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Gold or Bitcoin, which is the safe haven during the COVID-19 pandemic?

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ABSTRACT

This study compares the dynamic spillover effects of gold and Bitcoin prices on the oil and stock market during the COVID-19 pandemic via time-varying parameter vector autoregression. Both time-varying and time-point results indicate that gold is a safe haven for oil and stock markets during the COVID-19 pandemic. However, unlike gold, Bitcoin's response is the opposite, rejecting the safe haven property. Further analysis shows that the safe-haven effects of gold on the stock market become stronger when the pandemic critically spreads.

1. Introduction

In December 2019, the coronavirus disease 2019 (COVID-19) pandemic swept globally and engendered severe casualties and continuous economic turbulence. During this period, the stock price crash risk and oil turmoil are critical for investors (Cao, Wen, Zhang, et al., 2021; Duan, Ren, Shi, Mishra, & Yan, 2021; He, Zhou, Xia, et al., 2019; Ren, Li, Wen, & Lu, 2022; Wen, Xu, & Ouyang, 2019). Investors have sought to lower the losses during the market turmoil. Gold is considered as a traditional safe haven asset against extreme movements (Baur & Lucey, 2010; Beckmann, Berger, & Czudaj, 2015; Gözde & Ünalmış, 2014). However, a few studies report that gold's safe haven or hedging property seems invalid because commodity markets are gradually financialized (Adams & Glück, 2015; Baur & Glover, 2012; Bekiros, Boubaker, Nguyen, et al., 2017). Interestingly, some studies have shown that the emerging asset Bitcoin has a safe haven property similar to gold (Dyhrberg, 2016b). Moreover, its safe-haven properties may be better than gold because it is independent of a country's politics and economics (Selmi, Mensi, Hammoudeh, et al., 2018). Pho, Ly, Lu, et al. (2021) also state that Bitcoin is a better portfolio tool than gold for risk-seeking investors. Hence, investors may lose confidence in this traditional asset and turn to Bitcoin during the global financial crisis. Therefore, this paper focuses on the following question: Which asset is the safe haven during this COVID-19 pandemic, gold or Bitcoin?

To investigate this question, we apply the time-varying parameter vector autoregression (TVP-VAR) model to test the safe haven property of gold and Bitcoin. If an asset is unrelated or negatively correlated with

other assets or portfolios during an economic turmoil, it can be served as a safe haven asset (Baur & Lucey, 2010). This type of asset helps to compensate for the loss caused by the price drop of other assets or investment portfolios under extreme market conditions. Therefore, investors seek safe haven assets to reduce losses caused by the risk.

Gold has always served as a store of value and a means of exchange for centuries because of its durable, storable, portable, divisible, and easily standardized characteristics (Jastram, 2009). Because of its excellent physical properties, gold is considered one of the earliest forms of money (Baur & Glover, 2012; Bordo, 1981). Additionally, gold can compensate for losses caused by other assets because of its negative correlation. The view that gold can be considered as a safe haven asset is widely recognized, particularly in the depressed market environment (Baur & Lucey, 2010; Beckmann et al., 2015). For example, Gözde and Ünalmış (2014) document that gold is a safe haven for domestic and foreign investors, especially when the stock market declines more seriously. However, evidence suggests that gold's safe haven and hedging property probably disappear because of the co-movement and financialization of commodity markets (Adams & Glück, 2015; Baur & Glover, 2012; Bekiros et al., 2017; Klein, 2017). The failure of gold's safe-haven characteristics at some point led people to seek other safe-haven assets.

Bitcoin, an emerging asset, is gradually attracting attention. Bitcoin is the original cryptocurrency proposed by Nakamoto (2008). Since its release, Bitcoin has been gradually accepted as a payment tool in some businesses and areas (Polasik, Piotrowska, Wisniewski, et al., 2015). In addition to its role in transactions, Bitcoin also has excellent properties from the perspective of economics and finance. Especially since this

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emerging asset appeared in the aftermath of the 2008 global financial crisis, the safe haven or hedging property of Bitcoin has also been gradually realized by some investors and researchers (Bouri, Molnár, Azzi, et al., 2017; Dyhrberg, 2016a; Guo, Lu, & Wei, 2021). An equity portfolio that includes Bitcoin may improve the risk-return tradeoff (Bouri, Molnár, et al., 2017; Briere, Oosterlinck, & Szafarz, 2015).

Bitcoin has many similar characteristics to gold, such as both having apolitical attributes, safe haven property and independence of inflation (Shahzad, Bouri, Roubaud, et al., 2019), so it is also referred to as digital gold (Popper, 2015; Rogojanu & Badea, 2014; Selmi et al., 2018). In addition to some similarities, Bitcoin has its unique advantages over gold, such as being independent of a country’s politics and economics, based on accurate algorithms and sophisticated protocols. Hence, Bitcoin will not be affected by the common movement and financialization of commodities like gold. These properties make a comparison of the safe-haven properties between Bitcoin and gold meaningful. Especially in the context of the COVID-19 pandemic, the comparison of this property is more interesting. Governments worldwide have adopted many stimulating economic and fiscal packages to reduce depression and limit the unfortunate impact of COVID-19 (Cheng, Barceló, Hartnett, et al., 2020; Gourinchas, 2020). Various stimulus policy measures may change the relationship between financial markets. Fig. 1 shows that both gold and Bitcoin prices have been declining for a considerable while during the COVID-19 pandemic. The safe haven properties of gold and Bitcoin may be invalid. Given the similarities in the safe-haven properties of gold and bitcoin and the advantages of bitcoin in terms of independence, it is worth investigating whether gold or Bitcoin can be used as a safe haven for oil and stock markets during the COVID-19 pandemic.

As the COVID-19 pandemic has a time trend and the number of people infected with the disease gradually changes, the interactions between various economic variables entailed in this process would change over time. Therefore, the TVP-VAR model is suitable for our study because it explains the dynamic spillover of gold, Bitcoin, as well as oil and stock markets more flexibly and robustly. We can determine whether gold or Bitcoin is a safe haven for oil and stock markets and observe the changes in their safe haven properties. Furthermore, we apply the iterative cumulative sum of squares (ICSS) algorithm to select four key time points for the residual sequence to analyze the time-varying effect of gold, Bitcoin, and oil and stock markets at these four-time points. The ICSS algorithm is employed to identify shifts in the number of new COVID-19 infections, thus obtaining the time points

when the number of infected people changes drastically. Different from the manual selection time points, the ICSS algorithm is more accurate and better reflects the dynamic changes in the number of people affected by the COVID-19 pandemic. Further, we do a more comprehensive consideration to get the safe haven properties under these key time points. Our results hold up to a robustness check.

Our analysis yields three main results. First, both gold and Bitcoin can be excellent hedging tools for oil before the COVID-19 pandemic. However, only gold can be considered as a hedge for the stock market before the COVID-19 outbreak. Second, based on the negative spillover effect during the COVID-19 pandemic, we reveal that gold can be considered as a safe haven asset for oil and stock markets in the short term during the COVID-19 pandemic, Bitcoin cannot. Moreover, gold’s safe haven property for the stock market becomes stronger when the pandemic critically spreads. Finally, the key time-point impulse effects verify our findings in time-varying impulse responses. Gold can be considered a safe haven asset under the impact of most events, but Bitcoin is the opposite. The spillover effects of oil and stock markets on Bitcoin are positive and different under four special events.

The contributions of this study are as follows: first, while some studies examine the safe haven characteristics of gold and Bitcoin (Chemkha, BenSaïda, Ghorbel, et al., 2021; Shahzad et al., 2019), merely a few compare the similarity and differences between the safe haven property of gold and Bitcoin in multiple markets, namely, both oil and stock market shocks. Second, unlike some studies on the safe-haven property of gold and Bitcoin statically based on the copula or regression approach (Long, Pei, Tian, et al., 2021; Syuhada, Suprijanto, & Hakim, 2021), we focus on the dynamic changes by relying on the TVP-VAR model rather than the static regression, thus revealing the changes in the safe haven property during the COVID-19 pandemic. Third, some previous studies do not focus on the context of the COVID-19 pandemic (Selmi et al., 2018; Shahzad et al., 2019). This paper focuses on the number of new infections for the first time to select the key time points using the ICSS algorithm, thereby reflecting the impact of key events during the COVID-19 pandemic. Therefore, this paper comprehensively considers the safe haven properties from the combination of dynamic and static.

The remainder of this paper is organized as follows: Section 2 summarizes the related literature. Section 3 introduces the proposed model. Section 4 describes the data and descriptive statistics. Section 5 discusses the empirical results and the robustness check. Section 6 concludes the paper.

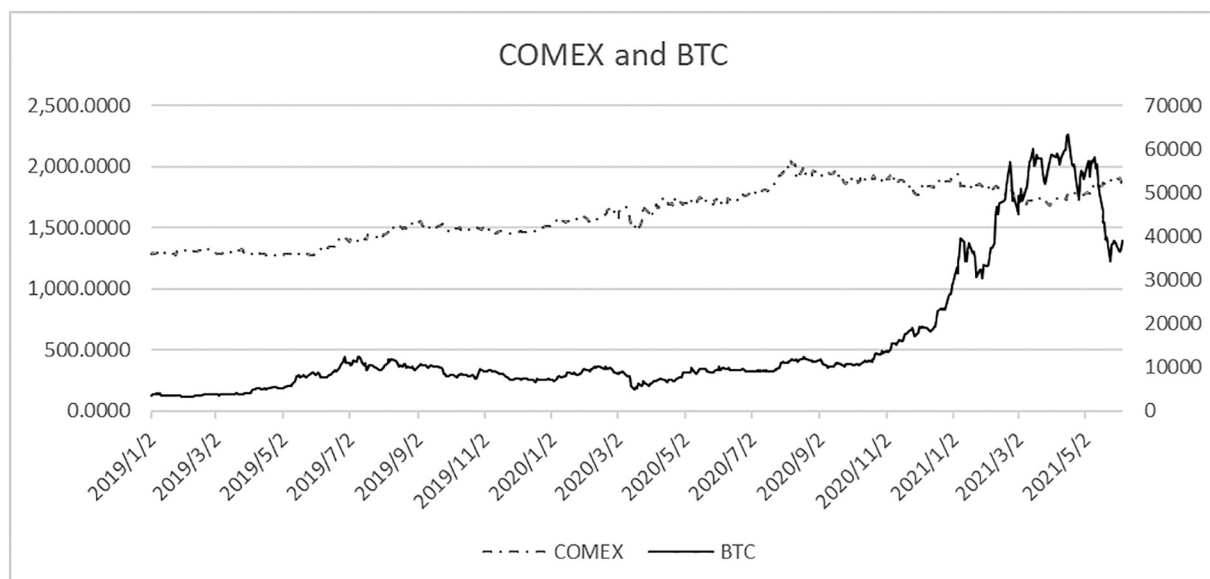


Fig. 1. Time trend of COMEX gold and Bitcoin.

2. Literature review

This paper is aligned with three strands of the recent literature. The first branch of literature is the study of gold's safe haven property. Ciner, Gurdgiev, and Lucey (2013) and Reboredo (2013) provide evidence that gold is a useful safe haven to hedge exchange rates and dollar depreciations, which is also verified by Capie, Mills, and Wood (2005). In earlier studies, Jaffe (1989) points out that adding golds to stock portfolios can obtain diversified returns, and gold can also provide protection to investors against oil or stock portfolio losses and improve its risk-adjusted return (Chkili, 2016; Lean & Wong, 2015). Selmi et al. (2018) show the usefulness of the gold in oil portfolios when oil price movement extremely. These indicate that investors will reduce their holdings of stocks and oil, and then turn to gold against extreme stock markets or oil movements. Many other scholars explore this property by studying the correlation of gold, oil and stock market (Baruník, Kočenda, & Vácha, 2016; Bredin, Conlon, & Poti, 2015; Dou, Li, Dong, & Ren, 2022; Dutta, Das, Jana, et al., 2020; Souček, 2013). Chkili (2016) holds that the relationship between gold and stock markets is negative in the period of the European debt crisis and the global financial crisis, showing that gold is a safe haven when a crisis occurs. Baur and McDermott (2010) analyze the 30-year samples from 1979 to 2009 and find that gold is a powerful safe haven for most developed stock markets at specific crisis periods.

However, Choudhry, Hassan, and Shabi (2015) examine the nonlinear dynamic interaction among gold return, stock market return and stock market volatility. They reveal that gold may not become a safe haven when the financial crisis outbreaks. Baur and Glover (2012) conclude that the safe haven property of gold may be affected by investor behavior, this is because gold cannot be considered as an investment asset and an effective hedge asset at the same time. Moreover, some studies concluded that gold's safe haven and hedging property seemed to be invalid because of the stronger co-movement and financialization of commodity markets (Adams & Glück, 2015; Baur & Glover, 2012; Bekiros et al., 2017; Klein, 2017). Therefore, Gold's safe haven ability has been questioned, and it makes sense to do further research.

This paper is also linked to another strand of the recent literature on studying Bitcoin's safe haven property. In recent years, it has often been argued that Bitcoin is a shelter from commodities and certainty currencies (Bouri, Molnár, et al., 2017; Dyhrberg, 2016a; Urquhart & Zhang, 2019). Bouri, Molnár, et al. (2017) also mention that Bitcoin is a great hedge and safe-haven when the commodity index faces turbulence, especially in the period before the collapse. Some studies find that Bitcoin can be considered as a safe haven or hedge against stock risks at some points (Bouri, Molnár, et al., 2017; Fang, Bouri, Gupta, et al., 2019). Corbet, Katsiampa, and Lau (2020a, 2020b) suggest that Bitcoin is a strong safe haven for oil and a weak safe haven for the stock market. Hedging strategies involving Bitcoin could also lower the portfolio's risk and improve the portfolio performance (Guesmi, Saadi, Abid, et al., 2019; Kajtazi & Moro, 2019; Nguyen, Chevapatrakul, & Yao, 2020). Differently, Bouri, Jalkh, Molnár, et al. (2017) find that Bitcoin is a poor hedging instrument, suited only for diversification. Klein, Thu, and Walther (2018) analyze the nature of including Bitcoin in a portfolio and find no evidence of stable hedging capabilities. Obviously, whether Bitcoin is a safe haven has not reached a consensus.

The context of the COVID-19 has received some attention in the literature since the onset of the COVID-19 pandemic. The safe-haven property of gold and Bitcoin becomes a burning issue. Some studies suggest that gold provides the great safe haven property during the COVID-19 pandemic (Akhtaruzzaman, Boubaker, Lucey, et al., 2021; Ji, Zhang, & Zhao, 2020; Salisu, Raheem, & Vo, 2021). However, Disli, Nagayev, Salim, et al. (2021) use wavelet coherence analysis and spill-over index methods to establish that gold cannot be a safe haven during the COVID-19 pandemic. Raheem (2021) concludes that although Bitcoin's characteristics have been widely acknowledged before the

COVID-19 pandemic, its safe haven property is invalid thereafter.

The third branch of literature is the comparative study of the safe-haven property of Bitcoin and gold. Dyhrberg (2016a, 2016b) indicates that Bitcoin shows the similarities to gold in the hedging capabilities. Both gold and Bitcoin provide a safe haven for oil price shocks (Selmi et al., 2018) or extreme stock market (Shahzad et al., 2019). Hence, investors may choose gold and Bitcoin as their assets during the economic crises. However, Klein et al. (2018) report that Bitcoin's safe haven property is not so good than gold's. Pho et al. (2021) suggest that gold is a better portfolio diversifier than Bitcoin for risk-averse investors, but not for risk-seeking investors. The above comparative analyses are not in the context of the COVID-19. With the outbreak of the COVID-19, studies also consider the COVID-19 into the comparative research. For example, Long et al. (2021) compare the safe-haven properties of Bitcoin and gold during the COVID-19, but they apply the NARDL model only considering the static aspect. Some scholars consider the dynamic research based on the dynamic conditional correlation model (Chemkha et al., 2021) or wavelet approach (Shehzad, Bilgili, Zaman, et al., 2021), but they focus on the hedge for major stock market. They do not take into account the impact on the oil market. Syuhada et al. (2021) only compare their safe haven property for energy commodities during the COVID-19. Neither considers both the stock and oil markets, which have been greatly impacted during the COVID-19 pandemic. Therefore, the existing research is still relatively limited.

Based on the above-mentioned literature review, opinions on whether gold and Bitcoin can be considered as safe havens during the COVID-19 pandemic have been inconsistent. Previous studies have not compared the changes in the safe haven property during the COVID-19 pandemic. They have not concluded whether the safe haven property becomes stronger or weaker. Unlike previous models, the TVP-VAR model can also provide us with a flexible and dynamic correlation, showing clear dynamic changes in the gold, Bitcoin, and oil and stock markets. Moreover, previous studies have not examined the safe haven characteristics of gold and Bitcoin for both oil and stock markets under this special event. Therefore, to fill these gaps, we use the TVP-VAR model to determine whether gold or Bitcoin can be considered as a safe haven for oil and stock markets during the COVID-19 pandemic. Both the changes and safe haven property under this special event can be realized using the TVP-VAR model. In contrast to previous studies on selecting the key time points, we manually obtain the number of new infections during the COVID-19 pandemic, and we subsequently use the ICSS algorithm to determine structural breakpoints to perform time-point impulse response analysis. The key time points selected through this method are highly representative.

3. Model

3.1. TVP-VAR model

Primiceri (2005) was the first to propose a TVP-VAR model, which was built based on the VAR model. In contrast to the traditional VAR model, the coefficient and variance covariance of the TVP-VAR model change with time. Many scholars use this popular approach to examine the nonlinear time-varying relationship between economic assets (Wen, Cao, Liu, et al., 2021; Zhao, Wen, & Wang, 2020). The TVP-VAR model is described as follows:

$$y_t = c_t + B_{1,t}y_{t-1} + \dots + B_{s,t}y_{t-s} + A_t^{-1} \sum_i \varepsilon_t \quad (1)$$

Where y_t is the observed $k \times 1$ order dependent variable vector; When analyzing the impact of the oil and stock market on the gold price, $y_t = [COMEX, WTI, SPX]$. When analyzing the impact of the oil and stock markets on the Bitcoin price, $y_t = [BIT, WTI, SPX]$. $B_{i,t}$ is a $k \times k$ order matrix with a time-varying coefficient, ε_t is the disturbance term, and A_t is the lower triangular matrix.

$$A_t = \begin{pmatrix} 1 & 0 & \dots & 0 \\ a_{21,t} & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ a_{k1,t} & \dots & a_{kk-1,t} & 1 \end{pmatrix} \quad (2)$$

Σ_t is a diagonal matrix

$$\Sigma_t = \begin{pmatrix} \sigma_{1,t} & 0 & \dots & 0 \\ 0 & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \dots & 0 & \sigma_{k,t} \end{pmatrix} \quad (3)$$

Furthermore, the model can also be written as

$$y_t = X_t \beta_t + A_t^{-1} \sum_{\tau} \varepsilon_{\tau}, t = s + 1, \dots, n \quad (4)$$

Where parameters β_t, A_t , and Σ_t are time-varying, assuming a_t is the superposition vector of the lower triangular elements in A_t , and $h_t = (h_{1t}, \dots, h_{kt})'$ where $h_{jt} = \log \sigma_{jt}^2, j = 1, \dots, k, t = s + 1, \dots, n$. It is assumed that these parameters follow the following random walk process:

$$\beta_{t+1} = \beta_t + \mu_{\beta t} \quad (5)$$

$$a_{t+1} = a_t + \mu_{a t} \quad (6)$$

$$h_{t+1} = h_t + \mu_{h t} \quad (7)$$

$$\beta_{s+1} \sim N(\mu_{\beta_0}, \sum \beta_0) \quad (8)$$

$$a_{s+1} \sim N(\mu_{a_0}, \sum a_0) \quad (9)$$

$$h_{s+1} \sim N(\mu_h, \sum h_0) \quad (10)$$

Owing to the hypothesis of the random walk process, based on the coefficients of the temporary and permanent displacement, progressive changes and structural mutations can be observed. The variance covariance matrix of the model innovation is a block diagonal matrix, where I is an n -dimensional identity matrix, and $\sum \beta, \sum \alpha$, and $\sum h$ are positive definite matrices. This method has many parameters and is difficult to estimate. To overcome this problem, we use the Bayesian reasoning method and Markov chain Monte Carlo (MCMC) to estimate the TVP-VAR model.

$$\begin{pmatrix} \varepsilon_t \\ \mu_{\beta t} \\ \mu_{a t} \\ \mu_{h t} \end{pmatrix} \sim N \left(0, \begin{pmatrix} I & 0 & 0 & 0 \\ 0 & \sum \beta & 0 & 0 \\ 0 & 0 & \sum a & 0 \\ 0 & 0 & 0 & \sum h \end{pmatrix} \right) \quad (11)$$

3.2. ICSS

The ICSS was first proposed by [Inclan and Tiao \(1994\)](#) to identify several structural breakpoints of volatility. The ICSS algorithm assumes that the sequence has a constant variance at the initial stage, but the variance changes under the influence of sudden events and remains unchanged until the next mutation occurs. The position where the variance changes is the structural breakpoint, and the specific process is presented as follows:

Suppose there are T sample observations, the residual sequences $\{\varepsilon_t\}$ of the newly infected people vis-à-vis COVID-19 are independent of each other and equally distributed in a white noise sequence with a mean of 0 and a variance of σ^2 . There are N_T structural breakpoints. Therefore, the sequence of the number of newly increased people infected by the COVID-19 can be divided into $N_T + 1$ intervals. The structural breakpoint sequence can be expressed as $\{k_1, k_2, \dots, k_{N_T}\}, 1 < k_1 < k_2 < \dots < k_{N_T} < T$. In the initial stage, it is assumed that the residual sequence of the number of newly increased people infected by COVID-19 has a stable

variance until the breakpoint appears. Subsequently, the variance remains the same until another breakpoint occurs. This process keeps repeating. N_T unknown breakpoints to the time series observations are given in the unconditional variance of T observations. The variance of each interval is denoted by σ_j^2 . Where $j = 0, 1, 2, \dots, N_T$, that is:

$$\sigma_0^2 = a_0^2 t \in [1, k_1] \quad (12)$$

$$\sigma_1^2 = a_1^2 t \in [k_1, k_2] \quad (13)$$

⋮

$$\sigma_{N_T}^2 = a_{N_T}^2 t \in [k_{N_T}, T] \quad (14)$$

We define the cumulative sum of squares from the beginning to the k observation of the sequence as $C_k = \sum_{t=1}^k \varepsilon_t^2, k = 1, 2, \dots, T$, then $C_T = \sum_{t=1}^T \varepsilon_t^2$. The test statistics are defined as follows:

$$IT = \sup_k |D_k \sqrt{T/2}| \quad (15)$$

D_k is the central cumulative sum of squares, $D_k = \frac{C_k}{C_T} - k/T$, and $D_0 = D_T = 0, C_T$ is the sum of the squared residuals of the entire sampling period. The D_k statistic fluctuates up and down at a value of 0 when there is no structural breakpoint in the test interval. However, the D_k value will significantly deviate from the 0 value up or down. A structural breakpoint occurs when the maximum value of $|D_k \sqrt{T/2}|$ exceeds the set critical value. Under the assumption that ε_t is a normally distributed random variable that is independent and identically distributed with zero mean, the asymptotic distribution of the test statistic is given as:

$$IT \Rightarrow \sup_k |W_r^*| \quad (16)$$

where $W_r^* \equiv W(r) - rW(1)$ is a Brownian bridge, and $W(r)$ is the standard Brownian motion. Under a given significance level, let k^* be the value of k when $\max_k |D_k|$. If $\max_k \{|D_k| \sqrt{T/2}\}$ exceeds a predetermined threshold, there is a structural breakpoint between the regions, namely k^* , where $\sqrt{T/2}$ is the standardized factor, and vice versa does not exist.

4. Data and descriptive statistics

The daily data utilized in our study cover the period from January 3, 2019, to June 4, 2021. China released information about the first infected person on December 31, 2019, which signified the onset of the COVID-19 outbreak. Therefore, our study can compare the differences before and after the COVID-19 outbreak. We apply the COMEX gold futures price (COMEX), the WTI oil price (WTI), and the S&P 500 index (SPX) to represent the international gold price, international oil price and stock markets, respectively. The WTI serves as a globally recognized benchmark for pricing all processed crude oil products. The S&P 500 is a stock index based on the 500 important listed companies in the United States which have a strong influence in the global stock market. This study chooses the COMEX gold futures price, WTI oil price, and the S&P 500 index, referring to the existing literature ([Hung & Vo, 2021](#); [Ren, Duan, Tao, Shi, & Yan, 2022](#); [Klein et al., 2018](#); [Śmiech & Papież, 2017](#)). The data are collected from the Wind database and <http://www.coi.ndesk.com>.

[Fig. 1](#) and [Fig. 2](#) show the time trend of the gold price, Bitcoin price, oil price, and stock market. The prices of oil and stock markets decline sharply during the COVID-19 outbreak. However, the price of gold increases during the COVID-19 pandemic. The prices fluctuated sharply before and after March and April 2020. Bitcoin prices have an upward trend, especially from October 2020 to March 2021, but decline sharply in April 2021. The original sequences of gold, Bitcoin, oil, and stock markets are not stationary at the 1% significance level, but they are stationary after a logarithmic difference. It should be noted that the

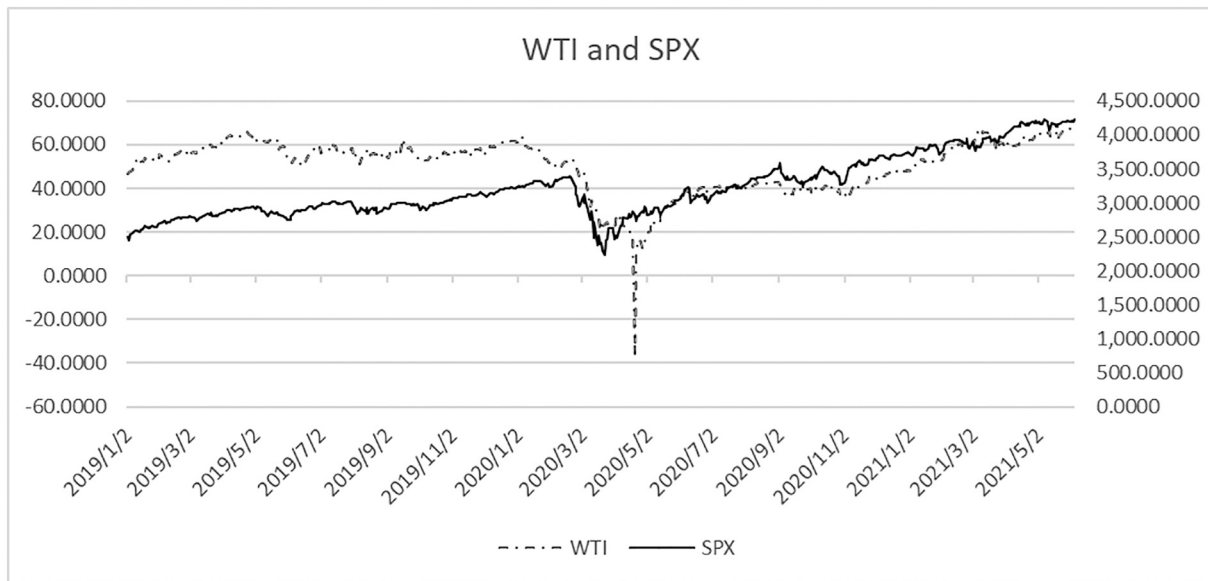


Fig. 2. Time trend of WTI crude oil and the S&P 500 index.

logarithmic difference represents the return rate. We use the augmented Dickey–Fuller test to examine the stationarity of the return rate. Each return series is stable at a significance level of 1%. Therefore, we apply the first-order logarithmic difference of these variables to the empirical study. The calculation formula is as follows:

$$r = \ln\left(\frac{P_t}{P_{t-1}}\right) = \ln P_t - \ln P_{t-1} \quad (17)$$

Furthermore, we manually collected the number of new infections in the World Health Organization (WHO) from January 3, 2020, to June 4, 2021. To obtain more accurate structural break points, we fit the number of newly infected people through the autoregressive–moving-average (ARMA) model to obtain the residual sequence, and then obtain four key time points using the ICSS algorithm.

The descriptive statistics regarding the return series of gold, Bitcoin, oil and stock markets are presented in Table 1. The skewness of the market return series of gold, Bitcoin, oil and stock markets is negative, and the kurtosis of each market return series is greater than 3, indicating that the return series presents the characteristics of peak and thick tail. The J-B statistics also show that each return series does not obey the normal distribution. Therefore, these return series are suitable for further research.

Table 1
descriptive statistics of each variable.

Variable	COMEX	BIT	SPX	WTI
observation	597	597	597	597
Mean	0.028	0.171	0.038	0.029
Median	0.039	0.079	0.064	0.094
Max	2.730	10.852	3.895	13.882
Min	-2.540	-13.721	-5.544	-26.130
Std. Dev.	0.472	1.996	0.672	2.105
Skewness	-0.181	-0.200	-1.150	-3.066
Kurtosis	7.780	8.976	19.710	53.010
JB	580.952***	892.198***	7077.549***	63,145.62***
ADF	-21.326***	-23.005***	-30.869***	-31.365***

Note: This table presents the results of descriptive statistics and ADF test. All the return series of the selected variables have passed the ADF test.

5. Empirical results and analysis

5.1. Time-varying effects at different time horizons

In this section, we adopt the TVP-VAR model to explore the impulse response of gold prices and Bitcoin prices to oil and stock market shocks in different lag periods, aiming to examine whether gold or Bitcoin is a safe haven for the oil and stock markets. According to the Akaike information criterion (AIC) and other information criteria, we construct a 1-period lag TVP-VAR model. We apply the MCMC method 10,000 times to obtain valid samples. Fig.3 and Fig.4 present the parameter estimation diagrams of MCMC, showing the sample autocorrelation functions, sample paths and posterior densities for selected parameters. The results indicate that the selected parameters are stationary and the sampling is effective.

Table 2 and Table 3 show the estimated results of selected parameters based on the MCMC in the TVP-VAR model for gold and Bitcoin respectively. The posterior means are positive and within 95% confidence intervals. The Geweke's CD test indicates that the null hypotheses cannot be rejected at the 95% confidence intervals for all parameters. The inefficiency factors are low, except for only one greater than 100. Hence, the MCMC algorithm produces the efficient posterior results. The results of the parameters and Geweke statistics indicate that the parameters can be effectively estimated using the MCMC method in this study. Through contrastive analysis, we capture the difference between gold and Bitcoin in connection with safe haven properties.

5.1.1. Time-varying response of gold and Bitcoin to oil at different time horizons

Fig. 5 shows the dynamic spillover effects of the gold and Bitcoin prices in response to a positive shock to the oil price. The impacts of oil on gold and Bitcoin are more significant in the short term but less significant in the medium and long term. There is an evident difference in the impact direction before and after the COVID-19 outbreak. Similarly, the effects of oil on gold and Bitcoin are mostly negative prior to the COVID-19 outbreak, but they change to positive when the pandemic begins. As highlighted by Baur and Lucey (2010), if an asset presents a negative interaction averagely with other assets during the normal term, this asset is a hedge; thus, gold and Bitcoin have a good hedging effect for oil before the COVID-19 pandemic. This corresponds with the finding that Bitcoin has some of the same hedging properties as gold and can be added to various tools to hedge market crises (Dyhrberg, 2016a). Both

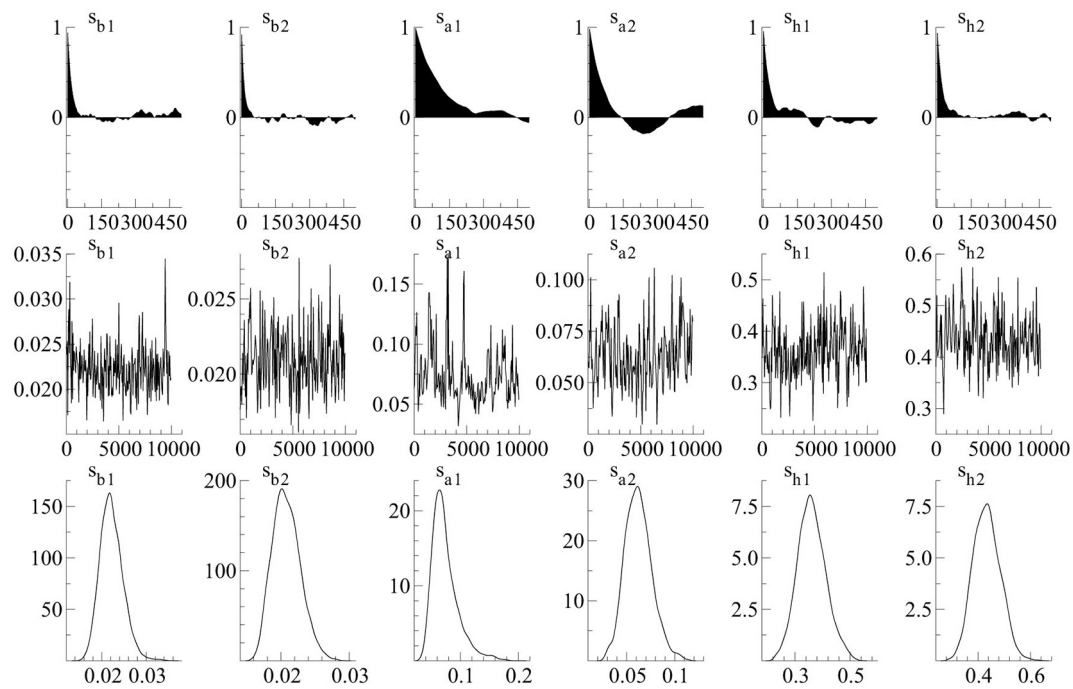


Fig. 3. Sample autocorrelation functions, sample paths and posterior densities for selected parameters.(gold). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.) Note: This fig shows the parameter estimation diagrams of MCMC for investigating gold, oil and the stock market. The top graphs report the autocorrelation function. All parameters are directly washed down from the high position, indicating that is autocorrelation. Figures in the middle show the sample paths. Fluctuating up and down and few extreme values indicate that the sample paths are stable. Bottom graphs show the posterior densities and are similar to the normal, hence the value sampling is effective.

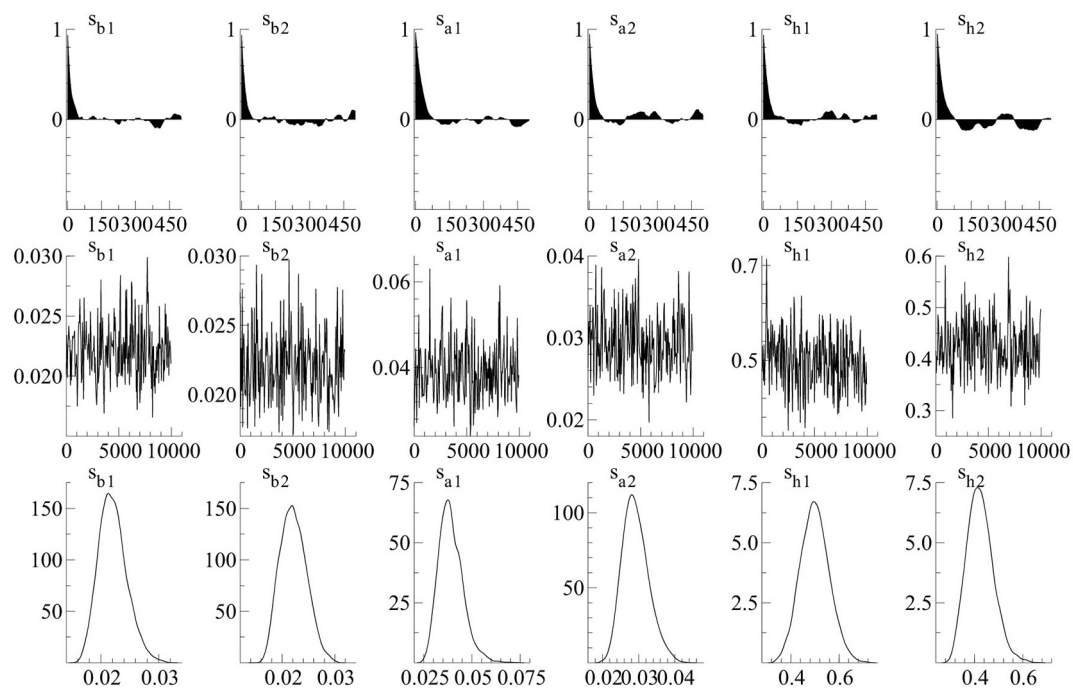


Fig. 4. Sample autocorrelation functions, sample paths and posterior densities for selected parameters.(BIT). Note: This fig shows the parameter estimation diagrams of MCMC for investigating Bitcoin, oil and the stock market. The top graphs report the autocorrelation function. All parameters are directly washed down from the high position, indicating that is autocorrelation. Figures in the middle show the sample paths. Fluctuating up and down and few extreme values indicate that the sample paths are stable. Bottom graphs show the posterior densities and are similar to the normal, hence the value sampling is effective.

Bitcoin and gold can serve as hedges for oil (Selmi et al., 2018).

There are also some differences in the time-varying responses of gold and Bitcoin. As shown on the left-hand side of Fig. 5, the time-varying responses of gold are positive at the beginning of the COVID-19

pandemic. Hence, gold is not an initial safe haven for oil. Thereafter, the time-varying responses change from positive to negative, but the negative relationship is weak and only lasts for a short time. Hence, gold’s safe haven property for oil appears in this short term, which is

Table 2
estimation results of selected parameters in the TVP-VAR model.

Parameter	ESTIMATION RESULT (Gold)					
	Mean	Stdev	95%L	95%U	Geweke	Inef.
sb1	0.0222	0.0026	0.0177	0.0278	0.004	31.07
sb2	0.0208	0.0021	0.0173	0.0252	0.831	20.90
sa1	0.0738	0.0230	0.0426	0.1350	0.284	156.74
sa2	0.0624	0.0140	0.0376	0.0927	0.639	76.93
sh1	0.3608	0.0511	0.2643	0.4708	0.175	57.85
sh2	0.4338	0.0514	0.3394	0.5359	0.905	44.41

Note: This table shows the estimation results of the selected parameters based on the MCMC estimation of the TVP-VAR model for gold, oil and the stock market. Mean is the mean of posterior parameters, Stdev is the standard deviation of posterior parameters and Inef. is the inefficiency factor. A effective MCMC sampling requires that the parameters are all in the 95% confidence interval, the Geweke's values are all less than the 5% critical value 1.96 and the inefficiency factor of most parameters is less than 100.

Table 3
estimation results of selected parameters in the TVP-VAR model.

Parameter	ESTIMATION RESULT (Bitcoin)					
	Mean	Stdev	95%L	95%U	Geweke	Inef.
sb1	0.0221	0.0024	0.0178	0.0274	0.043	30.33
sb2	0.0221	0.0025	0.0178	0.0273	0.733	25.69
sa1	0.0391	0.0064	0.0287	0.0541	0.114	43.64
sa2	0.0292	0.0036	0.0230	0.0373	0.000	34.11
sh1	0.4996	0.0597	0.0597	0.6213	0.001	33.38
sh2	0.4241	0.0547	0.0547	0.5429	0.947	27.57

Note: This table shows the estimation results of the selected parameters based on the MCMC estimation of the TVP-VAR model for Bitcoin, oil and the stock market. Mean is the mean of posterior parameters, Stdev is the standard deviation of posterior parameters and Inef. is the inefficiency factor. A effective MCMC sampling requires that the parameters are all in the 95% confidence interval, the Geweke's values are all less than the 5% critical value 1.96 and the inefficiency factor of most parameters is less than 100.

consistent with the findings of Wang and Lee (2021). Moreover, the safe haven property caused by specific events will weaken over time, resulting in the disappearance of the safe haven property in the long term. Along with the control of the COVID-19 pandemic, investors gradually step out of panic. Hence, the safe haven characteristic of gold is gradually withdrawn, and the interaction between oil and gold changes to positive in this case. However, the time-varying responses strongly change to negative after a while at around December 2020. This may be explained by the fact that investors are worried about secondary outbreaks of COVID-19 when the pandemic is not fully controlled. Therefore, they choose gold as a safe haven asset again.

Next, we examine the dynamic spillover effects of the Bitcoin price,

which are presented in the right-hand panel of Fig. 5. The first thing to note is that the time-varying responses are positive during the COVID-19 pandemic, indicating that Bitcoin cannot be a safe haven for oil during the COVID-19 pandemic. This finding is consistent with that of Choi and Shin (2021) that Bitcoin rejects the safe haven property due to financial uncertainty shocks. This may be because Bitcoin's ability to reduce the downside risk of energy commodities is limited (Syuhada et al., 2021). In particular, these positive dynamic spillover effects fluctuate up and down. This means that the interaction between Bitcoin and oil fluctuates over time. This may be attributed to the instability of Bitcoin.

From the aforementioned analysis, gold can be used as a safe haven asset for oil in the short term during the COVID-19 pandemic, but Bitcoin cannot. Similarly, both gold and Bitcoin can be considered as good hedging tools before the COVID-19 pandemic. Moreover, gold cannot be considered as a safe haven for oil at the beginning of the pandemic, and the safe haven effects are weak at the early stage of the COVID-19 pandemic. In addition, the safe haven effects of gold became stronger after December 2020.

5.1.2. Time-varying response of gold and Bitcoin to stock market at different time horizons

Regarding the impact of a positive shock in the stock market on gold and Bitcoin prices, as shown in Fig. 6, the spillover responses are more significant in the short term, but approximately zero in the medium and long term. In addition, the spillover effect of gold price is quite different from Bitcoin price.

As shown on the left-hand side of Fig. 6, the initial impact of this shock on gold price is positive, and then turns negative throughout the period before the breakout of the COVID-19 pandemic. Thus, gold has a good hedging effect against stock market shocks before the COVID-19 outbreak, which corresponds with the finding that gold can be considered as a hedge for the stock market (Choudhry et al., 2015). The time-varying impulse response of gold to stock market shocks is negative at certain times during the COVID-19 pandemic. This shows that gold can act as a safe haven in the short term when the stock market wobbles. We notice that the spillover effect is positive for a short time after the COVID-19 outbreak. This may be due to the turbulence of the international financial market and the panic of investor sentiment when the COVID-19 pandemic began. The huge impact of the gold market led to panic selling of gold and a decline in gold price. Therefore, the gold safe haven property weakens, as shown in the second positive effects in Fig. 6.

With the recovery of the stock market, investors tend to choose safe haven assets in this pandemic environment. Therefore, gold price responds negatively to a positive stock market shock between March 2020 and October 2020. In particular, as the COVID-19 pandemic spreads globally, the negative spillover becomes stronger, indicating that the safe haven property of gold is also strengthened. However, the negative

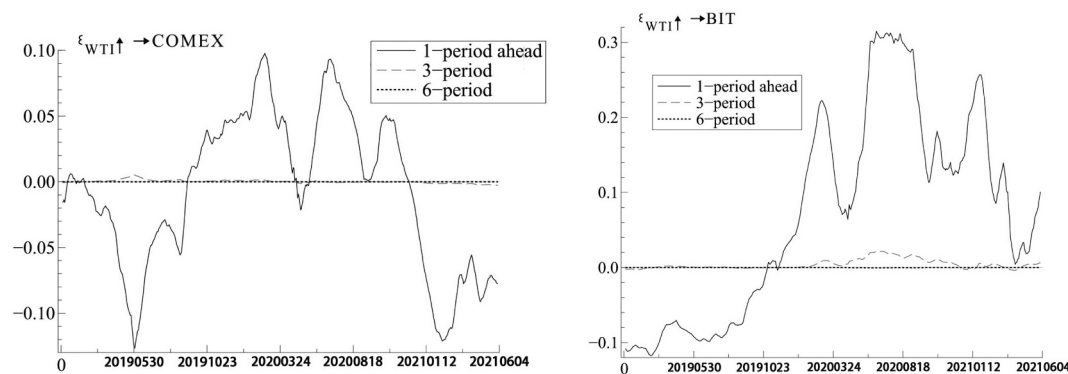


Fig. 5. Time-varying responses of gold price (left) and Bitcoin (right) to oil shocks. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

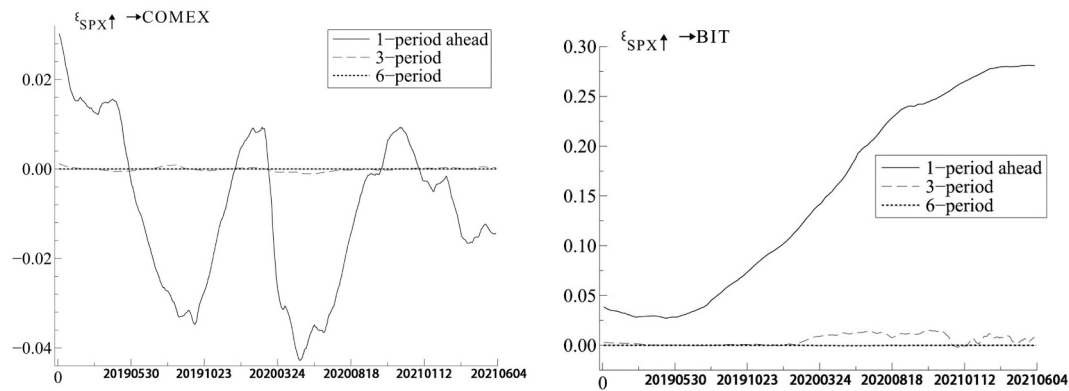


Fig. 6. Time-varying responses of gold price (left) and Bitcoin (right) to stock market shocks. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

spillover effect starts to weaken when it reaches a peak, which may be because gold, as a safe haven for the stock market, is only effective in the short term (Baur & Lucey, 2010). Thereafter, the spillover changes from negative to positive, which may be because the successful development of the COVID-19 vaccine alleviates the tension. Therefore, the safe haven property of gold withdrew. Furthermore, this impact turns negative in a short time, indicating that the safe haven property of gold appears again.

Considering the right-hand side of Fig. 6, compared to gold, the spillover of the Bitcoin price is always positive. This implies that Bitcoin is not a safe haven against stock market shocks during the COVID-19 pandemic, and it is also not a hedging tool for the stock market before the COVID-19 outbreak. Our results support the existing literature that documents Bitcoin as a poor hedge (Bouri, Jalkh, et al., 2017) and does not function as a safe haven (Klein et al., 2018; Long et al., 2021). Moreover, this dynamic spillover changes more regularly, showing an increasing positive correlation over time. This further implies that the spillover effect of the stock market on Bitcoin becomes stronger. Panagiotidis, Stengos, and Vravosinos (2019) also reports that the interaction between Bitcoin and traditional stock markets is significant. Overall, gold is a suitable safe haven for the stock market during the COVID-19 pandemic, but Bitcoin cannot be considered as a safe haven for the stock market. Moreover, gold's safe haven effects become stronger when the pandemic spreads more critically. Additionally, Bitcoin cannot hedge the risk of stock shocks prior to the COVID-19 pandemic, but gold is a good hedging tool for the stock market before the COVID-19 outbreak.

5.2. Time-varying effects at different time point shocks

We further study the specific time points to determine the impact of different events on gold and Bitcoin. Meanwhile, in terms of choosing the key points, we manually collect the number of infected people, and then establish the ARMA model to eliminate the trend of the infected people. Finally, key points can be obtained via the ICSS method.

5.2.1. The key time points selected by the ICSS method

The ICSS method hypothesizes that the return series present stable variance at the beginning of a period of time until an abrupt change occurs and then maintains the previous stability until the next shock occurs. With the repetition of the above-stated process, a time series with an unknown number of variance breaks is obtained. The ICSS algorithm has been widely applied in recent empirical research (Belhasine & Karamti, 2021; Mensi, Hammoudeh, & Yoon, 2015). This study establishes the ARMA model for the newly infected number of COVID-19 cases released by the WHO from January 3, 2020, to June 4, 2021. First, we check the stationarity of the newly infected population. The results show that the sequence is stable and can be modeled in the next step.

The model is identified mainly through the autocorrelation and partial autocorrelation functions. It is concluded that ARMA (7,2) is the optimal time series model, and the AIC values under the fitting results are the smallest. The residual sequence has no autocorrelation, and is a white noise sequence. The ARMA regression results are shown in Table 4.

The structural breakpoints of the residual sequence are detected via ICSS. As shown in Fig. 7, the ICSS method can duly capture the switching between the fluctuation mechanisms. Thereafter, we obtain eight structural breakpoints (including starting and end points) based on the residual sequences. It is easy to find that the turning point of COVID-19's progress is a basic reason for the structural change.

Finally, we choose four significant time points that correspond to several important events. These four points were March 25, 2020, when the WHO announced COVID-19 as the global pandemic; June 16, 2020, when the WHO announced that asymptomatic transmission was rare; November 12, 2020, when Pfizer announced the good news of the development of the vaccine; and January 11, 2021, when over 90 million people were reported to have been infected worldwide. The results of the structure break points and events are shown in Table 5. Therefore, the following time-point impulse response analysis is conducted according to the four structural break points stated above.

5.2.2. Time-varying responses of gold and Bitcoin to oil at different time points

Fig. 8 presents the impulse responses of gold and Bitcoin prices to oil price shocks at the four time points. The impulse response results of oil to gold and Bitcoin at time points have the greatest impact in the current period, and then begin to weaken to zero. Similarly, both the effects of gold and Bitcoin are mostly positive.

According to the graph on the left-hand side of Fig. 8, the time-varying effect responses of gold price to oil price shocks are initially positive except on January 11, 2021, when the number of infected people reportedly exceeded 90 million worldwide. This indicates that gold is a safe haven property against oil shocks only on January 11, 2021. The reason for this phenomenon may be that investors are concerned about the second outbreak of COVID-19, thereby leading to a high demand for gold. Meanwhile, the negative influence of oil on gold is only significant in the short term. This is because the safe haven property caused by specific events will weaken over time, resulting in the disappearance of the gold's safe haven characteristics in the long term (Wang & Lee, 2021). However, the time-varying effects are positive on March 25, 2020 (WHO announced COVID-19 as the global pandemic), June 16, 2020 (WHO announced asymptomatic transmission is rare), and November 12, 2020 (Pfizer announced the good news of the vaccine). Therefore, gold cannot be a safe haven asset for oil at these three time points. This result corresponds to the findings in the time-varying impulse responses that gold's safe haven effects for oil are weak at the early stage of the COVID-19 outbreak.

Table 4
Estimation results of the ARMA(7,2) regression.

ARMA regression							
Number	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Constant	-1721.088	4996.554	-0.340	0.731	-11,514.150	8071.977	18,053.340
L.ar	0.418	0.071	5.910	0.000	0.279	0.556	***
L2.ar	-0.433	0.058	-7.490	0.000	-0.547	-0.320	***
L3.ar	0.172	0.046	3.700	0.000	0.081	0.263	***
L4.ar	-0.125	0.052	-2.410	0.016	-0.227	-0.023	**
L5.ar	-0.186	0.057	-3.280	0.001	-0.298	-0.075	***
L6.ar	0.267	0.068	3.950	0.000	0.134	0.399	***
L7.ar	0.448	0.070	6.420	0.000	0.311	0.585	***
L1.ma	-0.562	0.080	-6.990	0.000	-0.719	-0.404	***
L2.ma	1.000	0.041	24.260	0.000	0.919	1.081	***
Constant	18,053.340
Mean dependent var	3358.003	SD dependent var.	.	48,080.055	.	.	.
Number of obs	353.000	Chi-square	.	4210.235	.	.	.
Prob > chi2	0.000	Akaike crit. (AIC)	.	8112.116	.	.	.
*** $p < .01$, ** $p < .05$, * $p < .1$							
Akaike's information criterion and Bayesian information criterion							
Obs	ll(null)	ll(model)	.	df	AIC	BIC	.
353	.	-4046.058	.	10	8112.116	8150.781	.

Note: This table shows the fitting result of ARMA(7,2) to obtain the residual sequence of removing the trend. From January 3, 2020 to June 4, 2020, a total of 353 newly-infected observations. From the p-value, significance, AIC and BIC, we conclude that the ARMA(7,2) is a effective time series model.

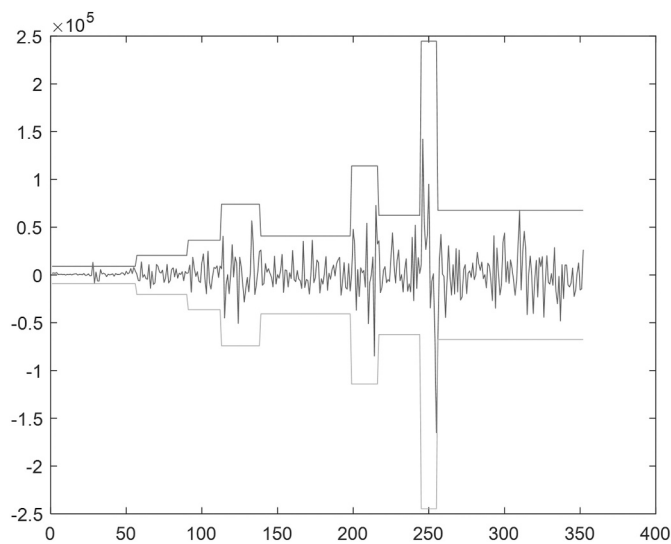


Fig. 7. Variance structure break points of new confirmed number of COVID-19 infections worldwide.

Table 5
results of the structure break points and events.

Break number	Break location	Break date	Events
1	58	2020.03.25	WHO announced COVID-19 as the global pandemic
2	114	2020.06.16	WHO announced asymptomatic transmission is rare
3	218	2020.11.12	Pfizer announced the good news of the vaccine
4	257	2021.01.11	More than 90 million people are infected worldwide

Note: Break location represent the the position where the residual sequence is mutated. Break date is the date corresponding to break location.

The right-hand side of Fig. 8 presents the time-varying responses of the Bitcoin price to oil shocks at four key time points. The results show that the time-varying effects at the four key points are all positive in the first period, thereby verifying our discoveries in the time-varying

impulse responses that Bitcoin is not a safe haven for oil shocks during the COVID-19 pandemic. Regarding the size of the time-varying effects, we note that the responses of Bitcoin price under these four key events are different. In detail, the time-varying effect was maximum on June 16, 2020 (WHO announced asymptomatic transmission is rare), followed by January 11, 2021, and November 12, 2020 (Pfizer announced the good news of the vaccine), and the minimum effect was on March 25, 2020 (WHO announced COVID-19 as the global pandemic).

5.2.3. Time-varying responses of gold and Bitcoin to stock market at different time points

Fig. 9 reports the impulse response of the gold and Bitcoin prices at four time points impacted by the stock market. Referring to Fig. 9, we conclude that the stock market's influence on the gold and Bitcoin price are remarkably changed on different dates. The time-varying responses at different time points also further support the findings of the dynamic spillover effects of stock market shocks on both Bitcoin and gold prices.

As shown on the left-hand side of Fig. 9, the influence of the stock market on the gold price is negative in the current period on June 16, 2020, and March 25, 2020, while it turns positive in the second time, showing that gold is a safe haven in the current period, which is consistent with the time-varying effects analysis that gold's safe haven property works in the short term. In addition, the negative influences reached a maximum on June 16, 2020, when the WHO announced that asymptomatic transmission was rare, but the negative influence was smaller on March 25, 2020, when the WHO announced COVID-19 as a global pandemic. This verifies our discoveries in time-varying impulse responses that the safe haven effects become stronger when the pandemic spreads seriously, namely, asymptomatic transmission. Another negative influence was on January 11, 2021, when the number of infected people exceeded 90 million worldwide. However, the impact of this incident was minimal, -0.004 , indicating that gold's safe haven property against stock market shocks was weak at this moment. The variation is that the impulse response is positive on November 12, 2020, when Pfizer announces the good news of the vaccine, implying that the safe haven property of gold withdraws under the impact of this event. This may be because the good news of the vaccine alleviated investors' bad expectations of the market. Therefore, the safe haven property of gold is invalid at this point.

The right-hand side of Fig. 9 shows that the influence of the stock market on the Bitcoin price at four key times is positive in the current period. This indicates that Bitcoin is not a safe haven under the impact of these four events, corresponding to the results of the time-varying effects

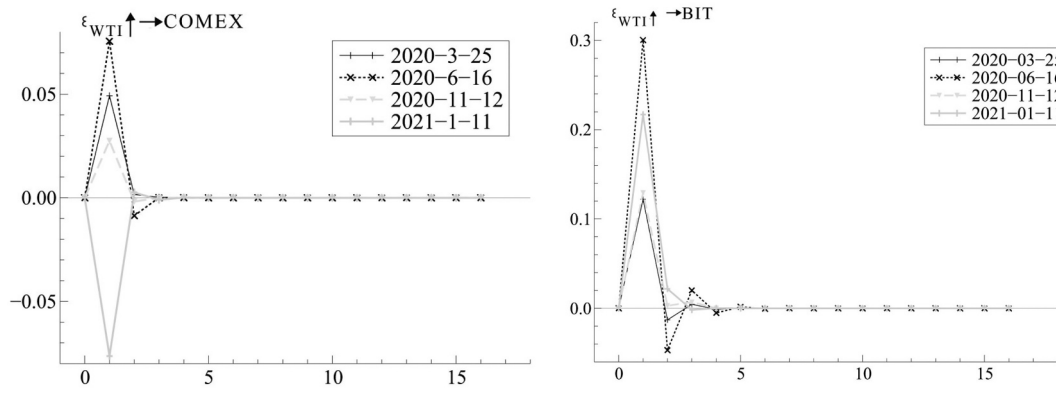


Fig. 8. Time-varying responses of gold price (left) and Bitcoin (right) to oil at different time points.

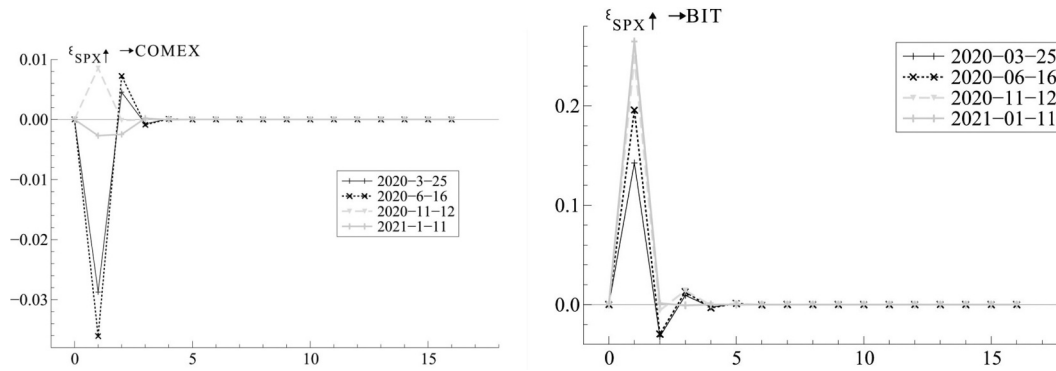


Fig. 9. Time-varying responses of gold price (left) and Bitcoin (right) to stock market at different time points.

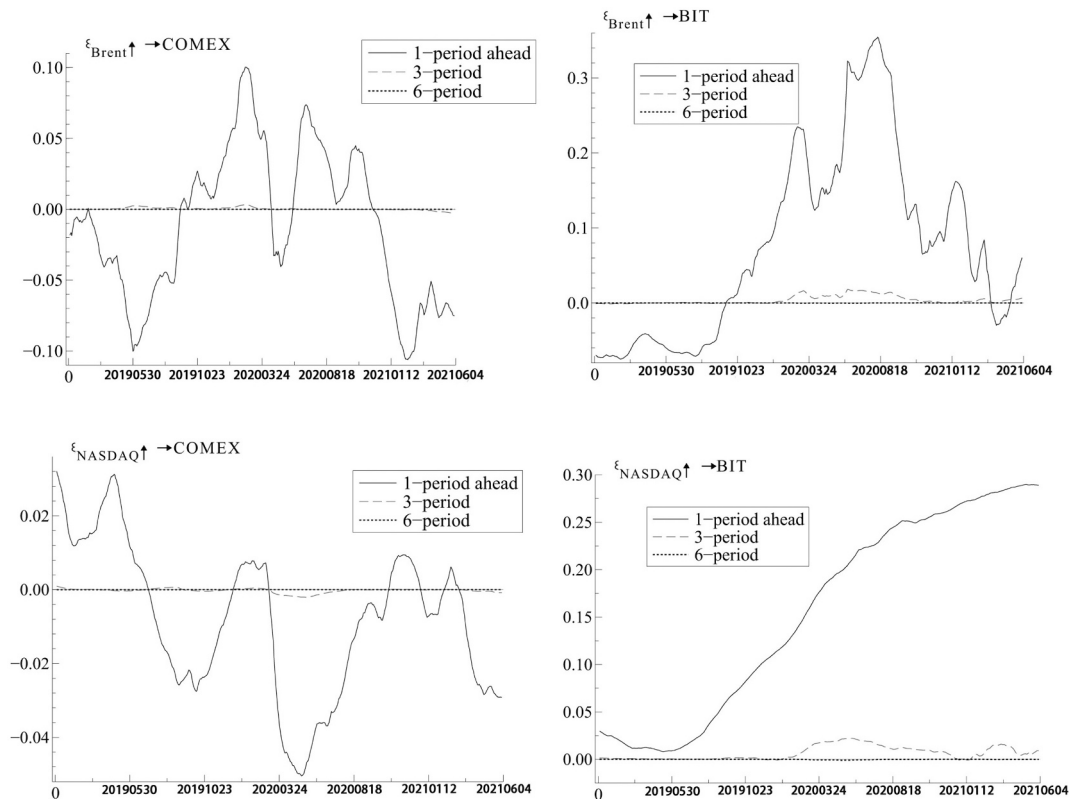


Fig. 10. Time-varying responses of gold price (left) and Bitcoin (right) to Brent oil and stock market shocks. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

presented above. Moreover, the maximum impact is 0.2 on January 11, 2021, and November 12, 2020, followed by 0.17 on June 16, 2020, and 0.13 on March 25, 2020. This further implies that the stock market's positive spillover effect on Bitcoin becomes stronger over time.

5.3. Robustness check

To test whether the results are robust, we apply the Brent crude oil price to represent the international oil price, and we replace the S&P 500 Index with the Nasdaq Index. The data are collected from a wind database. As reported in the Figs. 10 and 11, we find that the time-varying effect obtained after replacing the variables is similar to the previous results. Therefore, the empirical results are robust to a sensitivity check.

Fig. 10 shows the dynamic spillover effects of gold and Bitcoin prices in response to the Brent oil price and stock market shocks, respectively. Before the COVID-19 pandemic, the effects of gold and Bitcoin on Brent oil shocks are negative on average. This indicates that both gold and Bitcoin can hedge oil shocks before the COVID-19 pandemic. However, only gold can serve as a hedge for the stock market before the COVID-19 pandemic. During the COVID-19 outbreak, the time-varying impulse response of gold to oil and stock market shocks is negative at a certain time, and Bitcoin's response is positive. The results indicate that gold is a safe haven for oil and stock markets in the short term, but Bitcoin is not a safe haven.

Fig. 11 presents the impulse response of gold and Bitcoin prices at four-time points impacted by the Brent oil and stock markets, respectively. Gold's safe haven function plays a role under the impact of most events. However, the spillover effects of the stock market and oil on Bitcoin are positive, indicating that Bitcoin cannot be considered a safe

haven under the impact of the four special events.

6. Conclusion

Herein, we have studied the impulse response of gold, Bitcoin, oil and stock markets before and after the COVID-19 based on the TVP-VAR model to determine whether gold or Bitcoin can be considered as a safe haven for oil and stock markets during the COVID-19 pandemic. First, we explore their time-varying impulse responses in different lag periods. Our findings indicate that gold can be used as a safe haven asset for oil and stock markets during the COVID-19 pandemic, but Bitcoin cannot be regarded as a safe haven. Moreover, gold's safe haven property for the stock market becomes stronger when the pandemic spreads critically. Gold's safe haven effect is better for the stock market initially, and the safe haven effects for oil strengthen later. Moreover, both gold and Bitcoin have a good hedging effect on oil before the COVID-19 pandemic, but only gold can hedge stock market shocks prior to the COVID-19 pandemic.

Furthermore, we use the ARMA model to eliminate the trend of new infected cases during the COVID-19 pandemic, and then obtain the residual sequence using the ARMA model. The ICSS method based on the residual sequence is used to select the structural breakpoints as the time points of the time-varying effects at different times. Through the time-point impulse response analysis of four different structural breakpoints, it is found that the impulse response direction and intensity also vary under different events. Summarily, Bitcoin cannot be a safe haven against oil and stock market movements under the impact of the four special events. In contrast, gold can be considered as a safe haven for oil only under the impact of more than 90 million people infected

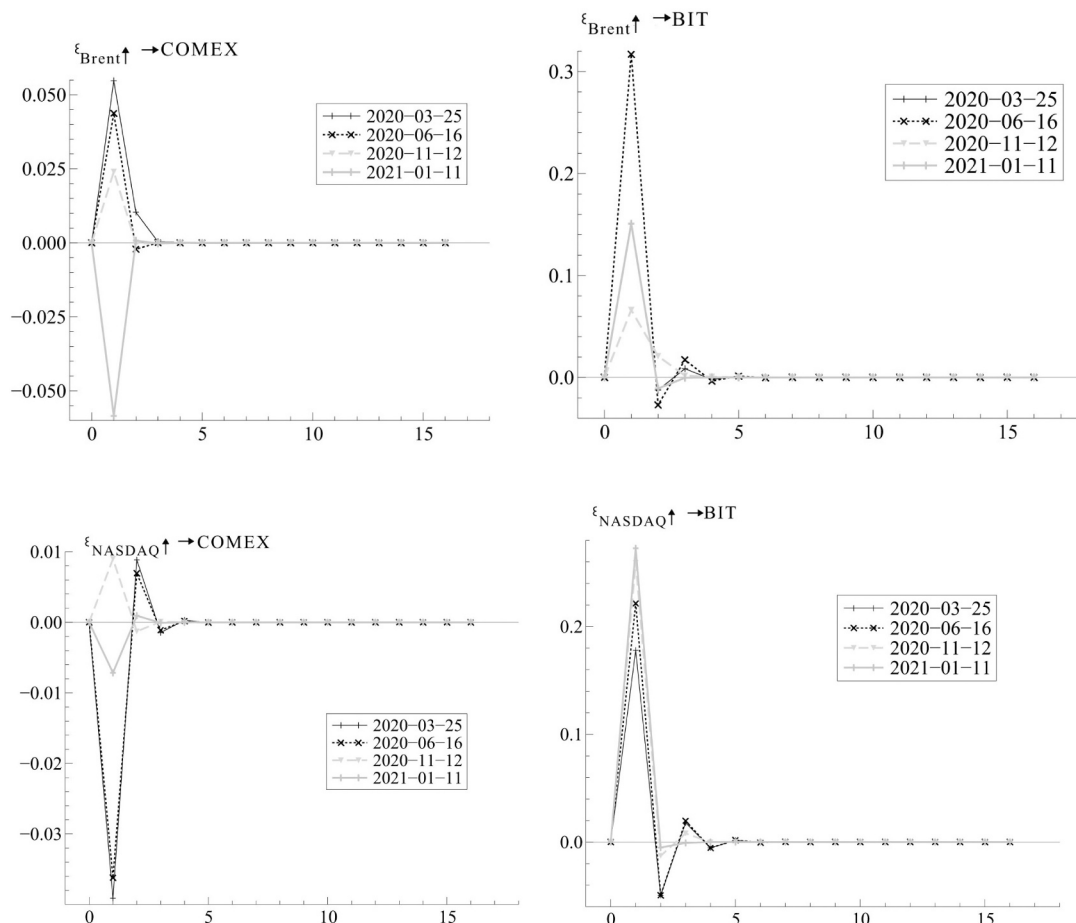


Fig. 11. Time-varying responses of gold price (left) and Bitcoin (right) to Brent oil and stock market at different time points. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

worldwide, but gold can against the stock market shocks on the key points, except when the good news about the development of the vaccine was announced. Additionally, gold's safe haven effects against stock market movement are stronger when the COVID-19 pandemic becomes more serious, namely, asymptomatic transmission. The aforementioned key time-point impulse effects support our discoveries in the time-varying impulse response.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

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