 0.9 quantiles considered extremely high.

During COVID-19, the results showed an average level of 37.58% (see Table 2), which almost returned to the pre-pandemic level. The market reacted to the spread of COVID-19 in early February 2020 as cases began rising in Europe. Contagion levels skyrocketed in March 2020, when the WHO confirmed a global pandemic. The early COVID-19 pandemic strongly increased interdependencies across different markets, from February to August. The second wave of the outbreak and lockdowns occurred between September to mid-November 2020. Subsequently, there were a few months with low contagion levels (Table 3), which then increased to medium levels that lasted until the end of the data sample. Overall, market contagion has been strongly impacted by the COVID-19 pandemic.

Table 2 Static Contagion, nine asset classes

	btc	us	eu	cn	usd	gold	gsci	vix	bond	FROM
Panel A: before COVID-19										
btc	97.08	0.07	0.04	0.20	0.63	1.22	0.06	0.63	0.06	0.32
us	0.36	43.80	13.70	1.14	0.42	1.27	3.92	29.42	5.96	6.24
eu	0.51	17.55	50.82	5.51	0.60	0.86	5.49	16.46	2.21	5.46
cn	0.22	7.15	10.95	70.31	0.83	0.23	3.96	5.45	0.90	3.30
usd	0.40	0.67	0.44	0.20	75.96	20.47	0.51	0.35	1.01	2.67
gold	0.85	1.02	1.82	0.08	17.74	66.19	0.28	0.56	11.46	3.76
gsci	1.68	6.56	7.34	3.67	1.04	0.66	69.35	5.02	4.69	3.41
vix	0.54	30.85	12.99	0.70	0.36	0.61	3.65	45.90	4.40	6.01
bond	0.13	7.90	2.77	0.34	1.48	12.44	4.40	5.30	65.24	3.86
TO	0.52	7.98	5.56	1.32	2.57	4.19	2.47	7.02	3.41	35.04
Panel B: during COVID-19										
btc	67.79	10.46	8.56	0.37	2.00	1.07	2.01	7.73	0.01	3.58
us	6.95	41.18	20.43	3.10	2.06	0.34	5.06	20.19	0.70	6.54
eu	5.85	23.41	46.97	3.82	1.61	0.27	5.63	11.94	0.49	5.89
cn	1.08	6.89	6.09	70.34	2.29	1.54	6.00	4.41	1.37	3.30
usd	3.17	10.11	7.04	0.85	63.20	5.50	1.47	4.72	3.94	4.09
gold	1.61	0.77	0.67	1.01	6.48	78.88	3.27	0.91	6.40	2.35
gsci	2.06	8.40	7.49	5.54	0.03	2.57	65.67	6.93	1.32	3.81
vix	5.74	25.54	11.49	1.39	1.70	0.05	5.10	48.31	0.69	5.74
bond	0.72	4.17	2.80	2.21	2.44	4.87	1.75	1.61	79.43	2.29
TO	3.02	9.97	7.17	2.03	2.07	1.80	3.36	6.49	1.66	37.58

This table shows the static spillover results for all assets. Panel A shows the static spillovers before COVID-19 and Panel B shows them during COVID-19. The results are based on a VAR model. Based on the Schwarz criterion (SC) and the Hannan-Quinn (HQ) criterion, a lag of 1 is suggested

Table 3 High and low spillover periods for all assets

Date	Contagion level
2020.02.03–2020.03.05	High
2020.03.06–2020.07.14	Extremely high
2020.07.15–2020.08.10	High
2020.08.11–2020.09.28	Low and medium
2020.09.29–2020.11.23	High
2020.11.24–2021.01.05	Medium
2020.12.30–2021.08.25	Low
2021.08.26–2022.04.30	Medium and low

This table depicts the high spillover periods for all variables during the COVID-19 pandemic. Two "high" and two "extremely high" spillover intervals were identified. The identification of "high" and "extremely high" periods is based on the abovementioned criteria. For overall spillover, 0.5 quantile is 42.68%, 0.75 quantile is 47.85%, and 0.9 quantile is 55.78%

The dynamics of Bitcoin

As for Bitcoin, Figs. 3 and 4 show the average contagion effects of Bitcoin from and to other markets over time. Before COVID-19, Bitcoin had the lowest contagion level compared to the eight other assets (Table 2). On average, 97.08% of return changes can be explained by cryptocurrency-related activities. The spillovers from and to other assets ranged from 0 to 4%. Bitcoin was therefore the asset least likely to be influenced by other markets. After the COVID-19 outbreak, Bitcoin became more connected with other markets. Only 67.79% of the changes persisted. Both directional spillovers no longer rank

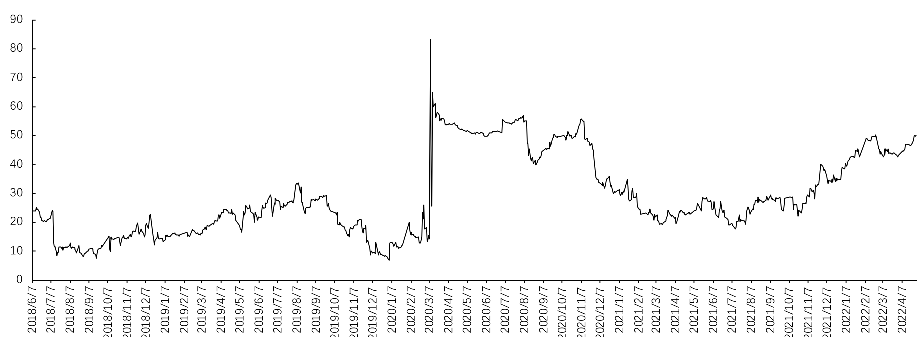


Fig. 3 Contagion from other markets to Bitcoin. *Note*: This figure depicts contagion levels from other markets to Bitcoin. The y-axis represents the total percentage of contagion levels

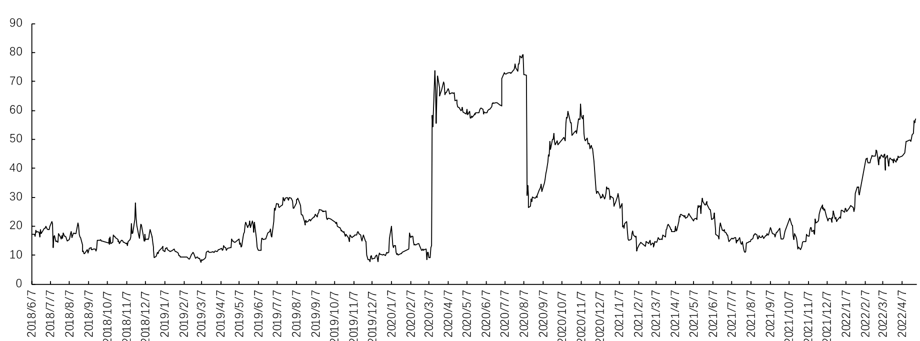


Fig. 4 Contagion from Bitcoin to other markets. *Note*: This figure depicts contagion levels from Bitcoin to other markets. The y-axis represents the total percentage of contagion levels

Table 4 High and low spillover periods for Bitcoin

From	Contagion level	To	Contagion level
2020.03.09–2020.08.10	Extremely high	2020.03.12–2020.08.10	Extremely high
2020.08.11–2020.11.27	High	2020.08.31–2020.12.22	High
2021.05.20–2021.05.24	Medium	2021.05.20–2021.05.24	High
2022.01.13–2022.04.30	High	2021.01.21–2022.04.30	High

This table describes the "high" and "extremely high" spillover periods between Bitcoin and other markets. "From" means spillover from other markets to Bitcoin, and "to" means Bitcoin spillovers to other markets. The criteria for "high" and "extremely high" periods are based on the abovementioned risk levels. For "from" spillovers, 0.5 quantile is 25.30%, 0.75 quantile is 42.05%, and 0.9 quantile is 50.84%. For "to" spillovers, 0.5 quantile is 19.08%, 0.75 quantile is 31.03%, and 0.9 quantile is 58.44%

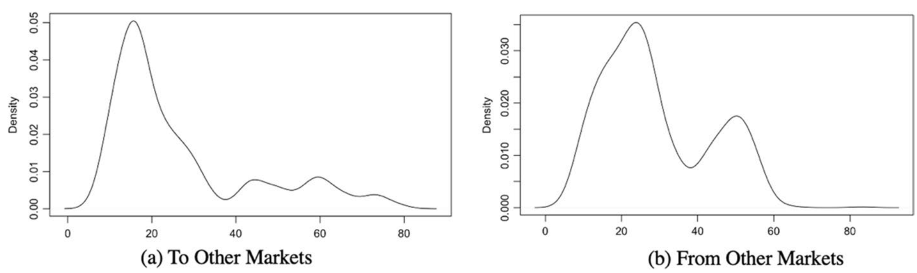


Fig. 5 Probability density distribution. *Note*: This figure depicts the from/to spillover probability density distribution of Bitcoin and the other eight markets. The y-axis represents the density distribution, and the x-axis represents each contagion level

last among the nine assets, indicating that Bitcoin is more closely connected to global markets and that Bitcoin's role as a safe haven is unsustainable during a pandemic. This aligns with findings from previous studies (Conlon et al. 2020; Yarovaya et al. 2022b).

Table 4 shows three high spillover periods for Bitcoin from and to other assets. During the first period, investors were still largely impacted by COVID-19-related fears and did not consider Bitcoin a safe haven, such that Bitcoin transmitted more spillovers than it received. In the second and third periods, spillovers to Bitcoin were slightly greater in the beginning than those from Bitcoin, which later reversed course. During this period, Bitcoin received spillovers from other markets sooner than it transmitted them to other markets. This may be due to the inefficiency of the Bitcoin market compared to other traditional assets (Naeem et al. 2021). Investors can leverage this inefficiency to monitor the increasing contagion levels to Bitcoin, and quickly react to upcoming risks.

Figure 5 shows that the probability of Bitcoin's contagion effect on other markets is lower than the probability of the Bitcoin market being affected by other markets. High transmission of risks and information to other assets is less likely. However, for the contagion effects from other markets to Bitcoin, the figure illustrates a bimodal distribution, meaning that Bitcoin is more likely to be impacted by other markets at extreme levels, which occurred during the first wave of COVID-19 shocks in early 2020. This further evidences that the role of cryptocurrencies has changed during the pandemic, and the safe haven properties of Bitcoin are diminishing under extreme shocks.

Figure 6 presents the net pairwise contagion between Bitcoin and the other assets. The dynamic contagions between Bitcoin and the other markets become stronger, which aligns with the findings of the static results (Fig. 1 and Table 2). Since the shock of the

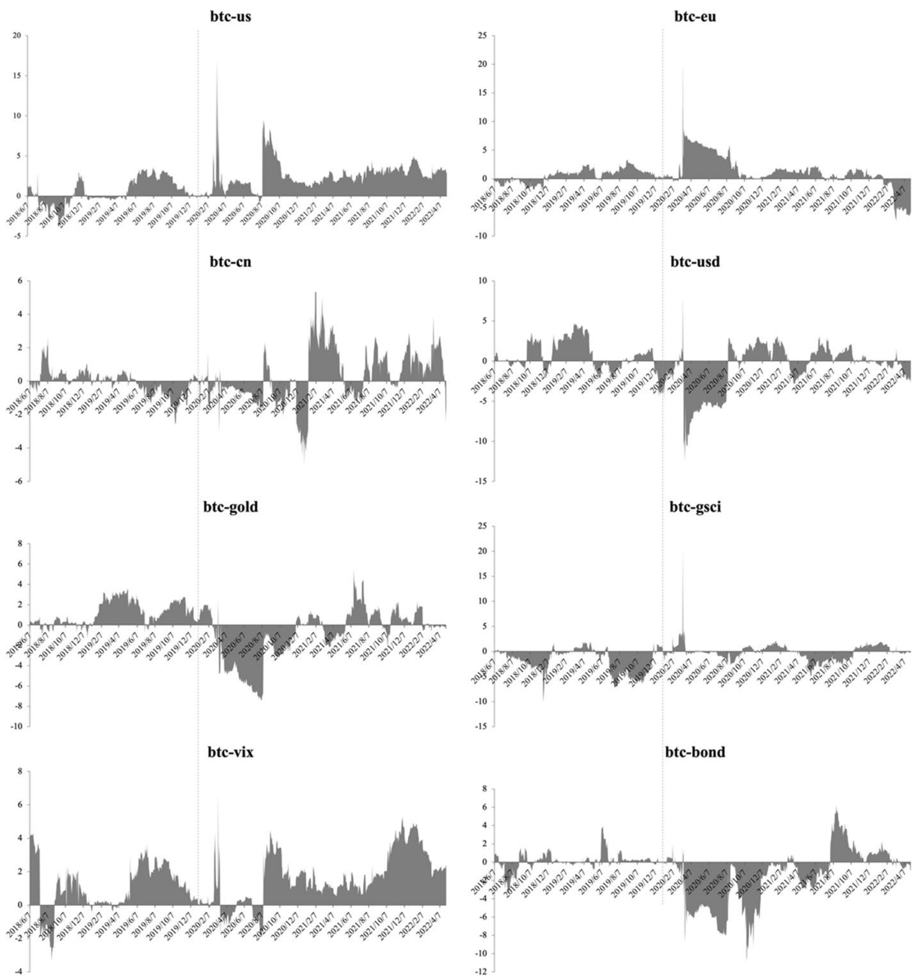


Fig. 6 Net Pairwise Contagion, nine asset classes. *Note*: This figure depicts the net pairwise spillover between Bitcoin and the other eight markets. The orange lines indicate the period before and during the COVID-19 pandemic. The y-axis represents net contagion. The gray shadow on the positive side means that the asset transmits risk to Bitcoin, and the negative percentage represents the asset receiving net contagion from Bitcoin

pandemic, the US and European markets have become net transmitters of Bitcoin, and their effects on the markets have increased. This is consistent with the results reported by Guo et al. (2021). This is because Quantitative Easing (QE) generates more money and increases liquidity in the financial market (Christensen and Gillan 2017). Furthermore, the cryptocurrency market has again attracted attention. Investors turn to Bitcoin as an alternative to bet on its diversifying function in the global crisis and as an inflation hedge on the one hand (Choi and Shin 2022) and, on the other hand, to invest in cryptocurrency for profit. Thus, more capital from developed economies entered the Bitcoin market. In late 2020, the Chinese market became a major transmitter of Bitcoin, indicating the hedging role of Bitcoin in the Chinese market. This result is consistent with that of Belhassine and Karamti (2021). During the COVID-19 shocks, the USD, gold, and bonds were at risk from Bitcoin. This is probably because the immediate shock of COVID-19 induced investors to liquidate their Bitcoin positions and turn to safer assets.

Studies have shown that gold and certain sovereign bonds can still function as safe assets during coronavirus outbreaks (Kinateder et al. 2021), and the USD is also considered to have safe haven properties in some cases (Flavin et al. 2014; Das et al. 2020). Gold is the traditional "last resort" during periods of global turmoil (Coudert and Raymond 2011; Selmi et al. 2018). The relationship between Bitcoin and commodity markets did not change significantly before and after the COVID-19 watershed. Bitcoin received more spillovers from the VIX, which might be explained by the fact that the VIX and US markets have close relationships (see Fig. 1), and US market fears drive market contagion (Karamti and Belhassine 2022).

In general, we can see that the contagion effects of Bitcoin on and from other assets experience dynamic changes during COVID-19 and do not follow exactly the same trend. After the initial shock of COVID-19, Bitcoin's spillover effects dropped, which resonates with the finding that the cryptocurrency market is resilient to the endless frictions of COVID-19 (Gherghina and Simionescu 2023); however, another round of increasing contagion levels began in late 2021. By contrast, the average contagion level of the full sample became relatively stable after 2020, when the second wave of COVID-19 ended. Second, the contagion effects from/to other markets are asymmetrical. Bitcoin received spillovers from other markets slightly sooner than it transmitted them to others, and also received more spillovers than it transmitted during the early outbreak. Third, focusing on the interrelationships between assets, we find that the contagion effects between Bitcoin and most markets, such as the US, European, and Chinese markets, have changed.

Analysis of global events

Bitcoin dynamics are difficult to explain when examining related data and figures. Based on empirical results from the above section specifically, the differences between general markets and important events can help explain the different dynamics, including cryptocurrency-specific affairs, macroeconomic policies, and geopolitical events. In this section, each network is based on the net spillovers of the event date.

August–November 2020: institutional players and the US presidential elections

A second spike occurred after the first pandemic shock, with the entry of institutional players becoming an important driver of the rising prices. One of the most important moments marking a major trend in Bitcoin investing is the launch of Bitcoin ETFs (exchange-traded fund). After a long struggle, the US Securities and Exchange Commission (SEC) approved the first Bitcoin ETF (ProShares Bitcoin Strategy Fund -BITO) on October 6, 2020. On the opening day, the trading volume quickly represented the second-largest ETF compared to all issued ETFs. In the first session, 23,103 million shares were traded, worth USD 950 million. Moreover, an increasing number of institutional players have joined the Bitcoin market, such as Grayscale, MicroStrategy, and Square, who purchased huge amounts of Bitcoin for their asset portfolios. The participation of institutional players stimulated the cryptocurrency market and improved the practical applications of Bitcoin as a diversifier and hedge. This potentially excited market sentiment and drove more individuals to join the market, thus increasing the net diversifier properties of Bitcoin for equity markets and the USD (Fig. 7).

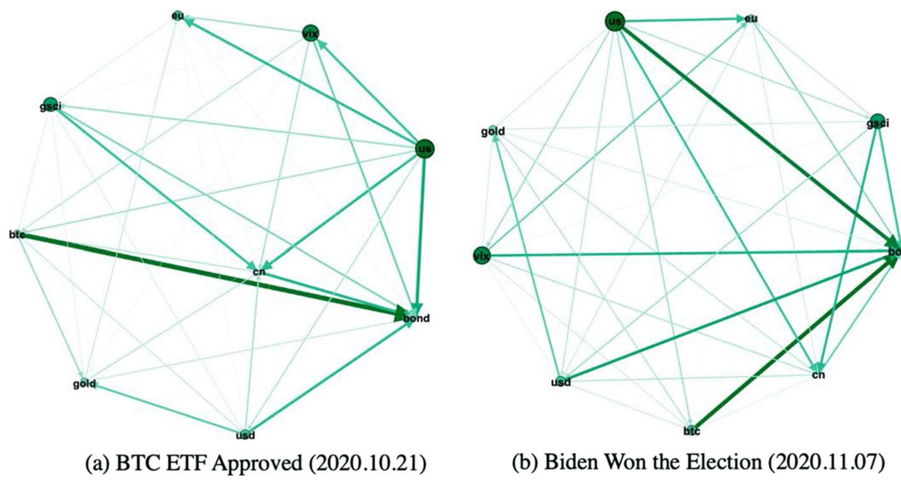


Fig. 7 Net contagion networks-1. *Note*: Panel **A** depicts the net spillovers between Bitcoin and other assets on October 21, 2020, when the Bitcoin ETF was approved by the US SEC. Panel **B** depicts the net spillovers between Bitcoin and other assets on November 7, 2020, when the winner of the US presidential elections was announced

In addition to specific crypto-related events, the impact of the US presidential elections cannot be ignored, which began in August and lasted until November 2020. On November 7, 2020, Joseph Biden defeated Donald Trump and became the 46^{th} US president. From the first voting day on November 3, 2020, the global financial markets began reacting strongly to the news. Before there is a clear result of presidential elections, uncertainty shows a clear tendency to rise in the months leading up to them (Baker et al. 2021). In the 2020 US elections, there was high uncertainty regarding the likely winner. The results show that Bitcoin is a net receiver of the US market and the USD, implying that it has a diversifying role. However, there are strong spillovers from Bitcoin to the bond market (Fig. 7). Historical data shows that when an election does not have a dominant candidate, stock market volatility and average returns increase (Li and Born 2006), and bond markets will tend to have higher returns than stock markets, thereby playing a diversifying role (Connolly et al. 2005). During this period, the overall market tends to have a lower risk appetite, and capital usually goes to safer assets such as bonds and gold (Bilgin et al. 2018). This explains why the US market, USD, and Bitcoin were the main net transmitters of bonds during this period.

May–September 2021: Chinese policy

China issued new regulations towards cryptocurrency assets during this period. Previous research has shown that Bitcoin and cryptocurrency markets are highly sensitive to political risks and regulations (Aysan et al. 2019; Wang et al. 2020; Aharon et al. 2021b), particularly to the uncertainties of Chinese policy (Borri and Shakhnov 2019; Cheng and Yen 2020). To better analyze such subtle relationships, this study identified two events during this time, namely: (1) the announcement by the Chinese Financial Stability and Development Committee (FSDC), under the State Council, of heightened regulations related to Bitcoin mining and trading activities on May 21, 2021; and (2) China's issuance of a regulation on September 24, 2021 entitled "*Notice on Further Preventing and*

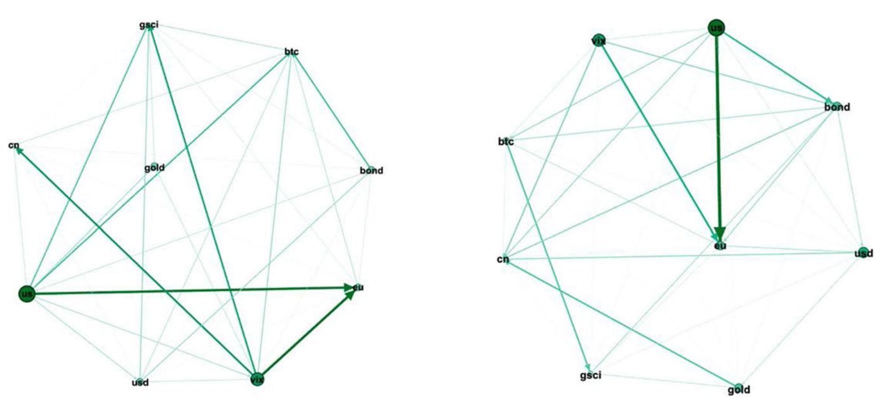
Resolving the Risks of Virtual Currency Trading and Speculation," indicating that all trading and speculative activities were considered illegal.

When the FSDC was released, Bitcoin prices plummeted, dropping by 4% in 10 min. When China issued the notice on September 24, 2021 and declared that services related to virtual currency settlement and the provision of trader information were prohibited, Bitcoin prices dropped by ~6% within an hour. Clearly, the contagion effect across different assets increased (Fig. 8). Based on the net contagion networks, Bitcoin-related risk was primarily transmitted to the commodity and bond markets after the first announcement. However, in the second scenario, Bitcoin received more spillovers from global markets. The Chinese government began having fewer impacts on the cryptocurrency market than before, which has been verified in other studies (Panagiotidis et al. 2019). The news affected the market, but the impact was milder and lasted for less time than before. Since China has mostly banned all activities related to cryptocurrencies, a reasonable expectation is that the cryptocurrency market will gradually stop reacting to Chinese regulations and policies.

January–April 2022: federal reserve actions and the Russia/Ukraine situation

Finally, this study selected recent global events to explain the growing spillover levels at the end of the dataset. We believe that two international events impacted the Bitcoin market during this period.

The first is hikes in interest rates by the US Federal Reserve ("the Fed"). Previous research has found that currency-based digital assets experience idiosyncratic spillovers in response to the Fed's interest rate and QE announcements (Corbet et al. 2020b). Due to the COVID-19 shocks, the Fed started another round of QE to stimulate the economy in March 2020, with the inflation rate reaching a three-decade high at the moment in late 2021. In January 2022, the Federal Open Market Committee's minutes signaled a strong rate hike as soon as March, stating that "we are prepared to use our tools to assure that higher inflation does not become entrenched" (Powell 2021). Bitcoin and other global markets thus experienced stronger spillover effects and market volatility. On the one hand, the announcement signaled a contraction of monetary policy, which means



(a) FSDC Prohibited Bitcoin Mining Activities (2021.05.21) (b) China Issued the Notice(2021.09.24)

Fig. 8 Net contagion networks-2. *Note*: Panel **A** depicts the net spillovers between Bitcoin and other assets on May 21, 2021, when China banned Bitcoin mining. Panel **B** depicts the net spillovers between Bitcoin and other assets on September 24, 2021, when China declared all trading activities illegal a global retrenchment in capital flows, a fall in global stock markets, and an increase in risk-aversion tendencies. As a risky global asset, Bitcoin also suffers. On the other hand, the Fed's rate hike will diminish Bitcoin's role as an inflation hedge for QE, causing more intense spillovers between Bitcoin and other markets (Fig. 9).

The second is the on-going situation between Russia and Ukraine. Although there are no Russian or Ukrainian markets in the sample dataset, the impact of such a major conflict cannot be ignored. Bitcoin is traded on a global market that can be influenced by various international phenomena. While Russia and Ukraine are the direct participants, the US and Europe have played key roles in this situation. Furthermore, the war reduced global risk appetites. At the beginning of the conflict, capital rushed to the USD and Chinese yuan as safer choices (Karamti and Belhassine 2022). This explains why the US and VIX markets transmit major risks to the European, USD, and Chinese markets (Fig. 9).

By the end of the dataset, spillovers between Bitcoin and other markets intensify, with attention on the war significantly affecting cryptocurrencies in the short term (Khalfaoui et al. 2022). These findings contradict the research that indicated Bitcoin showed relatively low risk during Russian and NATO tensions (Selmi et al. 2022), potentially indicating a change in post-COVID-19 Bitcoin dynamics. However, there are relatively low net contagions between Bitcoin and other assets, and the "from" spillovers are larger than the "to" spillovers when the Russia and Ukraine situation escalated on February 23, 2022. At the end of the selected data period, however, the "to" spillover became greater than the "from" spillover. Jointly, the evidence indicates that Bitcoin might not be a safe asset during this period but could work as a hedge or diversifier.

After Russia was hit by a series of sanctions, trading volumes between Rubles and cryptocurrencies spiked on Binance, according to Arcane Research (2022). For Russians, Bitcoin is an alternate payment method. However, Bitcoin adoption in Russia has attracted the attention of nation states. The Group of Seven (G7) countries declared they "will ensure that the Russian state and elites, proxies and oligarchs cannot leverage digital assets as a means of evading or offsetting the impact of international sanctions"

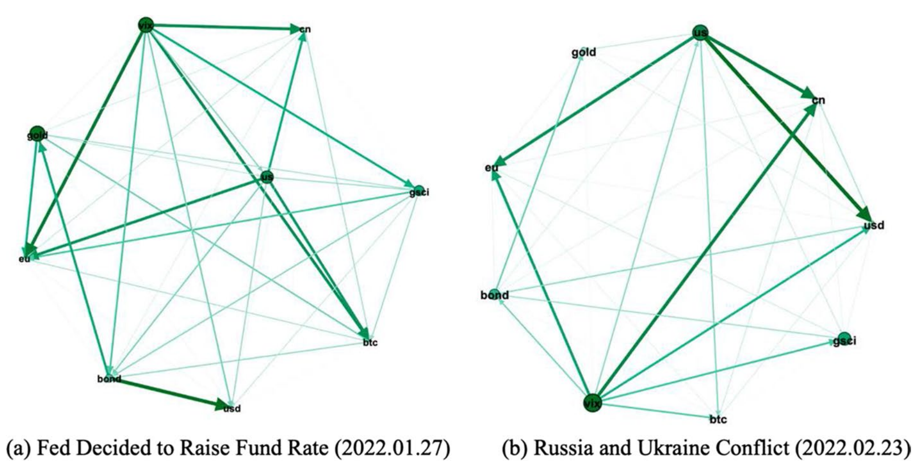


Fig. 9 Net contagion networks-3. *Note*: Panel **A** depicts the net spillovers between Bitcoin and other assets on January 27, 2022, when the US Federal Reserve decided to raise fund rates. Panel **B** depicts the net spillovers between Bitcoin and other assets on February 23, 2022, when the conflict between Russia and Ukraine escalated and Russia declared a "special military operation"

(Whitehouse 2022). Abuse of cryptocurrencies might cause different countries to further reconsider their role and development, which also explains the stronger Bitcoin dynamics in early 2022.

Discussion

This study has both theoretical and practical implications. First, it contributes to the research on cryptocurrency dynamics under the shocks of different events. Most studies consider the immediate crash after the COVID-19 outbreak as the only contagion source. This study extends the investigation to include major global events in the macro economy, geopolitics, and cryptocurrency industry, revealing that external events and cryptocurrency-specific affairs can impact Bitcoin's properties. Second, this study contributes to the literature on cryptocurrency portfolio management. By examining the spillover effects on a diversified portfolio before and during COVID-19, the paper found that Bitcoin is not a safe haven during crises, but could act as a diversifier in certain circumstances. This research also finds that Bitcoin "from" and "to" spillover periods are asymmetrical. Third, by integrating Diebold and Yilmaz's approach with network analysis, this study offers clear net spillover transmission mechanisms for various assets.

Our results have several implications for investments. First, Bitcoin is more impacted by other markets than it impacts others, and receives spillovers sooner than it begins reacting. Because of the asymmetry between "from" and "to" Bitcoin spillovers, investors should leverage such inefficiencies and time differences in contagion transmission, considering the growing market interdependency as a leading indicator of future risk levels rising in the Bitcoin market. Investors can thus better avoid windfall losses on different occasions, such as during political events, before policy changes, and when negative news circulates. Moreover, Bitcoin exhibits varying characteristics in different situations. After the initial COVID-19 shocks, financial markets experienced huge turbulence, as did Bitcoin, but Bitcoin's spillover effects lasted longer than the average. Investors should thus carefully consider different market conditions and events. Bitcoin demonstrates several high spillover periods, which indicate above-average risk in the Bitcoin market. During extreme global crises, Bitcoin is not a good safe haven for equity markets. Bitcoin should thus be combined with commodities, the USD, gold, and bonds in a single portfolio to diversify extreme risks. In addition, previous studies have shown that Bitcoin can effectively hedge risks during emerging events, such as the Brexit referendum (Stensås et al. 2019) and Sino-US relationships (Qin et al. 2021b). However, after the COVID-19 outbreak, Bitcoin was not immune to global events and is now more closely connected to other markets. Impacts from developed countries have become relatively stronger, and China still has some impact on Bitcoin although it is exiting the market. Major events in developed markets, particularly those able to cause macroeconomic changes and global turbulence, sometimes drive short-term market dynamics. When developing trading strategies, investors should thus pay closer attention to the impacts of macroeconomic news, geopolitical events, and crypto-industry developments. In extreme cases, Bitcoin cannot act as a safe haven but can work as a portfolio hedge or diversifier.

Policymakers should be aware of the increasing contagion effects between Bitcoin and global markets and enact relevant regulations to closely monitor risks. However, Bitcoin's asymmetric spillovers also show that the cryptocurrency market is less likely to cause systemic risks, which can ease concerns about crypto-driven financial instability. Moreover, policymakers can use key global events and cryptocurrency-related affairs to better predict the speculation cycle and high-risk periods of cryptocurrency markets, thereby ensuring stable development and suitable governance policies.

Conclusion

This study examined the roles and interactive relationships between Bitcoin and other markets in the context of COVID-19. First, the contagion effects of the pre- and mid-COVID-19 pandemic periods were compared. This study examines the descriptive results, the full-period static contagions, and the dynamic contagions of the entire data sample. Second, this study explored Bitcoin's dynamics and identified special patterns in its spillover effects. Third, to further explain the above findings, this study identified several global events to elucidate the differences between Bitcoin and other markets, including crypto-related issues, macroeconomic policies, and geopolitical events.

The findings show that Bitcoin had some risk resilience before the COVID-19 pandemic. However, after the outbreak, it was more likely to show extreme returns and greater connectedness to other markets. There are various high-contagion periods and dynamics between Bitcoin and the other markets assessed. Except for the initial COVID-19 outbreak in early 2020, this study finds three different high-contagion periods (August to November 2020, May 2021, and January to April 2022) and asymmetric effects between Bitcoin's "from" and "to" spillovers. For these three periods, this study identified various global events to explain such dynamics. Results showed that Bitcoin is not a safe haven in most cases, but can work as a hedge or diversifier in the post-COVID-19 context of major global events.

This study enriches the understanding of Bitcoin as a new financial asset and provides up-to-date knowledge on how it reacted to recent events in the context of COVID-19. Moreover, this study considers aftermath events beyond the first wave of COVID-19 to offer alternative explanations for changing market dynamics, and offers practical implications for both investment strategies for market participants and cryptocurrency governance for policymakers.

Finally, we acknowledge that the reasons for changing cryptocurrency dynamics are complex, and the events selected in this study only partially contribute to the explanation. COVID-19's aftermath has long-term effects, and many changes are intertwined with other factors, including market sentiment, capital flow, and the trading behaviors of individual investors, which future studies should therefore focus on. The field of cryptocurrencies remains nascent. Numerous unknowns and interesting findings await scholarly exploration.

Abbreviations

ADF	Augmented Dickey–Fuller
AIC	Akaike information criterion
BITO	ProShares Bitcoin strategy fund
BTC	Bitcoin price
CN	Shanghai Composite Index
ETF	Exchange traded fund
EU	Morgan Stanley Capital International Europe Index
FOMC	Federal Open Market Committee
FSDC	Chinese Financial Stability and Development Committee
G7	Group of seven

GARCH	Generalized auto-regressive conditional heteroskedasticity
GSCI	Goldman Sachs Commodity Index
HQ	Hannan quinn
NATO	North Atlantic Treaty Organization
QE	Quantitative easing
QVAR	Quantile vector auto-regressive
SC	Schwarz criterion
SEC	United States Securities and Exchange Commission
US	United States
USA	Morgan Stanley Capital International United States Index
USD	United States Dollar
VAR	Vector auto regressive
VIX	Volatility Index
WHO	World Health Organization

Acknowledgements
Thanks to the suggestions provided by Professor Shouyang Wang from the University of Chinese Academy of Science, and the great support of Professor Lars Bo Kaspersen of Copenhagen Business School. The authors are also very grateful for the valuable suggestions and precious recommendations formulated by the distinguished editor and all the anonymous referees.

Author contributions
XG is responsible for all the data collection, analysis, interpretation, and manuscript writing. All authors read and approved the final manuscript.

Funding
Not applicable.

Availability of data and materials
The datasets analyzed during the current study are available in the investing (https://www.investing.com/) and WIND database.

Declarations

Competing interests
The author declares no competing interests.

Received: 13 May 2022 Accepted: 6 May 2023
Published online: 29 February 2024

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