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Are Bitcoin and Gold a Safe Haven during COVID-19 and the 2022 Russia–Ukraine War?

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Abstract: Our investigation strives to unearth the best portfolio hedging strategy for the G7 stock indices through Bitcoin and gold using daily data relevant to the period 2 January 2016 to 5 January 2023. This study uses the DVECH-GARCH model to model dynamic correlation and then compute optimal hedge ratios and hedging effectiveness. The empirical findings show that Bitcoin and gold were rather effective hedge assets before COVID-19 and diversifiers during the pandemic and Russia–Ukraine war. From hedging effectiveness perspectives, gold and Bitcoin are safe-haven assets, and the investment risk of G7 stock indices could be hedged by taking a short position during thepandemic period and war except for the pair Nikkei/Gold. Additionally, gold beats Bitcoin in terms of hedging efficiency. We thus demonstrate the central role of Bitcoin and gold as financial market participants, particularly during market turmoil and downward movements. Our findings can be of interest to investors, regulators, and governments to take into consideration the role of Bitcoin in financial markets.

Keywords: Bitcoin; gold; G7 stock indices; hedging strategy; Russia–Ukraine war; COVID-19

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1. Introduction

The Russia–Ukraine war is an ongoing confrontation between Russia and Ukraine that started in February 2014, following the Ukrainian Dignity Revolution, and was initially centered on the status of Crimea and sections of the Donbas, both of which are recognized internationally as being part of Ukraine. Following a Russian military deployment on the Russia–Ukraine border beginning in late 2021, the war escalated substantially on 24 February 2022, when Russia launched a full-scale invasion of Ukraine signaling the start of the armed confrontation between the two countries.

Responding to Russia's attack on Ukraine, the European Union, the United States, the United Kingdom, and other Western nations attacked Russia's economy in several ways. Among the worst sanctions were those imposed by the United States and the European Union on Russia's central bank by freezing its assets in order to prevent Russia from utilizing its substantial foreign reserves to help support its currency, the ruble, and to impair Russia's capacity to pay for the Ukraine conflict. These sanctions are broad. Other nations, alongside Europe, have stepped in, including South Korea and Japan, and the sanctions have been enforced even by neutral nations such as Switzerland. The consequences do not have a severe impact on Russia's economy but they threaten the global economy, causing financial markets to tremble and making life more hazardous for everyone (Wiseman 2022).

From an academic standpoint, gold is the most safe-haven asset discussed, especially during periods of crisis (Baur and Lucey 2010; Baur and McDermott 2010, 2016; Bouoiyour et al. 2019; Corbet et al. 2020; Ghorbel et al. 2022; Hood and Malik 2013; Jeribi et al. 2020, 2021; Jeribi and Snene-Manzli 2021; Reboredo 2013). Cryptocurrencies, notably Bitcoin, are also well-known safe-haven assets (Conlon and McGee 2020; Feng et al. 2018; Ghorbel and Jeribi 2021a, 2021b, 2021c; Ghorbel et al. 2022; Jeribi et al. 2020; Jeribi and Snene-Manzli 2021; Kliber et al. 2019; Shahzad et al. 2019; Smales 2019).

While the whole world still tries to recover from the current COVID-19 health crisis, the Russia–Ukraine war emerged, causing turmoil in global financial markets. This will probably question the safe haven property of certain assets. Several analyses on the consequences of previous Ukraine–Russia wars prior to the most current crisis in 2022 have been released. For instance, Korovkin and Makarin (2019) investigated the economic consequences of the 2014 Russia–Ukraine war, noting that commercial interchange continued between the two countries despite the start of the conflict. Given that the 2022 Russia–Ukraine conflict is an ongoing issue with continually updated material streaming via various news channels, very little academic study compilation has been produced. In this respect, our study adds to the literature by assessing the hedging and safe haven properties of gold and Bitcoin for G7 investors during the 2022 Ukraine crisis. Our results indicate that both gold and Bitcoin could serve as hedge assets during stable periods. We thus join Dyhrberg (2016a), Stensås et al. (2019)[1], Shahzad et al. (2020)[2], and Bouri et al. (2020a) and oppose the findings of Wang et al. (2019), who argue that cryptocurrency is not a hedge for most of the international indices who found that cryptocurrency is not a hedge for most of the international indices. During extreme market conditions, they could serve as diversifiers, as found by Bouri et al. (2017b), for MSCI indices of the world, Europe and Pacific, S&P 500, FTSE 100, DAX 30, Nikkei 225, and Shanghai A-share. We prove the safe-haven property of Bitcoin for investors in G7 stock indices, expanding on the findings of (Conlon and McGee 2020; Feng et al. 2018; Ghorbel and Jeribi 2021a, 2021b, 2021c; Ghorbel et al. 2022; Jeribi et al. 2020; Jeribi and Snene-Manzli 2021; Kliber et al. 2019; Shahzad et al. 2019; Smales 2019; Shahzad et al. 2020; Bouri et al. 2020b)[3]. Additionally, gold is an effective safe haven during crisis, as proved by (Conlon and McGee 2020; Feng et al. 2018; Ghorbel and Jeribi 2021a, 2021b, 2021c; Ghorbel et al. 2022; Jeribi et al. 2020; Jeribi and Snene-Manzli 2021; Kliber et al. 2019; Shahzad et al. 2019; Smales 2019). In terms of hedging strategies, gold beats Bitcoin during crisis, whereas the hedging efficiency of Bitcoin was better during COVID-19 compared to the war period.

This study tries to provide contributions to the literature on cross-market co-movements in many aspects. First, we study the association structure among gold, Bitcoin, and developed stock markets. Such analysis enables the determination of new time-varying patterns which might govern the connectedness among commodity, cryptocurrency, and stock markets. Second, our analysis of the cross-broader asset holdings could provide interesting information for setting up stock-pricing models. Second, it helps us to better understand the intra- and inter-country (dis)similarities in terms of information spillovers. Third, this analysis investigates how cross-market linkages react to unprecedented events such as the Russia–Ukraine war. The remainder of our paper provides a literature review in Section 2, methodology in Section 3, data and different empirical results in Section 4, and finally, Section 5 concludes.

2. Literature Review

Recently, the world witnessed two major black swan events, namely the COVID-19 pandemic and the 2022 Russia–Ukraine war. The COVID-19 health crisis was first reported in Wuhan, China, and quickly escalated into a global sanitary problem driving the WHO to announce this health issue as a new global health crisis on 11 March 2020. The Russian–Ukrainian battle began on 24 February 2022 and has resulted in a vast number of deaths as well as Europe's largest refugee crisis since World War II. Both disasters maintained serious financial ramifications for the stock markets and the global economy.

Academic background in assessing the significant financial consequences of the unprecedented COVID-19 health crisis has been widely investigated (Albulescu 2021; Baig et al. 2020; Conlon and McGee 2020; Corbet et al. 2020; Jeribi et al. 2020; Jeribi and

Snene-Manzli 2021; Mazur et al. 2021; Zaremba et al. 2020; Zhang et al. 2020). However, research on the impact of Russian military actions on financial markets is quite scarce. Obviously, this crisis will result in higher inflation, lower household consumption due to higher prices (oil, gas, wheat, and minerals), supply chain interruptions, volatility, economic growth obstacles, investment reductions, and stock swings globally and in Europe in particular, given that both countries are substantial exporters to Europe. In this case, portfolio diversification through hedges and safe havens is becoming increasingly important.

According to Baur and Lucey (2010) and Baur and McDermott (2010, 2016), a safe-haven asset is a commodity in which an investor seeks refuge during periods of market collapse. It is non-correlated or negatively correlated with another asset or portfolio during times of turbulence. Because of its numerous characteristics, gold is considered a multi-dimensional asset. These characteristics include money, commodity, and risk avoidance (Wu et al. 2019). Gold is a hedging commodity in portfolio diversification and a safe haven in times of economic uncertainty and market volatility; therefore, studies have concentrated more on the risk avoidance feature. More significantly, gold has been shown to hold its value throughout market upheavals (Ji et al. 2020; Salisu et al. 2020; Salisu and Adediran 2020; Shahzad et al. 2020).

A substantial amount of studies have been conducted to determine if gold can be used as a safe haven (Bouri et al. 2020c; Shahzad et al. 2020), but the findings have been mixed. For instance, Baur and Lucey (2010) found that gold, on average, is a hedge against equities and a safe haven in times of excessive stock market volatility. Hood and Malik (2013) agreed that gold might be used as a hedge against the stock market in the United States. Gürgün and Unalmis (2014) investigated gold's safe haven and hedging features for stock prices from the viewpoints of both local and international investors, and they concluded that gold could be a hedge and a safe haven in the majority of the nations surveyed. More importantly, they discovered that the yellow metal is a safe haven in more nations as stock prices severely deteriorate.

Salisu et al. (2021a) confirmed the safe haven property of gold during the COVID-19 pandemic with greater effectiveness before the pandemic. Tauhidul et al. (2022) argued that investors are more attracted to gold due to the uncertainty caused by the COVID-19 pandemic. Additionally, Salisu et al. (2021b) investigated gold's role as a safe haven or hedging tool against crude oil price uncertainties during the early COVID-19 pandemic, concluding that gold has a substantial safe-haven characteristic against oil price risks. More recently, Ghorbel et al. (2022) discovered a negative asymmetric association between the yellow metal and the different stock prices using the NARDL model for the COVID-19 timeframe, implying that gold can function as a suitable hedging tool or a safe-haven against stock prices in the short and long term.

However, research suggests that gold's potential to act as a hedge or safe haven against the stock market varies regarding the markets (Beckmann and Czudaj 2015; Gürgün and Unalmis 2014) and the different market conditions. Bredin et al. (2015) demonstrated that gold works as a safe haven for US stock market prices during financial crises but not throughout the 1980s economic recessions. When studying the role of gold as a hedge and safe haven from the viewpoint of Chinese investors, Ming et al. (2020) discovered that gold is not a hedge against the Chinese stock market on average. On the other hand, they stated that gold operates as a safe haven when market returns are below their 1%, 5%, and 10% quantiles, as well as during the two crisis periods.

Baur and McDermott (2010) produced worldwide evidence that gold may operate as a hedge and a safe haven asset in major European stock markets and the United States but not in Australia, Canada, Japan, or significant developing markets such as those of the BRIC nations. Likewise, Iqbal (2017) demonstrated that gold does not serve as a hedge against the Pakistani and Indian stock markets. Similarly, Smiech and Papiez (2016) demonstrated that gold is a weak hedge against the US stock market by generalizing the Baur and Lucey (2010) model. According to Shahzad et al. (2019), gold is a poor safe refuge, but this behavior varies over time, and gold cannot protect investors' valuables during the COVID-19 spread

(Cheema et al. 2020). In addition, when researching the influence of the coronavirus on the Tunisian stock market, Jeribi and Snene-Manzli (2021) discovered that the yellow metal did not perform as a hedge or a safe haven for Tunisian investors during the outbreak.

On the other hand, cryptocurrency is another well-known safe-haven asset choice. As many analysts questioned gold's safe-haven capacity during the Global Financial Crisis period (Baur and Glover 2012; Bekiros et al. 2017; Klein 2017), Bitcoin was launched around that time as a remedy to the fragile global financial system. Despite its significant price volatility, the tradability of Bitcoin units on specific trading platforms has rendered it an investment asset (Polasik et al. 2015).

Interestingly, Bitcoin provides a safe haven against sovereign risk and the instability of the global financial system (Bouri et al. 2017b). Since Bitcoin is immune to economic and financial factors (Corbet et al. 2018), it is considered a significant diversifier (Bouri et al. 2017a, 2017b; Brière et al. 2015; Dyhrberg 2016b), particularly during financial market downturns (Bouri et al. 2017b). Ji et al. (2018) investigated the network structure that exists between Bitcoin and a variety of asset classes (including equities indices). They demonstrated that Bitcoin has a relatively weak association with equities, but the link is not consistent over time and is influenced by structural fractures. Guesmi et al. (2018) used a multivariate GARCH model to investigate the coupled dynamics of Bitcoin and various financial assets, and they suggest that Bitcoin might provide investors with diversification and hedging advantages.

According to Bouri et al. (2017b), Bitcoin can only be used as a powerful safe haven against weekly dramatic down moves in Asian stock markets. Bouri et al. (2018) employed copula-based models to discover that Bitcoin can operate as a safe haven against financial difficulties. Bouri et al. (2020) investigated the link between global economic policy uncertainty and the volatility of Bitcoin, commodities, stocks, and bonds, and their findings showed that Bitcoin might be used as a hedging strategy. Bouri and Gupta (2019) also verified the hedging efficiency of Bitcoin against economic uncertainty in a similar analysis. Bouri et al. (2020c) discovered that Bitcoin could operate as a hedge against equities market instability caused by trade policy uncertainty.

Furthermore, Corbet et al. (2020) stated that digital assets, such as precious metals during previous crises, acted as a safe haven during COVID-19. Kumar (2020) tested the safe-haven property of gold and Bitcoin during the COVID-19 outbreak and discovered that both assets acted as safe havens. Using the NARDL approach, Jeribi et al. (2021) investigated the safe-haven properties of five main cryptocurrencies during the COVID-19 epidemic, revealing that they only served as a safe haven for three developing markets throughout the crisis period. Moreover, Liu (2019) proved that the addition of Bitcoin resulted in significant portfolio profits.

Nonetheless, opinions on the function of Bitcoin are frequently drastically different. Bouri et al. (2017b) investigated whether Bitcoin may operate as a hedge and safe haven for key international stock indexes, bonds, oil, gold, the general commodities index, and the US dollar index using the dynamic conditional correlation model. According to their empirical findings, Bitcoin is a poor hedge and should only be used for diversification purposes. Klein et al. (2018) compared Bitcoin's characteristics to those of other asset classes, and their portfolio analysis shows that Bitcoin is not a safe-haven asset and cannot even hedge risk in developed markets. Al-Khazali et al. (2018) investigated the influence of macroeconomic news shocks on Bitcoin and gold prices. They verified gold's safe-haven status, whilst Bitcoin acted like a hazardous asset.

Choi and Shin (2022) examined the hedging ability of Bitcoin against inflation during the COVID-19 pandemic. Their results indicated that it acts as a hedge against inflation but not as a safe haven. Będowska-Sójka and Kliber (2021) indicated that both Bitcoin and Ethereum acted as weak safe havens against the stock market indices. According to Lahmiri and Bekiros (2020), cryptocurrency markets were more volatile and irregular during the worldwide COVID-19 pandemic. Similarly, Conlon and McGee (2020) discovered that Bitcoin could not be considered a safe haven or a hedge against the COVID-19 catastrophic decreasing market. Jeribi and Snene-Manzli (2021) argued that the cryptocurrency market became more volatile with the arrival of the COVID-19 epidemic; however, it did not serve as a safe haven for Tunisian investors but rather as a diversifier during the pandemic. Ghorbel et al. (2022) also revealed that cryptocurrency had a small role as a safe haven during the COVID-19 crisis.

From the foregoing, the safe-haven character is susceptible to market selection and conditions, underlining the need for more research on the spillover across the stock, cryptocurrency, and gold markets, particularly with the outbreak of the Russia–Ukraine war.

3. Methodology

Our study aims to determine the hedging and safe haven properties of gold and Bitcoin for G7 investors before, during the pandemic, and during the 2022 Ukraine crisis.

3.1. Diagonal VECH-GARCH (DVECH-GARCH) Model

The VECH GARCH model was proposed by Bollerslev et al. (1988). The model is given in Equations (1) and (2).

$$r_t = H_t^{1/2} \varepsilon_t, \tag{1}$$

$$vech(H_t) = c + A\, vech\left(r_{t-1} r'_{t-1}\right) + B\, vech(H_{t-1}), \tag{2}$$

where r_t is the N × 1 vector of returns at time t, for t = 1, 2, . . . ,T, H_t is the N × N conditional matrix of r_t, and ε_t is the multivariate white noise process with covariance identity matrix of order N. The *vech (.)* shows an operator clustering the lower triangular part of the matrix. c is an N × (N + 1)/2 vector of constants, and A and B are square N × (N + 1)/2 parameter matrices.

The VECH-GARCH model's equations are really flexible to evaluate symmetric responses of conditional covariances and variances to past cross-products of returns and square returns. Conditional covariances depend on both cross-products of returns and past conditional variances (de Almeida et al. 2015). Moreover, some researchers (Bollerslev and Wooldridge 1992; Chrétien and Ortega 2014; Gourieroux 1997; Hafner 2003; Hafner and Preminger 2009) established the model. For instance, Chrétien and Ortega (2014) applied the model for the stock returns with eight dimensions, and it showed the best performance compared with other traditional GARCH methods.

The diagonal VECH-GARCH (DVECH-GARCH) model is a version of the VECH-GARCH model, including restrictions for conditional covariance matrices. Bollerslev et al. (1988) suggested the model, and according to their assumptions, A and B matrices in Equation (2) are diagonal.

$$vech(H_t) = c^* + A^* o r_{t-1} r'_{t-1} + B^* o H_{t-1}. \tag{3}$$

In Equation (3), A^*, B^*, and c^* are N × N symmetric parameter matrices, and o denotes the Hadamard product. The conditional covariance matrix (H_t) will be positive definite if A^* and B^* are positive semi-definite and c^* is positive definite (Ding and Engle 2001).

We use the DVECH-GARCH model to obtain dynamic conditional variances of all variables, dynamic conditional covariances, and dynamic conditional correlations between Bitcoin, gold, and G7 stock indices in three different periods (before COVID-19, during the COVID-19, and during the Russia–Ukraine war).

3.2. Hedge Ratio

In this study, we show a long position (buying) of one dollar in the G7 indexes must be a hedged position (selling) of $\beta_{i,j,t}$ dollar in Bitcoin or gold with optimal hedge ratio and hedge effectiveness for our analysis period.

We calculate the optimal hedge ratio ($\beta^*_{i,j,t}$) using the ratio of dynamic conditional covariances between Bitcoin or gold and G7 stock indices and dynamic conditional variances of Bitcoin or gold in Equation (4) (Kroner and Sultan 1993).

$$\beta^*_{i,j,t} = \frac{h_{i,j,t}}{h_{i,i,t}}, \tag{4}$$

where i is the Bitcoin or gold, and j denotes G7 indices. $h_{i,j,t}$ is the conditional covariance between the returns of Bitcoin or gold and the returns of G7 stock indices; $h_{i,i,t}$ is the conditional variances of Bitcoin or gold.

3.3. Hedging Effectiveness (HE)

We calculate the optimal portfolio weights using Equations (5) and (6) (Kroner and Ng 1998).

$$W^*_{i,j,t} = \frac{h_{j,j,t} - h_{i,j,t}}{h_{i,i,t} - 2h_{j,j,t} + h_{j,j,t}}, \tag{5}$$

$$W^*_{i,j,t} = \begin{cases} 0, \text{if } W^*_{i,j,t} < 0 \\ W^*_{i,j,t}, \text{if } 0 \leq W^*_{i,j,t} \leq 1 \\ 1, \text{if } W^*_{i,j,t} > 1 \end{cases}, \tag{6}$$

where $W^*_{i,j,t}$ is the weight on the first asset (Bitcoin or gold) in a one-dollar portfolio of two assets (first asset and G7 stock index) at time t. Therefore, $1 - W^*_{i,j,t}$ shows the optimal portfolio holding of the G7 stock indices assets.

We eventually obtain hedging effectiveness (HE) using Equation (7) to evaluate the hedging strategy of Bitcoin or gold with G7 stock indices (Ku et al. 2007).

$$HE = \frac{Variance_{unhedged} - Variance_{hedged}}{Variance_{unhedged}}. \tag{7}$$

$Variance_{unhedged}$ and $Variance_{hedged}$ indicate the variance of the unhedged portfolio and the variance of the hedged portfolio, respectively. A higher HE denotes a greater portfolio risk reduction and a better hedging strategy.

4. Data and Results

Our study period ranges from 2 January 2016 to 5 January 2023, with a total of 1611 daily observations. Prices of Bitcoin, gold, and the G7 stock market indices, including the United States (S&P 500), France (CAC40), Germany (DAX40), the United Kingdom (FTSE 100), Italy (FTSE-MIB 30), Japan (Nikkei 225), and Canada (SP-TSX) are used. Data were collected from the database DataStream. All the price series were transformed into natural logarithms and defined by $r_{i,t} = \log\left(\frac{P_{i,t}}{P_{i,t-1}}\right)$, where $P_{i,t}$ reflects the asset i closing price at time t. Our study period is divided into three sub-periods: the pre-COVID-19 period (2 January 2016 to 31 December 2019), the COVID-19 period (2 January 2020 to 24 February 2022), and the Ukrainian war period (25 February 2022 to 5 January 2023).

Table 1 reports the Bitcoin, gold, and the G7 stock indices descriptive statistics during the three periods: the pre-COVID-19, during COVID-19, and the Russia–Ukraine war. Interestingly, the mean return of Bitcoin and Gold decreased during the Russian military actions with negative returns. Additionally, stock indices were significantly impacted by the war, reaching negative mean returns as SP500, FTSE-MIB, Nikkei, and SP-TSX, except for CAC40, DAX 30, and FTSE100 with significant positive returns. These are quite interesting since this return increase was joined with a slight decrease in the standard deviation. In fact, we found evidence for the decrease in Bitcoin standard deviation during the Russian military actions compared to before and during COVID-19. We also noted a slight decrease in the standard deviation of all G7 stock indices compared to the COVID-19 period.

Table 1. Descriptive statistics.

Variables	Descriptives	Period		
		Pre-COVID-19	During COVID-19	During Russia–Ukraine War
Bitcoin	Mean	0.0027	0.0030	−0.0037
	Median	0.0027	0.0028	−0.0002
	Maximum	0.2218	0.1937	0.1024
	Minimum	−0.2474	−0.4973	−0.2821
	Std. Dev.	0.0463	0.0485	0.0401
	Skewness	−0.0777	−1.9580	−1.8464
	Kurtosis	7.0432	23.7102	13.6797
	Jarque–Bera	700.5574	10,291.6800	1191.7990
Gold	Mean	0.0004	0.0004	−0.0002
	Median	0.0004	0.0011	−0.0001
	Maximum	0.0394	0.0430	0.0309
	Minimum	−0.0324	−0.0589	−0.0284
	Std. Dev.	0.0075	0.0103	0.0097
	Skewness	0.2594	−0.7645	0.0595
	Kurtosis	5.0364	7.1580	3.5585
	Jarque–Bera	188.9692	454.6780	3.0429
S&P500	Mean	0.0005	0.0005	−0.0005
	Median	0.0005	0.0013	−0.0015
	Maximum	0.0484	0.0897	0.0540
	Minimum	−0.0418	−0.1277	−0.0442
	Std. Dev.	0.0080	0.0160	0.0153
	Skewness	−0.6390	−1.0155	−0.0615
	Kurtosis	7.8328	18.3487	3.5200
	Jarque–Bera	1069.3360	5553.2350	2.6651
CAC40	Mean	0.0003	0.0002	0.0002
	Median	0.0004	0.0011	−0.0004
	Maximum	0.0406	0.0806	0.0688
	Minimum	−0.0838	−0.1310	−0.0509
	Std. Dev.	0.0095	0.0156	0.0140
	Skewness	−0.8525	−1.3654	0.3920
	Kurtosis	10.7762	16.4670	5.9162
	Jarque–Bera	2711.9660	4374.3020	85.1119
DAX30	Mean	0.0003	0.0002	0.0001
	Median	0.0007	0.0008	0.0005
	Maximum	0.0345	0.1041	0.0762
	Minimum	−0.0707	−0.1305	−0.0451
	Std. Dev.	0.0097	0.0157	0.0146
	Skewness	−0.5903	−1.0315	0.4801
	Kurtosis	6.9719	16.8962	6.0780
	Jarque–Bera	734.7256	4572.1840	97.0288
FTSE100	Mean	0.0002	0.0000	0.0003
	Median	0.0004	0.0006	0.0008
	Maximum	0.0352	0.0867	0.03844
	Minimum	−0.0352	−0.1151	−0.0354
	Std. Dev.	0.0080	0.0138	0.0100
	Skewness	−0.1409	−1.2332	−0.1421
	Kurtosis	5.3644	16.6258	5.1374
	Jarque–Bera	242.6107	4442.0700	43.3944

Table 1. *Cont.*

Variables	Descriptives	Period Pre-COVID-19	During COVID-19	During Russia–Ukraine War
FTSEMIB30	Mean	0.0001	0.0002	-8.05×10^{-6}
	Median	0.0007	0.0013	0.0006
	Maximum	0.0491	0.0855	0.0672
	Minimum	−0.1333	−0.1854	−0.0644
	Std. Dev.	0.0129	0.0171	0.0156
	Skewness	−1.1287	−2.8930	−0.2834
	Kurtosis	15.5474	33.2730	5.6318
	Jarque–Bera	6955.0070	22,006.7500	67.6462
Nikkei	Mean	0.0003	0.0002	-2.59×10^{-5}
	Median	0.0004	0.0003	0.0010
	Maximum	0.0691	0.0773	0.0386
	Minimum	−0.0825	−0.0627	−0.0305
	Std. Dev.	0.0115	0.0137	0.0122
	Skewness	−0.4538	0.1016	0.1036
	Kurtosis	10.5439	7.3376	3.5394
	Jarque–Bera	2470.5290	436.8313	3.1159
SP-TSX	Mean	0.0003	0.0004	−0.0003
	Median	0.0006	0.0013	0.0002
	Maximum	0.0290	0.1130	0.0329
	Minimum	−0.0249	−0.1318	−0.0315
	Std. Dev.	0.0059	0.0150	0.0104
	Skewness	−0.3594	−1.7967	−0.1019
	Kurtosis	5.3593	31.9811	3.4354
	Jarque–Bera	260.2983	19,756.9600	2.1572

The Skewness statistics exhibit negative values for almost stocks and Bitcoin during the COVID-19 pandemic except for Nikkei. Overall, the assumption of normality was decisively precluded for all returns series of almost all the stock markets. However, Russian military action showed that the marginal distributions are asymmetrical to the left for which the values are negative, except for the Nikkei, DAX30, CAC 40, and Gold with positive values suggesting marginal distributions asymmetrical to the right. We tested the heaviness of tails with Kurtosis statistics, and we remarkably noticed a decrease in these values during the war compared to the COVID-19 period. Furthermore, the Jarque–Bera statistics tended to reject the normality hypothesis for almost all series (except for Gold, SP500, Nikkei, and SP-TSX in war times) given their high significant values, especially during the COVID-19 pandemic. Our result is similar to Lorenzo and Arroyo (2022). They concluded that since the right tail of the distribution is fatter, the asset has more extreme positive return values on the right tail. The assumption of normality is definitely rejected for almost all return series according to the Jarque–Bera normality test.

Figure 1 presents the daily return movements of the studied assets. From this figure, comparative analysis concluded that the volatility of these stock exchanges plunged with time. Hence, it is clearly documented that the impact of the pandemic is deeper than the war on return and that it becomes normal as time passes which is a good sign for the financial market of G7 countries.

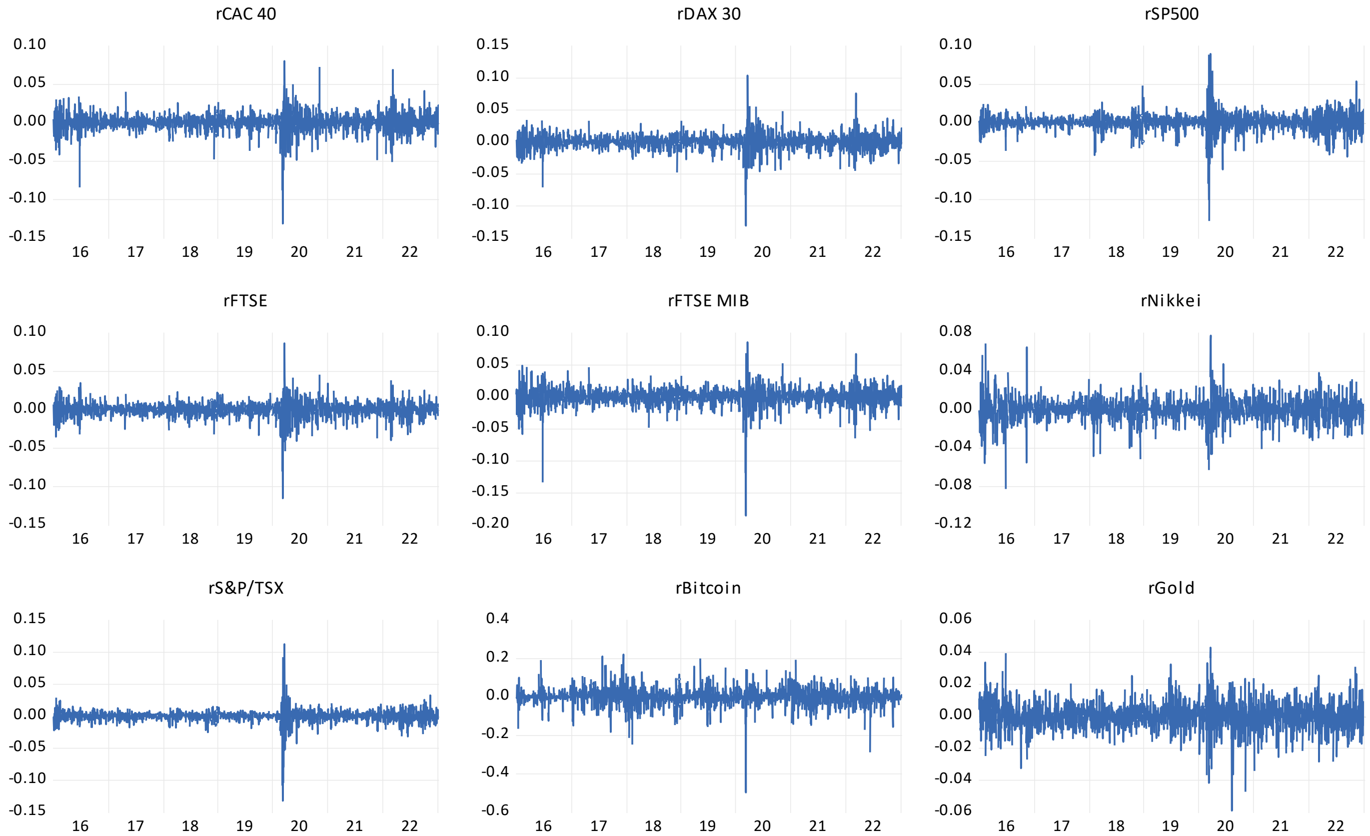

Figure 1. Daily return index dynamics regarding the entire period.

In Table 2, we analyzed the dependence structure between Bitcoin and G7 stock indices. We noticed that dependence significantly increased during the Russia–Ukraine war. It was even more important than during the pandemic COVID-19 pandemic. We also noticed that Bitcoin is more correlated with SP500 (40.17%) during the war and weakly correlated with Nikkei (1.6%) through Kendall's tau. This correlation is obtaining more scope (except for Nikkei) during military actions compared to the COVID-19 pandemic. Thus, Bitcoin could be a diversifier during stress or turmoil for investors during the Russia–Ukraine war and during COVID-19 and an effective hedge during stable periods except for DAX30, FTSE MIB, and SP-TSX, as shown by (Bouri et al. 2017a, 2017b; Brière et al. 2015; Dyhrberg 2016b; Guesmi et al. 2018), especially during dramatic down moves. Some studies (Conlon and McGee 2020; Feng et al. 2018; Ghorbel and Jeribi 2021a, 2021b, 2021c; Ghorbel et al. 2022; Jeribi et al. 2020; Jeribi and Snene-Manzli 2021; Kliber et al. 2019; Shahzad et al. 2019; Smales 2019) prove adversely.

Table 2. Static Correlations for a Bitcoin-G7 indices portfolio.

Indices	Period	Pearson's Rho	Spearman's Rho	Kendall's Tau
S&P 500	Pre-COVID-19	−0.0381	−0.0372	−0.0252
	During COVID-19	0.3703	0.2617	0.1757
	During Russia–Ukraine War	0.5586	0.5696	0.4017
CAC40	Pre-COVID-19	−0.0010	−0.0050	−0.0038
	During COVID-19	0.3250	0.1672	0.1126
	During Russia–Ukraine War	0.3685	0.3194	0.2225
DAX30	Pre-COVID-19	0.0052	0.0059	0.0035
	During COVID-19	0.3321	0.1615	0.1084
	During Russia–Ukraine War	0.3715	0.3124	0.2139

Table 2. *Cont.*

Indices	Period	Pearson's Rho	Spearman's Rho	Kendall's Tau
FTSE 100	Pre-COVID-19	−0.0252	−0.0170	−0.0122
	During COVID-19	0.3202	0.1440	0.0970
	During Russia–Ukraine War	0.3175	0.2568	0.1774
FTSEMIB30	Pre-COVID-19	−0.0074	0.0085	0.0053
	During COVID-19	0.3990	0.1588	0.1066
	During Russia–Ukraine War	0.3918	0.3545	0.2475
Nikkei	Pre-COVID-19	−0.0535	−0.0207	−0.0139
	During COVID-19	0.1222	0.0382	0.0263
	During Russia–Ukraine War	0.1275	0.0295	0.0160
SP-TSX	Pre-COVID-19	0.0355	0.0311	0.0206
	During COVID-19	0.4009	0.2387	0.1615
	During Russia–Ukraine War	0.5257	0.4842	0.3394

Note: Pearson correlation measures linear correlation. Kendall's Tau calculations are based on concordant and discordant pairs, and Spearman's rho calculations are based on deviations.

Similarly, in Table 3, we analyzed the dependence structure between Gold and G7 stock indices. We interestingly reported a clear increase in dependence, especially during the war, compared to the COVID-19 pandemic and the normal period (through Kendall's tau). In fact, the correlation coefficients were negatively close to zero before the spread of the coronavirus and turned out to be positive during the pandemic; they were also significantly higher during the war. We can conclude that Gold was an effective hedge before COVID-19 and a diversifier during the pandemic and the war. Thus, we can decrease one's losses by taking an offsetting position in gold during the pandemic only.

Table 3. Static Correlations for a Gold–G7 indices portfolio.

Indices	Period	Pearson's Rho	Spearman's Rho	Kendall's Tau
S&P 500	Pre-COVID-19	−0.1683	−0.1262	−0.0846
	During COVID-19	0.1457	0.0802	0.0548
	During Russia–Ukraine War	0.2631	0.2225	0.1537
CAC40	Pre-COVID-19	−0.2693	−0.1991	−0.1349
	During COVID-19	0.0834	0.0200	0.0141
	During Russia–Ukraine War	0.1195	0.1841	0.1303
DAX30	Pre-COVID-19	−0.2667	−0.2163	−0.1475
	During COVID-19	0.1327	0.0365	0.0262
	During Russia–Ukraine War	0.1188	0.1779	0.1236
FTSE 100	Pre-COVID-19	−0.1462	−0.1044	−0.0704
	During COVID-19	0.1059	0.0264	0.0177
	During Russia–Ukraine War	0.1113	0.1378	0.0978
FTSEMIB 30	Pre-COVID-19	−0.2382	−0.1778	−0.1208
	During COVID-19	0.0878	0.0174	0.0127
	During Russia–Ukraine War	0.1397	0.2018	0.1396
Nikkei	Pre-COVID-19	−0.1619	−0.1073	−0.0724
	During COVID-19	0.1083	0.0352	0.0237
	During Russia–Ukraine War	0.0306	0.0382	0.0240
SP-TSX	Pre-COVID-19	−0.0427	−0.0183	−0.0132
	During COVID-19	0.1902	0.1438	0.0990
	During Russia–Ukraine War	0.4356	0.4262	0.2937

Note: Pearson correlation measures linear correlation. Kendall's Tau calculations are based on concordant and discordant pairs, and Spearman's rho calculations are based on deviations.

Gold was a strong hedger before the crisis and a diversifier of the stress periods[4]. Our results corroborate previous studies concerning the COVID-19 pandemic as a stress period (Baur and Lucey 2010; Baur and McDermott 2010, 2016; Bouoiyour et al. 2019; Corbet et al. 2020; Ghorbel et al. 2022; Hood and Malik 2013; Jeribi et al. 2020, 2021; Jeribi and Snene-Manzli 2021; Reboredo 2013).

Next, we assessed the consequences of the time-varying dependence structure between Bitcoin, gold, and G7 stock indices in order to design an optimal portfolio and hedge risk during the two most critic mitigated periods (COVID-19 and the Russian military actions in Ukraine). Such analysis seems relevant and decisive to international investors as well as to the management of risks induced by cryptocurrency and stock indices price fluctuations. We analyzed the hedging strategy effectiveness for Bitcoin and gold with G7 stock market indices portfolios.

To do so, we reported the model results (β, W, and HE). In fact, the hedging strategy consists of finding how much a long position (buy) of one dollar in the G7 indices should be hedged by a short position (sell) of β dollar in Bitcoin or gold. For gold, the hedge ratio slightly varies over time and switches from negative to positive values except for SP-TSX and is always positive for Bitcoin, whatever the period or asset. Our results exhibit low values of hedging ratio for the pairs of Bitcoin–G7 stock indices, ranging from 0.62% to 2.26% before the COVID-19 pandemic. The highest positive hedging ratio was recorded for the pair of FTSE MIB and Bitcoin. A positive hedge ratio suggests that a short position in Bitcoin is needed to minimize the risk for G7 stock indices investors. During the war, the hedging ratios increased for all the pairs, recording a higher increase than during the pandemic and ranging from 0.46% to 5.29% (during the pandemic) and from 0.57% to 10.25% (during the war). Such results suggest that a short position in Bitcoin is needed to minimize the risk of a long position in each of the G7 stock indices. Thus, the investment risk of conventional financial assets can be hedged by taking short positions in the cryptocurrency market during turmoil. Our results join those of Popper (2015), Dyhrberg (2016a), and Bouri et al. (2017b), who found that Bitcoin can be a hedge and a diversifier, while Klein et al. (2018) proved that Bitcoin behaves the exact opposite of gold.

We also noted that the hedging ratio for the pairs of gold–G7 stock indices fluctuated from −20.42% to 1.57% before the COVID-19 pandemic. However, during the COVID-19 pandemic, the hedging ratios increased for all the pairs, recording higher positive values than before the pandemic and ranging from 0.89% to 15.08%. During the war, the hedging ratio fluctuated from −2% to 34.03%. This finding suggests that the G7 stock indices can be hedged by taking short positions in gold during different stress periods. Interestingly, during the war, the hedging ratios increased significantly and reached a maximum of 34%. Thus, the investment risk of conventional financial assets can be hedged by taking short positions in gold during extreme market conditions except for Nikkei and long positions in gold during stable periods except for SP-TSX. Our findings were, in part, confirmed by previous studies of Sherman (1986), McCown and Zimmerman (2006), Hillier et al. (2006), and Miyazaki and Hamori (2013), who found evidence that the correlations between gold and other financial assets were low or even negative and thus it is a hedge asset. We proved the results of Baur and Lucey (2010), who found that gold is a hedge against stocks on average and did not find evidence of its safe haven property in extreme stock market conditions.

Thus, the results show that gold has a strong hedging property, especially during military action, given that their hedge ratios are more important than before the COVID-19 pandemic. Remarkably, the higher variability in the hedge ratio for the G7 stock indices, especially in the three studied periods, suggests that investors should redress their positions more frequently to maintain a risk-minimizing position, which generally implies a higher cost of hedging.

Next, we tested the hedge effectiveness of Bitcoin and gold with G7 stock indices. The results regarding the hedging effectiveness (Table 4) show that hedging strategies involving Bitcoin and stocks' assets modestly reduce the portfolio risk. The hedging effectiveness was more important during the COVID-19 pandemic than during the war for all G7 stock indices. Interestingly, it increased during the pandemic and decreased during the war. Globally, as a hedge asset, Bitcoin allows us to reduce investment risk, especially during crisis periods.

Table 4. β, $W^{*}_{i,j,t}$, and HE for a Bitcoin-G7 indices portfolio.

Indices	Period	β	$W^{*}_{i,j,t}$	HE
S&P 500	Pre-COVID-19	0.0111	0.0343	0.0376
	During COVID-19	0.0529	0.0440	0.2908
	During Russia–Ukraine War	0.1025	0.0496	0.1322
CAC40	Pre-COVID-19	0.0173	0.0516	0.0754
	During COVID-19	0.0243	0.0734	0.1826
	During Russia–Ukraine War	0.0352	0.0762	0.0710
DAX30	Pre-COVID-19	0.0206	0.0506	0.0615
	During COVID-19	0.0292	0.0684	0.1195
	During Russia–Ukraine War	0.0414	0.0715	0.0665
FTSE 100	Pre-COVID-19	0.0143	0.0331	0.0533
	During COVID-19	0.0194	0.0526	0.1843
	During Russia–Ukraine War	0.0227	0.0365	0.0722
FTSEMIB 30	Pre-COVID-19	0.0226	0.0837	0.1475
	During COVID-19	0.0337	0.0788	0.2337
	During Russia–Ukraine War	0.0489	0.0872	0.1549
Nikkei	Pre-COVID-19	0.0062	0.0612	0.1415
	During COVID-19	0.0046	0.0616	0.1624
	During Russia–Ukraine War	0.0057	0.0529	0.0269
SP-TSX	Pre-COVID-19	0.0185	0.0131	0.0106
	During COVID-19	0.0369	0.0282	0.3302
	During Russia–Ukraine War	0.0523	0.0202	0.0325

Note: β indicates the number of dollars in Bitcoin or gold that should be invested through a short position (sell) to hedge a long position (buy) in the G7 indices. HE, hedging effectiveness, evaluates the hedging strategy of Bitcoin or gold with G7 stock indices. $W^{*}_{i,j,t}$ is the weight on the first asset (Bitcoin or gold) in a one-dollar portfolio of two assets (first asset and G7 stock index) at time t.

Finally, we analyzed the hedging effectiveness of gold for the G7 stock indices at Table 5. Gold can be considered a potential hedge asset during the Russia–Ukraine War for all G7 stock indices investors but is slightly less effective than during the COVID-19 period. We noted the hedging effectiveness of the pairs during turmoil. Gold was proved to be an effective hedge asset for investors in G7 stock indices during stress periods or turmoil.

Table 5. β, $W^{*}_{i,j,t}$, and HE for a Gold–G7 indices portfolio.

Indices	Period	β	$W^{*}_{i,j,t}$	HE
S&P 500	Pre-COVID-19	−0.0640	0.4698	0.6696
	During COVID-19	0.0965	0.5337	0.7129
	During Russia–Ukraine War	0.3019	0.7632	0.6426
CAC40	Pre-COVID-19	−0.1660	0.5734	0.7266
	During COVID-19	0.0089	0.5936	0.6974
	During Russia–Ukraine War	0.1178	0.6452	0.6237
DAX30	Pre-COVID-19	−0.1721	0.5983	0.7295
	During COVID-19	0.0536	0.6178	0.6822
	During Russia–Ukraine War	0.1319	0.6795	0.6529
FTSE 100	Pre-COVID-19	−0.0617	0.5040	0.6084
	During COVID-19	0.0441	0.5302	0.6187
	During Russia–Ukraine War	0.0833	0.4810	0.4749
FTSEMIB 30	Pre-COVID-19	−0.2042	0.6747	0.8048
	During COVID-19	0.0176	0.6489	0.7282
	During Russia–Ukraine War	0.1650	0.7252	0.6810
Nikkei	Pre-COVID-19	−0.1314	0.6011	0.7541
	During COVID-19	0.0326	0.5792	0.6044
	During Russia–Ukraine War	−0.0200	0.5272	0.5727
SP-TSX	Pre-COVID-19	0.0157	0.3605	0.4368
	During COVID-19	0.1508	0.4072	0.7047
	During Russia–Ukraine War	0.3403	0.5622	0.3699

Note: β indicates the number of dollars in Bitcoin or gold that should be invested through a short position (sell) to hedge a long position (buy) in the G7 indices. HE, hedging effectiveness, evaluates the hedging strategy of Bitcoin or gold with G7 stock indices. $W^{*}_{i,j,t}$ is the weight on the first asset (Bitcoin or gold) in a one-dollar portfolio of two assets (first asset and G7 stock index) at time t.

To sum up, concerning the hedging effectiveness, the results show that Bitcoin and gold are effective hedges during turmoil (pandemic and war). Specifically, gold is a more effective hedge than Bitcoin during stress. This result arises from the larger ability of gold to lessen the risk compared to Bitcoin. This finding is somewhat related to previous studies showing that gold plays a crucial role in financial markets with flight-to-quality in times of market distress since it is widely regarded as a safe haven asset (Narayan et al. 2010; Klein et al. 2018, and Junttila et al. 2018).

Based on the DVECH-GARCH modeling procedure, we were able to estimate the dynamic conditional correlations (see details at Appendix A) between G7 stock markets and financial assets (Bitcoin and gold) during three different periods (before COVID-19, during the COVID-19, and during the Russia–Ukraine war). Using the Baur and Lucey (2010) method, we found that Bitcoin cannot be considered a safe-haven asset neither during the COVID-19 nor during the Ukraine–Russia crisis for G7 investors. However, gold acted as a strong hedging instrument during the two crisis periods. Our results align with those of Shahzad et al. (2019), Cheema et al. (2020), Conlon and McGee (2020), Ghorbel and Jeribi (2021b), Jeribi and Snene-Manzli (2021), and Ghorbel et al. (2022) who discovered a weak safe-haven role for cryptocurrencies during the pandemic and argued that gold is considered the best safe-haven asset during crisis.

5. Conclusions

The present paper investigated the nonlinear relationship between Bitcoin, gold, and conventional financial assets (G7 stock indices) and consequently provides insights into the economic and financial benefits of digital assets and gold for financial investors, especially during turmoil.

Using the corrected DVECH-GARCH model and time-varying optimal hedge ratios and hedge effectiveness, the authors assessed the capabilities of Bitcoin and gold to generate benefits from portfolio diversification as well as hedging strategies. Our research strived to advance the knowledge of the current issue in three different ways. Firstly, the current analysis provides practical implications during stable and stressful periods (COVID-19 and the Russia–Ukraine War). Second, pertinent pragmatic discernments are driven due to the use of the novel dynamic technique, which is different from earlier research. Third, the DVECH-GARCH model is more flexible and provides reliable results. Finally, our empirical approach overcomes the linearity drawback of the dependency structure through the asset components of the portfolio, which is addressed by the DVECH-GARCH model that allows us to calculate a dynamic correlation coefficient based on nonlinear data pulled from the calculation of Kendall's tau. We thus strived to reveal the volatility spillover between the indicators.

Interestingly, we proved that the hedge ratios are time-varying, which implies that investors have to regularly monitor and adjust their hedged positions. Notably, the hedge effectiveness of gold is superior to that of Bitcoin for all G7 stock indices. Such a result arises from the larger ability of gold to lessen the risk during turmoil. We also demonstrated that Bitcoin is rather a diversifier during stress or turmoil for investors and an effective hedge during stable periods except for DAX30, FTSE MIB, and SP-TSX. Gold was an effective hedge before the COVID-19 pandemic and a diversifier during the pandemic and war.

In fact, the investment risk of conventional financial assets can be hedged by taking short positions in the cryptocurrency market and gold during turmoil, except for Nikkei.

We also noted that gold has a stronger hedging property compared to Bitcoin. Remarkably, the higher variability in the hedge ratio for the G7 stock indices, especially in the three studied periods, suggests that investors should change their positions more frequently to maintain a risk-minimizing position, which generally implies a higher cost of hedging.

The above outcomes help international investors and portfolio managers to make their investments in G7 stock indices more stable by taking hedging positions in Bitcoin or gold. Particularly, this would help them protect against the high risk inherent to stress periods, such as the COVID-19 pandemic and the Russia–Ukraine war. Short positions in Bitcoin and gold are required during the COVID-19 pandemic and the war. This could help investors and portfolio managers to make G7 stock indices investments more appealing. The results indicate that these countries' authorities need to be cautious and should focus on those strategies which help them to combat the effect of external shock on their stock market. Notwithstanding the encouraging consequences, this experiential research unquestionably grieves from some explicit precincts. In the beginning, our study made insinuations of the above conclusions based on an investigation of seven stock markets. A supplementary inclusive examination can be carried out by comprising a greater number of countries concurrently. Furthermore, the dynamics of correlations between Bitcoin/gold and G7 stock indices may change when lower frequency data are used. This would help long-term investors refine their decisions. Additionally, wavelet-based models would help account for the heterogeneity of investors regarding their investment horizons.

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Appendix A

Table A1. D-VECH model results (Bitcoin-G7 indices).

Covariance specification: Diagonal VECH
GARCH = C + A1 × RESID(−1) × RESID(−1)′ + B1 × GARCH(−1)

		Transformed Variance Coefficients		
	Coefficient	Std. Error	z-Statistic	Prob.
C(1,1)	0.0002	1.64×10^{-5}	9.3843	0.0000
C(1,2)	1.13×10^{-5}	5.67×10^{-6}	2.0025	0.0452
C(1,3)	1.06×10^{-5}	5.07×10^{-6}	2.0916	0.0365
C(1,4)	3.72×10^{-6}	1.58×10^{-6}	2.3625	0.0182
C(1,5)	8.38×10^{-6}	5.43×10^{-6}	1.5435	0.1227
C(1,6)	8.42×10^{-6}	4.34×10^{-6}	1.9405	0.0523
C(1,7)	6.16×10^{-6}	1.44×10^{-5}	0.4264	0.6698
C(1,8)	6.37×10^{-6}	2.33×10^{-6}	2.7311	0.0063
C(2,2)	9.75×10^{-6}	5.68×10^{-7}	17.1547	0.0000
C(2,3)	9.24×10^{-6}	3.19×10^{-7}	28.9931	0.0000
C(2,4)	5.35×10^{-6}	5.71×10^{-7}	9.3740	0.0000
C(2,5)	6.92×10^{-6}	4.78×10^{-7}	14.4862	0.0000
C(2,6)	9.90×10^{-6}	6.95×10^{-7}	14.2314	0.0000
C(2,7)	4.53×10^{-6}	1.32×10^{-6}	3.4413	0.0006
C(2,8)	4.29×10^{-6}	5.08×10^{-7}	8.4418	0.0000
C(3,3)	1.03×10^{-5}	1.50×10^{-7}	68.7691	0.0000
C(3,4)	5.44×10^{-6}	5.82×10^{-7}	9.3524	0.0000
C(3,5)	6.24×10^{-6}	4.26×10^{-7}	14.6616	0.0000
C(3,6)	9.94×10^{-6}	5.61×10^{-7}	17.7344	0.0000
C(3,7)	4.30×10^{-6}	1.28×10^{-6}	3.3532	0.0008
C(3,8)	4.14×10^{-6}	5.06×10^{-7}	8.1952	0.0000
C(4,4)	5.30×10^{-6}	5.51×10^{-7}	9.6172	0.0000
C(4,5)	4.05×10^{-6}	5.15×10^{-7}	7.8739	0.0000
C(4,6)	6.08×10^{-6}	7.81×10^{-7}	7.7828	0.0000
C(4,7)	2.44×10^{-6}	1.03×10^{-6}	2.3765	0.0175
C(4,8)	3.09×10^{-6}	3.56×10^{-7}	8.6831	0.0000

Table A1. *Cont.*

Covariance specification: Diagonal VECH				
GARCH = C + A1 × RESID(−1) × RESID(−1)′ + B1 × GARCH(−1)				
		Transformed Variance Coefficients		
	Coefficient	Std. Error	z-Statistic	Prob.
C(5,5)	7.60×10^{-6}	7.52×10^{-7}	10.1075	0.0000
C(5,6)	6.47×10^{-6}	5.86×10^{-7}	11.0431	0.0000
C(5,7)	3.76×10^{-6}	1.31×10^{-6}	2.8668	0.0041
C(5,8)	3.26×10^{-6}	4.28×10^{-7}	7.6276	0.0000
C(6,6)	1.33×10^{-5}	1.19×10^{-6}	11.1172	0.0000
C(6,7)	4.33×10^{-6}	1.37×10^{-6}	3.1525	0.0016
C(6,8)	4.84×10^{-6}	6.60×10^{-7}	7.3334	0.0000
C(7,7)	1.30×10^{-5}	1.83×10^{-6}	7.0877	0.0000
C(7,8)	2.86×10^{-6}	1.16×10^{-6}	2.4695	0.0135
C(8,8)	3.58×10^{-6}	4.90×10^{-7}	7.3086	0.0000
A1(1,1)	0.1673	0.0177	9.4333	0.0000
A1(1,2)	0.0768	0.0216	3.5642	0.0004
A1(1,3)	0.0651	0.0213	3.0608	0.0022
A1(1,4)	0.0783	0.0194	4.0459	0.0001
A1(1,5)	0.0514	0.0236	2.1793	0.0293
A1(1,6)	0.0530	0.0221	2.3965	0.0166
A1(1,7)	0.0198	0.0518	0.3830	0.7017
A1(1,8)	0.0730	0.0221	3.3000	0.0010
A1(2,2)	0.1816	0.0122	14.8709	0.0000
A1(2,3)	0.1580	0.0104	15.1995	0.0000
A1(2,4)	0.1712	0.0135	12.6501	0.0000
A1(2,5)	0.1635	0.0116	14.1222	0.0000
A1(2,6)	0.1625	0.0111	14.6545	0.0000
A1(2,7)	0.0893	0.0216	4.1275	0.0000
A1(2,8)	0.1699	0.0136	12.5238	0.0000
A1(3,3)	0.1411	0.0106	13.3482	0.0000
A1(3,4)	0.1497	0.0126	11.8470	0.0000
A1(3,5)	0.1344	0.0103	13.0799	0.0000
A1(3,6)	0.1463	0.0104	14.0216	0.0000
A1(3,7)	0.0852	0.0204	4.1879	0.0000
A1(3,8)	0.1484	0.0126	11.7470	0.0000
A1(4,4)	0.2472	0.0215	11.4902	0.0000
A1(4,5)	0.1477	0.0141	10.4550	0.0000
A1(4,6)	0.1572	0.0147	10.6687	0.0000
A1(4,7)	0.0805	0.0277	2.9061	0.0037
A1(4,8)	0.2182	0.0186	11.7094	0.0000
A1(5,5)	0.1594	0.0144	11.0501	0.0000
A1(5,6)	0.1379	0.0113	12.2322	0.0000
A1(5,7)	0.0789	0.0241	3.2788	0.0010
A1(5,8)	0.1600	0.0145	11.0421	0.0000
A1(6,6)	0.1635	0.0122	13.4494	0.0000
A1(6,7)	0.0892	0.0212	4.2090	0.0000
A1(6,8)	0.1525	0.0133	11.4414	0.0000
A1(7,7)	0.2519	0.0274	9.1856	0.0000
A1(7,8)	0.0851	0.0275	3.0969	0.0020
A1(8,8)	0.2299	0.0214	10.7601	0.0000
B1(1,1)	0.7888	0.0169	46.6692	0.0000
B1(1,2)	0.6066	0.1231	4.9297	0.0000
B1(1,3)	0.6888	0.1034	6.6610	0.0000
B1(1,4)	0.8452	0.0345	24.5295	0.0000
B1(1,5)	0.6579	0.1817	3.6203	0.0003
B1(1,6)	0.7684	0.0849	9.0545	0.0000
B1(1,7)	0.3689	1.3507	0.2731	0.7848
B1(1,8)	0.7841	0.0584	13.4368	0.0000
B1(2,2)	0.7858	0.0093	84.7881	0.0000

Table A1. *Cont.*

Covariance specification: Diagonal VECH				
GARCH = C + A1 × RESID(−1) × RESID(−1)′ + B1 × GARCH(−1)				
		Transformed Variance Coefficients		
	Coefficient	Std. Error	z-Statistic	Prob.
B1(2,3)	0.7968	0.0073	108.6502	0.0000
B1(2,4)	0.7593	0.0166	45.7590	0.0000
B1(2,5)	0.7855	0.0104	75.2647	0.0000
B1(2,6)	0.7936	0.0096	82.9526	0.0000
B1(2,7)	0.6811	0.0742	9.1751	0.0000
B1(2,8)	0.7618	0.0172	44.3395	0.0000
B1(3,3)	0.8073	0.0074	109.0195	0.0000
B1(3,4)	0.7747	0.0163	47.4583	0.0000
B1(3,5)	0.8082	0.0097	83.4686	0.0000
B1(3,6)	0.8017	0.0083	96.2105	0.0000
B1(3,7)	0.6944	0.0692	10.0282	0.0000
B1(3,8)	0.7766	0.0175	44.4442	0.0000
B1(4,4)	0.7502	0.0167	44.9456	0.0000
B1(4,5)	0.7639	0.0201	37.9954	0.0000
B1(4,6)	0.7613	0.0213	35.8015	0.0000
B1(4,7)	0.6765	0.1000	6.7675	0.0000
B1(4,8)	0.7580	0.0164	46.0973	0.0000
B1(5,5)	0.7841	0.0149	52.4669	0.0000
B1(5,6)	0.8057	0.0117	68.7610	0.0000
B1(5,7)	0.6727	0.0920	7.3081	0.0000
B1(5,8)	0.7667	0.0180	42.5071	0.0000
B1(6,6)	0.7925	0.0107	73.8906	0.0000
B1(6,7)	0.7138	0.0655	10.8950	0.0000
B1(6,8)	0.7690	0.0196	39.2040	0.0000
B1(7,7)	0.6650	0.0303	21.9254	0.0000
B1(7,8)	0.5979	0.1309	4.5694	0.0000
B1(8,8)	0.7535	0.0187	40.3032	0.0000

Note: (1): Gold, (2): CAC40, (3): DAX30, (4): SP500, (5): FTSE, (6): FTSEMIB, (7): NIKKEI, and (8): TSX. We only reported the variance equations part. If the researchers demand all results, we can share them.

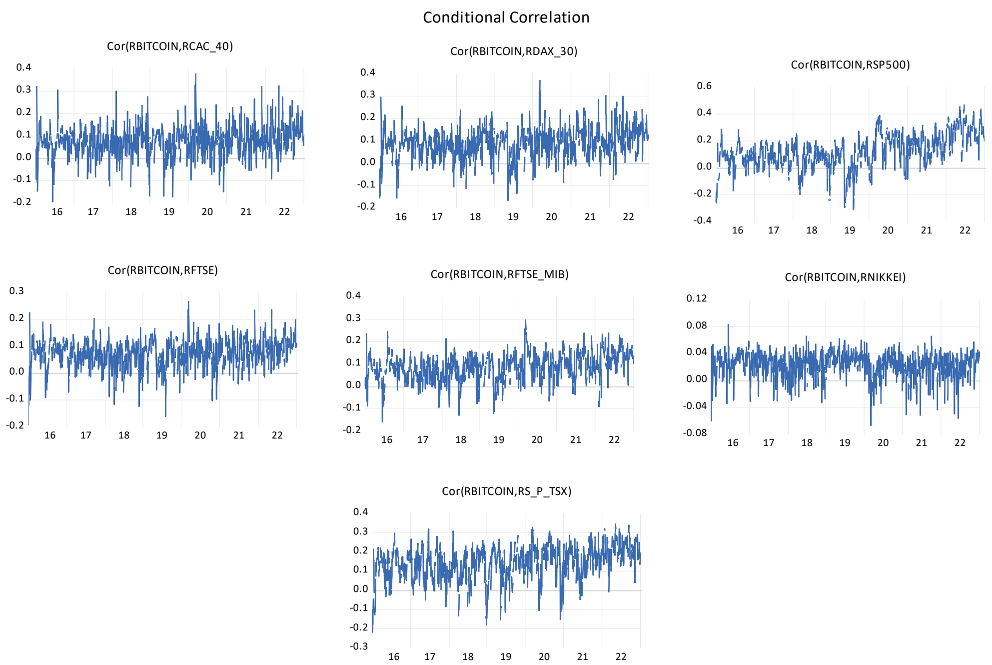

Figure A1. Dynamic conditional correlation evolution between Bitcoin and each of the G7 stock market indices.

Table A2. D-VECH model results (GOLD-G7 indices).

Covariance specification: Diagonal VECH
GARCH = C + A1 × RESID(−1) × RESID(−1)′ + B1 × GARCH(−1)

	Transformed Variance Coefficients			
	Coefficient	Std. Error	z-Statistic	Prob.
C(1,1)	1.42×10^{-6}	3.26×10^{-7}	4.3426	0.0000
C(1,2)	1.38×10^{-7}	1.78×10^{-7}	0.7740	0.4389
C(1,3)	5.77×10^{-8}	1.64×10^{-7}	0.3510	0.7256
C(1,4)	1.45×10^{-7}	1.29×10^{-7}	1.1239	0.2610
C(1,5)	3.81×10^{-8}	1.44×10^{-7}	0.2637	0.7920
C(1,6)	1.50×10^{-7}	1.96×10^{-7}	0.7695	0.4416
C(1,7)	1.43×10^{-7}	1.58×10^{-7}	0.9044	0.3658
C(1,8)	2.77×10^{-7}	1.10×10^{-7}	2.5245	0.0116
C(2,2)	7.17×10^{-6}	3.19×10^{-7}	22.4768	0.0000
C(2,3)	6.30×10^{-6}	3.25×10^{-7}	19.3919	0.0000
C(2,4)	2.82×10^{-6}	1.78×10^{-7}	15.8706	0.0000
C(2,5)	5.00×10^{-6}	2.37×10^{-7}	21.1195	0.0000
C(2,6)	7.01×10^{-6}	3.90×10^{-7}	17.9937	0.0000
C(2,7)	2.41×10^{-6}	2.55×10^{-7}	9.4738	0.0000
C(2,8)	2.60×10^{-6}	1.59×10^{-7}	16.3154	0.0000
C(3,3)	6.29×10^{-6}	3.90×10^{-7}	16.1159	0.0000
C(3,4)	2.63×10^{-6}	1.87×10^{-7}	14.1152	0.0000
C(3,5)	4.46×10^{-6}	2.58×10^{-7}	17.3072	0.0000
C(3,6)	6.45×10^{-6}	4.13×10^{-7}	15.6071	0.0000
C(3,7)	2.20×10^{-6}	2.59×10^{-7}	8.5009	0.0000
C(3,8)	2.37×10^{-6}	1.62×10^{-7}	14.6537	0.0000
C(4,4)	3.25×10^{-6}	2.06×10^{-7}	15.8234	0.0000
C(4,5)	2.36×10^{-6}	1.69×10^{-7}	13.9304	0.0000
C(4,6)	2.88×10^{-6}	2.28×10^{-7}	12.6097	0.0000
C(4,7)	1.45×10^{-6}	2.01×10^{-7}	7.2044	0.0000
C(4,8)	1.97×10^{-6}	1.29×10^{-7}	15.2092	0.0000
C(5,5)	5.36×10^{-6}	3.11×10^{-7}	17.2332	0.0000
C(5,6)	4.97×10^{-6}	3.02×10^{-7}	16.4371	0.0000
C(5,7)	1.92×10^{-6}	2.16×10^{-7}	8.8654	0.0000
C(5,8)	2.18×10^{-6}	1.50×10^{-7}	14.5525	0.0000
C(6,6)	8.92×10^{-6}	6.34×10^{-7}	14.0687	0.0000
C(6,7)	2.33×10^{-6}	3.13×10^{-7}	7.4589	0.0000
C(6,8)	2.69×10^{-6}	2.06×10^{-7}	13.0605	0.0000
C(7,7)	7.26×10^{-6}	6.88×10^{-7}	10.5584	0.0000
C(7,8)	1.18×10^{-6}	1.54×10^{-7}	7.6740	0.0000
C(8,8)	2.14×10^{-6}	1.50×10^{-7}	14.2812	0.0000
A1(1,1)	0.0448	0.0050	8.9266	0.0000
A1(1,2)	0.0902	0.0061	14.8814	0.0000
A1(1,3)	0.0784	0.0057	13.8914	0.0000
A1(1,4)	0.0975	0.0074	13.1735	0.0000
A1(1,5)	0.0814	0.0062	13.1340	0.0000
A1(1,6)	0.0825	0.0058	14.1276	0.0000
A1(1,7)	0.0819	0.0070	11.7103	0.0000
A1(1,8)	0.0966	0.0069	13.8997	0.0000
A1(2,2)	0.1817	0.0071	25.5267	0.0000
A1(2,3)	0.1580	0.0062	25.6121	0.0000
A1(2,4)	0.1963	0.0068	28.8162	0.0000
A1(2,5)	0.1640	0.0068	24.2592	0.0000
A1(2,6)	0.1661	0.0061	27.1445	0.0000
A1(2,7)	0.1650	0.0073	22.5519	0.0000
A1(2,8)	0.1945	0.0069	28.2070	0.0000
A1(3,3)	0.1374	0.0061	22.4792	0.0000
A1(3,4)	0.1707	0.0062	27.7446	0.0000
A1(3,5)	0.1426	0.0060	23.5920	0.0000

Table A2. *Cont.*

Covariance specification: Diagonal VECH
GARCH = C + A1 × RESID(−1) × RESID(−1)′ + B1 × GARCH(−1)

	Transformed Variance Coefficients			
	Coefficient	Std. Error	z-Statistic	Prob.
A1(3,6)	0.1444	0.0057	25.2061	0.0000
A1(3,7)	0.1435	0.0066	21.8106	0.0000
A1(3,8)	0.1691	0.0063	26.9917	0.0000
A1(4,4)	0.2121	0.0095	22.4028	0.0000
A1(4,5)	0.1772	0.0065	27.1272	0.0000
A1(4,6)	0.1795	0.0064	27.9984	0.0000
A1(4,7)	0.1783	0.0089	19.9917	0.0000
A1(4,8)	0.2101	0.0082	25.5651	0.0000
A1(5,5)	0.1481	0.0076	19.5028	0.0000
A1(5,6)	0.1500	0.0061	24.7480	0.0000
A1(5,7)	0.1490	0.0076	19.7058	0.0000
A1(5,8)	0.1756	0.0066	26.6188	0.0000
A1(6,6)	0.1519	0.0064	23.7560	0.0000
A1(6,7)	0.1509	0.0066	22.9162	0.0000
A1(6,8)	0.1778	0.0062	28.5054	0.0000
A1(7,7)	0.1499	0.0108	13.8856	0.0000
A1(7,8)	0.1767	0.0086	20.5936	0.0000
A1(8,8)	0.2082	0.0089	23.3227	0.0000
B1(1,1)	0.9365	0.0078	119.4844	0.0000
B1(1,2)	0.8512	0.0088	97.3101	0.0000
B1(1,3)	0.8769	0.0089	98.7774	0.0000
B1(1,4)	0.8513	0.0106	80.6946	0.0000
B1(1,5)	0.8613	0.0102	84.5252	0.0000
B1(1,6)	0.8696	0.0096	90.2320	0.0000
B1(1,7)	0.8625	0.0143	60.1847	0.0000
B1(1,8)	0.8496	0.0106	80.1649	0.0000
B1(2,2)	0.7735	0.0055	140.3956	0.0000
B1(2,3)	0.7969	0.0052	154.5904	0.0000
B1(2,4)	0.7737	0.0051	151.8311	0.0000
B1(2,5)	0.7828	0.0056	141.0820	0.0000
B1(2,6)	0.7903	0.0054	145.3758	0.0000
B1(2,7)	0.7839	0.0078	100.9599	0.0000
B1(2,8)	0.7721	0.0052	147.2636	0.0000
B1(3,3)	0.8210	0.0056	146.0587	0.0000
B1(3,4)	0.7971	0.0052	153.1472	0.0000
B1(3,5)	0.8064	0.0055	146.1735	0.0000
B1(3,6)	0.8142	0.0056	146.6485	0.0000
B1(3,7)	0.8076	0.0082	97.9905	0.0000
B1(3,8)	0.7955	0.0052	153.5707	0.0000
B1(4,4)	0.7738	0.0069	112.5035	0.0000
B1(4,5)	0.7829	0.0056	140.7238	0.0000
B1(4,6)	0.7905	0.0059	133.1670	0.0000
B1(4,7)	0.7840	0.0091	86.1304	0.0000
B1(4,8)	0.7722	0.0061	125.8899	0.0000
B1(5,5)	0.7921	0.0073	109.0117	0.0000
B1(5,6)	0.7997	0.0058	137.2994	0.0000
B1(5,7)	0.7932	0.0084	94.3148	0.0000
B1(5,8)	0.7813	0.0057	136.7357	0.0000
B1(6,6)	0.8075	0.0067	120.0668	0.0000
B1(6,7)	0.8009	0.0085	94.1766	0.0000
B1(6,8)	0.7889	0.0056	140.0178	0.0000
B1(7,7)	0.7943	0.0115	68.9509	0.0000
B1(7,8)	0.7824	0.0084	93.0574	0.0000
B1(8,8)	0.7707	0.0069	112.3783	0.0000

Note: (1): Gold, (2): CAC40, (3): DAX30, (4): SP500, (5): FTSE, (6): FTSEMIB, (7): NIKKEI, and (8): TSX. We only reported the variance equations part. If the researchers demand all results, we can share them.

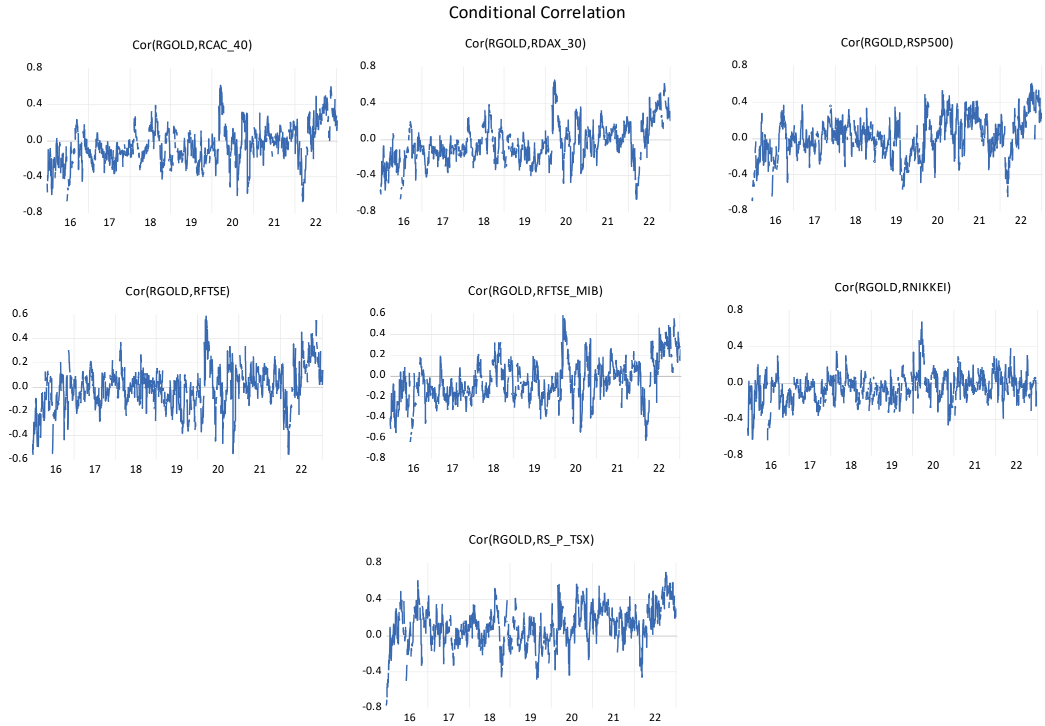

Figure A2. Dynamic conditional correlation evolution between Gold and each of the G7 stock market indices.

Notes

[1] Bitcoin is a strong hedge for most of the developing markets but only an effective diversifier for the developed markets.

[2] Only for Canada.

[3] Bitcoin, Ripple, and Stellar are safe havens for all US equity indices.

[4] An asset might be suitable for investment from a risk perspective. If the asset is negatively correlated with another asset, putting them together decreases risk significantly. In line with Baur and Lucey (2010) we differentiate between a diversifier, hedge, and safe haven. A diversifier is an asset that has a weak positive correlation with another asset on average. A weak (strong) hedge is an asset that is uncorrelated (negatively correlated) with another asset on average. A weak (strong) safe haven is an asset that is uncorrelated (negatively correlated) with another asset on average during times of stress, Bouri et al. (2017b).

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