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ul. Powstańców Wielkopolskich 16, 61-895 Poznań, Poland
phone +48 61 854 31 54, +48 61 854 31 55
www.wydawnictwo.ue.poznan.pl, e-mail: wydawnictwo@ue.poznan.pl
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Are cryptocurrencies safe havens during the COVID-19 pandemic? A threshold regression perspective with pandemic-related benchmarks[1]

***Teodora Cristina Barbu*[2], *Iustina Alina Boitan*[3], *Cosmin-Octavian Cepoi*[4]**

Abstract: The paper employs a threshold regression framework conditioned by two COVID-19 related proxies, to investigate whether Bitcoin and Ether exhibit short-term safe haven or diversifier features for stock and bond markets. Both cryptocurrencies fulfil a diversifier role for the responsible investments represented by sustainable stock market indices, a safe haven role for major bond markets and a mixed role for a selection of representative stock market indices. Furthermore, in times characterized by an increasing number of COVID-19 daily cases or deaths the statistical relationship between both cryptocurrencies and the main financial market determinants weakens.

Keywords: Bitcoin, Ether, COVID-19, stock market index, sustainable indices, bond yield, threshold regression.

JEL codes: G11, G13, G14, G15, G17.

Introduction

The severe global health crisis which emerged in February 2020 has triggered unprecedented economic, social and financial distress. Against this background the emergence of a strand of literature can be noticed related to practitioners' and academia's increased interest on checking cryptocurrencies' properties of

[1] Article received: 25 May 2021, accepted 25 June 2022.

[2] Faculty of Finance and Banking, Bucharest University of Economic Studies, Romania, Clădirea Mihail Moxa, Strada Mihail Moxa 5-7, București 010961, Romania, teodora.barbu@fin.ase.ro, ORCID: https://orcid.org/0000-0003-0064-962X.

[3] Faculty of Finance and Banking, Bucharest University of Economic Studies, Clădirea Mihail Moxa, Strada Mihail Moxa 5-7, București 010961, Romania, corresponding author: iustina.boitan@fin.ase.ro, ORCID: https://orcid.org/0000-0001-6510-5063.

[4] "Victor Slăvescu" Centre for Financial and Monetary Research, Academia Română, Corp B, Calea 13 Septembrie 13, București 050731, Romania, cosmin.cepoi@fin.ase.ro, ORCID: https://orcid.org/0000-0002-5529-4339.

acting as a safe haven, hedge or diversifier of assets in this turbulent, uncertain time and where their findings are mixed, even contradictory.

The role of safe haven assets in portfolio protection is widely agreed being used by investors especially in times of market instability or turmoil to limit their exposures. Although safe havens are primarily used by investors to protect the value of their portfolio traders may too take advantage of them. By identifying which assets are likely to appreciate while others decline traders could adopt a forward-looking behaviour by forecasting potential price movements and substantiate further trading strategies. On a longer horizon a one-size-fits-all approach should not be adopted as a safe haven may prove efficient for a particular financial or economic downturn but may not exhibit the same results in another distress event. Traditionally there are a few safe havens that kept their top position in investors' and traders' preferences over the years including: gold, government bonds and defensive stocks (Baur & Lucey, 2010; Coudert & Raymond, 2010; Ciner, Gurdgiev, & Lucey, 2013; Hood & Malik, 2013; Huang & Chang, 2021; Choudhury, Kinateder, & Neupane, 2022). However, the preference for safe havens can change over time so it is important to keep up with investment trends.

Similarly as with previous studies this paper follows the definition proposed by Baur and Lucey (2010), Bouri, Molnar, Azzi, Roubaud and Hagfors (2017), Smales (2019): an asset is a weak (strong) hedge if it is uncorrelated (negatively correlated) with another asset on average; an asset is a weak (strong) safe haven if it is uncorrelated (negatively correlated) with another asset during distress times.

The paper contributes to existing literature in several novel ways. A brief description of the premises of the paper is given by highlighting in parallel the ways in which the paper is different from previous research. First the paper's aim is to examine the safe heaven, hedge or diversifier features of the most representative cryptocurrencies at global level (Bitcoin and Ether) in the context of the COVID-19 pandemic. A comprehensive coverage between February–December 2020 is used. Compared with other studies analyzing only data related to the pandemic onset, here a longer timeframe is proposed to cover the various stages of the pandemic and their subsequent impact on major cryptocurrencies' returns. Second a threshold regression framework is employed to capture the sudden breaks occurring in cryptocurrencies' returns conditioned by changes in the level of COVID-19 related variables. This method was seldom used so far in this field of research the choice being substantiated by the more granular perspective it provides. Third to account for pandemic effects two proxy variables are employed, namely the worldwide daily new cases and the worldwide daily deaths. Both variables bring negative information related to the severity of the pandemic but the latter is more impactful from an emotional standpoint. Empirical findings show which of them determines most changes in investors' financial behaviour patterns. Fourth a broad sample of

stock market indices and bonds covering all geographic regions (Europe, US, Asia) is used to account for changes in investors' preference for holding a specific type of financial asset during a period of high distress. Another new feature of the dataset addressed by existing literature to an insignificant extent is in employing not only classical stock market indices but also several sustainable indices traded on regulated markets to take into account the preferences of environmentally and socially responsible investors as a specific segment of investors.

The paper is structured as follows: Section 1 reviews recent research related to cryptocurrencies' roles within the financial market and in competition with other financial or real assets, Section 2 describes the data and methodology employed, Section 3 presents the results obtained and the last one concludes.

1. Literature review

A strand of literature recently emerged and insufficiently explored, sometimes providing contradictory results, attempts to answer the question of whether cryptocurrencies may be used as a safe haven, hedge or diversifier asset. One can discriminate between studies published in the pre-pandemic period and studies performed after the COVID-19 outbreak.

For example Kliber, Marszałek, Musiałkowska and Świerczyńska (2019) focus on whether the Bitcoin may act as a safe haven, hedge or diversifier tool in correlation with countries' economic conditions and with the particular currency of trade. Their findings are different and mixed depending on geographic regions: for investments denominated in local currency Bitcoin acted as a diversifier, hedge or safe haven. In the case of USD denominated investments the empirical results for all countries suggest that Bitcoin is a weak hedge. In a similar fashion Kajtazi and Moro (2019) have empirically validated that Bitcoin may be used in portfolio management and diversification of US, European and Chinese assets the performance of the portfolio being improved mainly due to the increase in returns and not to decreases of volatility.

There are also various individual research approaches. For instance Dyhrberg (2016) and Demir, Gozgor, Lau and Vigne (2018) argue that Bitcoin may be used for hedging risks generated by the FTSE index or for contracts having gold as an underlying asset. Aysan, Demir, Gozgor and Lau (2019) uncover that Bitcoin is an important hedging tool against global geopolitical risks while Sebastião and Godinho (2019) claim that Bitcoin futures exhibit hedge capabilities by mitigating the losses in the spot market and by hedging the price risk for other cryptocurrencies. Beneki, Koulis, Kyriazis and Papadamou (2019) investigate the hedge properties between Bitcoin and Ether.

There are also contradictory opinions and findings regarding Bitcoin's ability of being a safe haven for stock markets. Smales (2019), Chaim and Laurini

(2019) bring explanations against because of Bitcoin's high volatility, illiquidity, transaction costs or the potential bubble witnessed by Bitcoin.

Since the outbreak of the COVID-19 pandemic several studies tried to revisit the relationship between cryptocurrencies and stock markets. Christy Dwita, Irwan and Zaafri Ananto (2020) have studied the features of Bitcoin and Ether at the beginning of the pandemic and reveal that they both display short-term safe haven characteristics for US stock markets and the gold price. In addition, they document that Ether might be a better safe haven than Bitcoin during a short extreme stock market downturn having as their drawback a higher return volatility than Bitcoin. Gil-Alana, Abakah and Rojo (2020), Bouri, Shahzad and Roubaud (2020) come to similar conclusions for Bitcoin. Shahzad, Bouri, Roubaud and Kristoufek (2020) supports the view that Bitcoin can be a safe haven conditioned by stock market features, time horizons and investment horizons. By explicitly examining the relationship between Bitcoin, Ether and Ripple and the number of COVID-19 cases and death Demir, Bilgin and Karabulut (2020) identify that cryptocurrencies can serve as a tool to hedge portfolios in the context of the risks posed by the pandemic. Gil-Alana and others (2020) encourage investors to diversify their portfolios by including also exposures on cryptocurrencies because they are different from conventional financial and economic assets.

The most comprehensive approach is that of Wątorek and others (2020) which analyze the correlations between the 100 cryptocurrencies with the largest capitalization. Regarding the impact of the COVID-19 pandemic on cryptocurrencies the authors conclude that there is currently a phase of transition from the opportunity to hedge investors' portfolios to the status of the global financial market in which they are substantially related to traditional financial instruments such as currencies, stocks and commodities.

Another study gathering a large number of cryptocurrencies is performed by Jiang, Lie, Wang and Mu (2021) which test the safe haven role of six cryptocurrencies with the largest market capitalization against representative stock market indices. The results indicate in most cases a positive statistically significant relationship which is a clear sign that cryptocurrencies cannot act as a strong hedge or safe haven against stock markets but as a diversifier asset.

There is also a recently emerged strain of literature claiming that Bitcoin and Ether are not a safe haven for the international equity markets. Conlon, Corbet and McGee (2020) examine the downside risk hedging ability of three cryptocurrencies (namely Bitcoin, Ether and Tether) against a series of representative stock markets indices until April 2020. The conclusions show that Bitcoin and Ether are not, in general, safe havens for international equity markets.

A similar finding is that of Conlon and McGee (2020) which claims that the Bitcoin price moves closely with S&P500 and hence cannot act as safe haven. The authors started from a general belief that Bitcoin is a safe haven compared to traditional assets for several reasons including independence from monetary

policy. However, these properties of Bitcoin are no longer manifest in a period of significant turmoil represented by the COVID-19 crisis. They tested the extent to which an investor holding a portfolio with a significant share of Bitcoin can reduce its exposure to market risk compared to an investor holding a portfolio consisting only of shares, represented in their study by the S&P 500 index. For data related to the pandemic outbreak Bitcoin no longer acts as a safe haven for investors who want to diversify their portfolios.

A radical opinion is formulated by Corbet, Larkin and Lucey (2020) and indicates Bitcoin as an amplifier of contagion and not as a diversifier asset. They explain that the inclusion of cryptocurrency in investors' portfolios is not recommended as this asset does not have the capacity to reduce portfolio risks due to positive correlations with other financial assets.

At the beginning of the COVID-19 pandemic Hockett (2020) launched a pessimistic prediction regarding Bitcoin claiming that in times of crisis investors always show a flight to "safe assets" and the safest one has long been US government securities. A related study is performed by Cheema, Faff and Szulczyk (2020) which answers the question of whether traditional safe assets during the 2008 global financial crisis maintained their safe haven status also during the COVID-19 pandemic. Their conclusions point out that gold lost its attraction during the COVID-19 pandemic although it was a safe haven during the financial crisis while US Treasury securities served as safe havens during both crises. As Bitcoin failed the safe haven asset test and proved to be an extremely speculative asset during COVID-19 the authors claim that the asset-backed Tether serves better as a safe haven against stock market losses during COVID-19 and recommend that investors prefer asset-backed cryptocurrencies. A similar proposal to transform cryptocurrencies into secure assets can also be found in Hoang and Baur (2020), who suggest the creation of stable cryptocurrencies by linking them to assets such as gold or other currencies, a good example being Tether which is the first and largest asset-backed cryptocurrency (a stable currency).

A complementary research approach is that of Mnif, Jarboui and Mouakhar (2020) which started from the assumption that cryptocurrency markets are complex systems based on speculation, and assessed the efficiency of the cryptocurrency market before and after the pandemic outbreak. Findings indicate that Bitcoin was more efficient before the COVID-19 pandemic outbreak but it proved less effective compared to Ether after the pandemic outbreak.

The authors Lahmiri and Bekiros (2020) analyzed the evolution of information efficiency and estimated the degrees of stability and irregularity present on the cryptocurrency market and the international stock market, before and during the COVID-19 pandemic. During the pandemic, it was found that: (a) the level of stability in the cryptocurrency markets decreased significantly while the level of irregularity significantly increased; (b) the level of stability in the international stock markets did not change; (c) cryptocurrencies have

become more volatile; (d) equity stability has not been affected; (e) cryptocurrencies and stock markets have a similar degree of stability in price dynamics. Thus, from the perspective of information efficiency investments in digital assets during crises such as the COVID-19 pandemic could be considered riskier as opposed to stock markets.

Considering the aforementioned studies, the following research hypothesis is tested:

H1: The impact exhibited by a series of financial variables on cryptocurrency depends on the severity of the COVID-19 pandemic proxied by the number of cases and the number of deaths.

2. Data and methodology

The dataset comprises the price of Bitcoin and Ether (the 2 most traded cryptocurrencies, from the standpoint of the traded volume) several representative conventional and sustainable stock market indexes in the US, Europe and Asia, gold and oil prices and bond yields. The time series cover the period February 2020–December 2020, with daily observations. Table 1 presents a brief description of data series used for the subsequent analysis.

Table 1. Variables employed—data sources and explanations

Variables	Description and source
Bitcoin price	Daily closing price of Bitcoin. Source: https://bitcoin.org/en
Ether price	Daily closing price of Ether Source: Yahoo Finance
Bitcoin traded volume	Billion USD. Source: https://bitcoin.org/en
Ether traded volume	Billion USD. Source: Yahoo Finance
Bond yields USA	United States 5-Year Bond Yield. Source: Bloomberg
Bond yields CHN	China 5-Year Bond Yield. Source: Bloomberg
Bond yields JAP	Japan 5-Year Bond Yield. Source: Bloomberg
Bond yields GER	Germany 5-Year Bond Yield. Source: Bloomberg
Bond yields UK	United Kingdom 5-Year Bond Yield. Source: Bloomberg
Gold price	Daily spot closing price of Gold. Source: Bloomberg
Brent oil price	Leading global price benchmark for purchases of oil worldwide Source: Bloomberg
S&P 500Index	Market-capitalization-weighted index of the 500 largest U.S. listed firms. Source: Bloomberg
Nikkei 225 Index	Market-capitalization-weighted index of Japan's top 225 companies listed on Tokyo Exchange. Source: Bloomberg

Variables	Description and source
DAX Index	Market-capitalization-weighted index of Germany's top 30 blue-chips listed on Frankfurt Stock Exchange. Source: Bloomberg
FTSE100 Index	Market-capitalization-weighted index including the largest 100 companies which list on the London Stock Exchange. Source: Bloomberg
SHANGHAI Index	Market-capitalization-weighted index including all the A-shares and B-shares listed on Shanghai Stock Exchange. Source: Bloomberg
Rusell 2000Index	Market-capitalization-weighted index measuring the performance of 2,000 smallest-cap American companies. Source: Federal Reserve Economic Data
VIX index	Real-time market index representing the market's volatility expectations over the next 30 days. It measures the level of risk, fear, or stress in the market. Source: Federal Reserve Economic Data
S&P 500ESG	Market-cap-weighted index that measures the performance of securities meeting sustainability criteria, while maintaining similar overall industry group weights as the S&P 500. Source: Bloomberg
DowJones Sustainability (DJS) Asia-Pacific	Measures the performance of Asia-Pacific sustainability leaders, identified through a corporate sustainability assessment (the top 20% of the 600 largest companies in the Asia-Pacific region). Source: Bloomberg
DowJones Sustainability (DJS) emerging markets	Comprises emerging-market sustainability leaders representing the top 10% of the largest 800 companies in twenty emerging markets, based on long-term economic, environmental and social criteria. Source: Bloomberg
DowJones Sustainability (DJS) Europe	Comprises European sustainability leaders representing the top 20% of the largest 600 European companies in the S&P Global index based on long-term economic, environmental and social criteria. Source: Bloomberg
Economic policy uncertainty	The economic and policy uncertainty index based on media news for United States of America. Source: http://policyuncertainty.com
COVID-19 daily cases—worldwide	Source: European Center for Disease Prevention and Control
COVID-19 daily deaths—worldwide	Source: European Center for Disease Prevention and Control

Source: Own work.

To study the nonlinear impact exerted by different variables on cryptocurrencies' return a threshold regression analysis was used in line with Tong (1983) and Hansen (2011, p. 123–127). These approaches are suitable substitutes to classical OLS methods when it comes to capturing asymmetric patterns or sudden breaks that can be observed in financial time series. The threshold regres-

sion models are widely seen as a versatile approach to estimate the relationship between a given set of variables, in the presence of a threshold variable being able to better model and explain the economic relationships that characterize the non-linear specifications (Ramirez-Rondan & Terrones, 2021). The main feature and hence advantage consist in splitting the initial data sample into two regions, based on the threshold estimated value followed by the distinct estimation of the regression coefficients which are allowed to differ across the two regions. A threshold regression with two regions can be specified as follows Equation (1):

$$y_t = \begin{cases} x_t\beta + z_t\delta_1 + \epsilon_t, & -\infty < w_t \leq \gamma \\ x_t\beta + z_t\delta_2 + \epsilon_t, & \gamma < w_t \leq \infty \end{cases} \tag{1}$$

In Equation (1), y_t is the dependent variable (Bitcoin and Ether daily percentage change), the set of explanatory variables without threshold effects are given by x_t and might also include lagged values of y_t while z_t is a matrix of independent variables featuring some region-specific coefficients captured by δ_1 and δ_2. Furthermore, β is a vector containing region-invariant estimates, w_t is the threshold variable given by COVID-19 related information while ϵ_t is an IID error term with zero mean and constant variance σ^2. Region 1 contains those observations associated with w_t less than the threshold γ. Similarly, Region 2 is restricted to the subset of observations where the value of w_t is greater than γ. The advantage brought by including also a threshold in the specification of the regression model is that it helps in delineating one state from another. The output of the estimation consists of a set of coefficients (one effect) up to the threshold and another set of coefficients (another effect) beyond it.

Performing inference on γ which is a nuisance parameter is a difficult task mainly due to its nonstandard asymptotic distribution. In this regard, to identify the threshold value ($\hat{\gamma}$) it is necessary to perform the least square optimization to Equation (2) with T observations and two regions:

$$y_t = x_t\beta + z_t\delta_1 I\left(-\infty < w_t \leq \gamma\right) + z_t\delta_2 I\left(\gamma < w_t \leq \infty\right) + \epsilon_t \tag{2}$$

The threshold is calculated based on the following minimization algorithm:

$$\hat{\gamma} = \arg min_{\gamma \in \Gamma}\, S_{T_1}\left(\gamma\right) \tag{3}$$

In Equation (3), $\Gamma \in (-\infty, \infty)$, T_1 is a sequence of values in w_t, with $T_1 < T$ and corresponds to the number of observations between two certain quantiles of w_t distribution. In addition, $S_{T_1}(\gamma)$ can be computed as:

$$S_{T_1}\left(\gamma\right) = \sum_{t=1}^{T}\left[y_t - x_t\beta - z_t\delta_1 I\left(-\infty < w_t \leq \gamma\right) - z_t\delta_2 I\left(\gamma < w_t \leq \infty\right)\right]^2 \tag{4}$$

Equation (4) represents a T_1 $x1$ vector of SSR given γ which is a T_1 $x1$ vector of potential thresholds.

Before estimating the threshold regression, it is very important to investigate the stationarity path for each variable. In Table 2 the results of the ADF test for both levels are presented.

Table 2. ADF test (null: the series has a unit root)

Variables	Levels	
	***t*-statistic**	**probability**
Bitcoin return	0.6748	0.9914
Ether return	0.5644	0.9933
Bitcoin volume	–2.3826	0.1478
Ether volume	–3.3086	0.0156
BY_US	–0.3608	0.0063
BY_CHN	–0.4435	0.8980
BY_JAP	–3.5190	0.0083
BY_GER	–3.5360	0.0079
BY_UK	–1.9645	0.3025
Gold Price	–1.7333	0.4131
Brent OIL Price	–1.8627	0.3495
SP500	–1.1315	0.7035
Nikkei225	–0.4409	0.8987
DAX	–1.4439	0.5602
FTSE100	–2.5943	0.0956
SHANGHAI	–1.2035	0.6730
Rusell Index	–2.5165	0.1129
VIX	–2.8999	0.0469
EPU	–3.1678	0.0233
SP500ESG	–1.0773	0.7249
DJS Asia-Pacific	–0.8912	0.7897
DJS Emerging markets	–1.2649	0.6460
DJS Europe	–2.2638	0.1848

Source: Own work.

As can be seen in Table 2 most of the variables are not stationary and considering them in this format might lead to some misleading conclusions. However, when considering the percentage change all the variables exhibit a stationary pattern regardless of if they were stationary in levels or not. For this reason, we will specify our model using the percentage change of the covariates.

Furthermore, to avoid any misleading conclusions caused by the multicollinearity the correlation matrix of the variables was computed.[5] The pairwise correlation coefficients do not exceed the threshold of 40% regardless the selected covariates. This fact is valid when e the percentage change modification is used.

3. Results

First the threshold regression framework is applied distinctly for each cryptocurrency by considering as benchmark variable the worldwide COVID-19 daily cases (in percentage change). The algorithm identified a cut-off threshold for the benchmark variable of –1.75%, a value that divides the sample into two extreme regions. Region 1 corresponds to a decreasing number of daily cases from one day to another with at least 1.75% while Region 2 belongs to a stage of COVID-19 pandemic when the threshold is higher than –1.75%. The Stata16 commands used for estimating the threshold regressions initially perform a linearity test to see the exact number of thresholds. In this situation there was only one threshold.

The estimates in Table 3 indicate that only two out of twenty variables preserve their statistical significance (a *p*-value below 10%) and show irrespective of the level of the threshold. Therefore, they exert a stable and persistent influence on Bitcoin return no matter what the evolution of the pandemic. Interestingly most variables exhibit an impact on Bitcoin price in times when the daily cases exhibit a downward trend (threshold < –1.75%). This finding may be explained by the investors' confident belief that the pandemic will end and the ripple effects on the economy and financial system will be finally contained. On the contrary in times of increasing COVID-19 daily cases investors become more risk averse.

Table 3. Bitcoin determinants, conditioned by the evolution of COVID-19 daily cases

Covariates	Region 1 (threshold <–1.75%)			Region 2 (threshold >–1.75%)		
	Coef.	Std. Err.	Prob.	Coef.	Std. Err.	Prob.
Bitcoin traded volume	0.0495	0.0257	**0.0540**	0.0445	0.0148	**0.0030**
BY_US	–0.1553	0.0800	**0.0520**	–0.0832	0.0413	**0.0440**
BY_CHN	–0.6285	0.3145	**0.0460**	–0.1760	0.1965	0.3710
BY_JAP	–0.0598	0.0443	0.1770	0.0216	0.0273	0.4270
BY_GER	0.0837	0.1511	0.5800	–0.2022	0.0650	**0.0020**
BY_UK	–0.0072	0.0031	**0.0190**	–0.0013	0.0035	0.7200

[5] The results can be made available upon request.

Covariates	Region 1 (threshold <–1.75%)			Region 2 (threshold >–1.75%)		
	Coef.	Std. Err.	Prob.	Coef.	Std. Err.	Prob.
Gold Price	0.3547	0.4348	0.4150	0.3750	0.2685	0.1630
Brent OIL Price	0.0978	0.0690	0.1560	0.0123	0.0463	0.7900
SP500	–9.9878	5.0210	**0.0470**	1.0751	3.2063	0.7370
Nikkei225	0.1182	0.4052	0.7710	–0.4024	0.2422	**0.0970**
DAX	1.2997	0.5427	**0.0170**	0.1457	0.3445	0.6720
FTSE100	1.0360	0.7893	0.1890	–0.3039	0.5226	0.5610
SHANNGHAI	–0.2760	0.3797	0.4670	0.0611	0.2777	0.8260
Rusell Index	–0.1514	0.1108	0.1720	–0.0457	0.0767	0.5510
VIX	0.1184	0.0886	0.1810	0.0263	0.0602	0.6620
EPU	0.0283	0.0138	**0.0400**	0.0016	0.0079	0.8360
SP500ESG	9.5094	4.7149	**0.0440**	–0.9194	3.1264	0.7690
DJS Asia-Pacific	0.0778	0.5452	0.8870	0.0950	0.3226	0.7680
DJS Emerging markets	0.8322	0.4994	**0.0960**	–0.2624	0.3218	0.4150
DJS Europe	–0.1009	0.9099	0.9120	0.5394	0.5927	0.3630

Source: Own calculation using Stata 16.

As Table 3 suggests an increase in Bitcoin daily traded volume triggers a further increase in Bitcoin return irrespective the evolution of the pandemic. In times of increased economic policy uncertainty overlapped with a pandemic downturn the Bitcoin price tends to increase.

The relationship between Bitcoin return and the UK, US and Chinese bond yields is negative and significant in times of a decreasing number of daily cases. The negative sign between bond yields percentage change and Bitcoin return holds during pandemic times no matter the cut-off threshold, suggesting investor preference for optimizing their earnings by substituting investments in bonds with those in Bitcoin and hence a safe haven feature of Bitcoin. Consequently, a decrease in bond yields makes Bitcoin investments more attractive and fuels its price increase.

S&P500 and Nikkei225 are negatively related with Bitcoin return thus the cryptocurrency is exhibiting safe haven features for these indices while DAX is positively related.

Two out of four sustainable stock market indices exhibit a positive and significant relationship with Bitcoin price dynamics which is present only in times of pandemic downturns. The explanation may be that investors regain their confidence and are more willing to invest in various alternative financial assets than in traditional ones. This positive dependence suggests the diversifier role of the cryptocurrency, a result in line with Jiang and others (2021).

Table 4 synthesizes the estimates for Ether and shows that two out of twenty variables maintain their statistical significance and sign irrespective the level

Table 4. Ether determinants, conditioned by the evolution of COVID-19 daily cases

Covariates	Region 1 (threshold <–1.75%)			Region 2 (threshold >–1.75%)		
	Coef.	Std. Err.	Prob.	Coef.	Std. Err.	Prob.
Ether traded volume	0.1225	0.0304	**0.0000**	0.0537	0.0190	**0.0050**
BY_US	–0.1954	0.1015	**0.0540**	–0.1099	0.0525	**0.0360**
BY_CHN	–0.7173	0.3996	**0.0730**	–0.1329	0.2491	0.5940
BY_JAP	–0.0724	0.0558	0.1950	0.0180	0.0346	0.6040
BY_GER	–0.0203	0.1926	0.9160	–0.2723	0.0825	**0.0010**
BY_UK	–0.0148	0.0039	**0.0000**	0.0002	0.0045	0.9710
Gold Price	–0.3678	0.5481	0.5020	0.6128	0.3415	**0.0730**
Brent OIL Price	0.1509	0.0875	**0.0850**	–0.0062	0.0586	0.9160
SP500	–10.9419	6.3064	**0.0830**	3.8873	4.0385	0.3360
Nikkei225	–0.0417	0.5148	0.9350	–0.3339	0.3071	0.2770
DAX	1.6544	0.6818	**0.0150**	0.1049	0.4377	0.8110
FTSE100	–0.6883	0.9954	0.4890	–0.8925	0.6604	0.1770
SHANNGHAI	–0.4313	0.4841	0.3730	–0.2310	0.3521	0.5120
Rusell Index	–0.1955	0.1421	0.1690	–0.0771	0.0971	0.4270
VIX	0.1510	0.1169	0.1970	0.0308	0.0763	0.6870
EPU	0.0313	0.0174	**0.0730**	0.0073	0.0100	0.4650
SP500ESG	10.9159	5.9482	**0.0660**	–3.2752	3.9342	0.4050
DJS Asia-Pacific	–0.0538	0.6777	0.9370	0.2530	0.4086	0.5360
DJS Emerging markets	0.8702	0.6188	0.1600	–0.3065	0.4083	0.4530
DJS Europe	1.6840	1.1493	0.1430	0.7541	0.7511	0.3150

Source: Own calculation using Stata 16.

of the pandemic proxy. The same as for Bitcoin, US bonds' yield and the cryptocurrency own traded volumes are stable determinants of the cryptocurrency price in both upturns and downturns of the pandemic.

The relationship between Ether return and the UK, US and Chinese bond yields percentage change is negative and significant in times of a decreasing number of daily cases (see Table 4), the same as for Bitcoin. Therefore, both cryptocurrencies act as safe haven for the bond market during pandemic times.

The gold return exerts a statistically positive impact on Ether return only during distress periods characterized by increases in the number of COVID-19 daily cases. This result confirms the expectation of Christy Dwita and others (2020) who claim that during the pandemic a safe haven return should be positively associated with the gold return. The oil return exhibits a behaviour similar to the one of gold, but only in times of decreasing COVID-19 daily cases.

Ether return is negatively related with S&P50, suggesting a safe haven role for this index, and positively related with DAX and the sustainable index

S&P500ESG. Christy Dwita and others (2020) uncovered too that Bitcoin and Ether exhibit safe-haven qualities for stock market indices (S&P500) their empirical analysis being conducted up to April 2020.

By comparing the determinants of Bitcoin and Ether daily percentage change conditioned by the threshold variable COVID-nineteen daily new cases common conclusions arise: there are safe haven features for bond markets and US stock markets while increasing investor interest for trading the sustainable index S&P500ESG is positively associated with cryptocurrencies' price.

In the following the same threshold regression framework and the same set of variables are applied by considering as benchmark variable the worldwide COVID-19 daily deaths (in percentage change). The algorithm identified a cut-off threshold for the benchmark variable of –8.9%, and divided the sample into two different regions. The new findings are summarized in Table 5.

Table 5. Bitcoin determinants, conditioned by the evolution of COVID-19 daily deaths

Covariates	Region 1 (threshold <–8.9%)			Region 2 (threshold >–8.9%)		
	Coef.	Std. Err.	Prob.	Coef.	Std. Err.	Prob.
Bitcoin traded volume	0.0404	0.0193	**0.0370**	0.0654	0.0156	**0.0000**
BY_US	–0.1639	0.0901	**0.0690**	–0.0480	0.0370	0.1940
BY_CHN	–0.6186	0.3149	**0.0490**	–0.2491	0.1850	0.1780
BY_JAP	–0.0179	0.0497	0.7180	–0.0133	0.0222	0.5490
BY_GER	0.1073	0.1481	0.4690	–0.2190	0.0609	**0.0000**
BY_UK	–0.0052	0.0028	**0.0590**	–0.0070	0.0035	**0.0480**
Gold Price	1.4702	0.4210	**0.0000**	0.2695	0.2495	0.2800
Brent OIL Price	0.0200	0.1332	0.8810	0.0196	0.0370	0.5960
SP500	5.9246	5.5232	0.2830	–2.2435	2.9762	0.4510
Nikkei225	–0.3442	0.4117	0.4030	–0.4031	0.2218	**0.0690**
DAX	0.1398	0.6043	**0.8170**	0.6622	0.3186	**0.0380**
FTSE100	–0.2912	0.8881	0.7430	0.0064	0.4584	0.9890
SHANNGHAI	0.2590	0.3616	0.4740	0.2266	0.2632	0.3890
Rusell Index	–0.0593	0.1049	0.5720	–0.0181	0.0705	0.7980
VIX	0.0725	0.0780	0.3530	–0.0284	0.0594	0.6330
EPU	0.0148	0.0155	0.3410	–0.0044	0.0072	0.5450
SP500ESG	–4.7590	5.1349	0.3540	2.1408	2.8937	0.4590
DJS Asia-Pacific	0.5839	0.5588	0.2960	–0.1875	0.2755	0.4960
DJS Emerging markets	–0.9730	0.6355	0.1260	0.0592	0.2675	0.8250
DJS Europe	1.3913	1.0052	0.1660	–0.1214	0.5253	0.8170

Source: Own calculation using Stata 16.

The safe haven feature of Bitcoin in respect of the UK, US and Chinese bond still holds being negative and statistically significant in times of a decreasing number of daily deaths (see Table 5). When the number of daily deaths enters an upward trend the safe haven feature is significant only against the German and UK bond markets. Therefore, a first conclusion is that no matter what the COVID-19 threshold variable used the relationship between Bitcoin price dynamics and major bond markets remains unchanged.

Changes in the gold price exert a statistically positive impact on Bitcoin return but only in periods witnessing decreases in the number of COVID-19 daily deaths which is a finding in line with the expectation of Christy Dwita and others (2020).

As regards the stock market, in times of an increasing number of deaths Bitcoin exhibits safe haven features for Nikkei225 (negative and significant estimated coefficient) and diversifier features against DAX, with which it is positively related.

The same methodological framework has been applied also for Ether, by considering as benchmark variable the worldwide COVID-19 daily deaths (in percentage change). The new cut-off threshold and findings are synthesized in Table 6.

Table 6. Ether determinants, conditioned by the evolution of COVID-19 daily deaths

Covariates	Region 1 (threshold <–8.9%)			Region 2 (threshold >–8.9%)		
	Coef.	Std. Err.	Prob.	Coef.	Std. Err.	Prob.
Ether traded volume	0.1083	0.0244	**0.0000**	0.0846	0.0210	**0.0000**
BY_SUA	–0.1548	0.1185	0.1910	–0.0673	0.0488	0.1680
BY_CHN	–1.0614	0.4137	**0.0100**	–0.1233	0.2450	0.6150
BY_JAP	–0.0759	0.0653	0.2450	–0.0095	0.0293	0.7460
BY_GER	–0.0949	0.1971	0.6300	–0.2750	0.0803	**0.0010**
BY_UK	–0.0123	0.0036	**0.0010**	–0.0071	0.0047	0.1280
Gold Price	1.2131	0.5551	**0.0290**	0.3661	0.3294	0.2660
Brent OIL Price	0.2086	0.1797	0.2460	0.0205	0.0487	0.6730
SP500	5.4536	7.2982	0.4550	–0.8817	3.8874	0.8210
Nikkei225	–0.4492	0.5419	0.4070	–0.3966	0.2927	0.1750
DAX	0.4102	0.7914	0.6040	0.6956	0.4205	**0.0980**
FTSE100	–2.1508	1.1789	**0.0680**	–0.5410	0.6082	0.3740
SHANNGHAI	0.2428	0.4777	0.6110	0.0040	0.3468	0.9910
Rusell Index	–0.0756	0.1375	0.5830	–0.0722	0.0928	0.4370

Covariates	Region 1 (threshold <–8.9%)			Region 2 (threshold >–8.9%)		
	Coef.	Std. Err.	Prob.	Coef.	Std. Err.	Prob.
VIX	0.1253	0.1037	0.2270	–0.0167	0.0784	0.8310
EPU	0.0297	0.0203	0.1430	–0.0010	0.0095	0.9190
SP500ESG	–3.8129	6.8039	0.5750	1.2012	3.7743	0.7500
DJS Asia-Pacific	0.4097	0.7372	0.5780	0.0070	0.3641	0.9850
DJS Emerging markets	–1.4683	0.8416	**0.0810**	0.0452	0.3536	0.8980
DJS Europe	3.3409	1.3385	**0.0130**	0.0424	0.6976	0.9520

Source: Own calculation using Stata 16.

According to results in Table 6, the periods characterized by decreases in the number of COVID-19 daily deaths of at least nine percentage points correspond to Ether safe haven features in respect with bond markets in UK and China with the gold return and stock markets (FTSE100, DowJones Sustainability Emerging markets). On the other hand when the number of daily deaths increases Ether exhibits safe haven features only in relation to the German bond market.

To sum up, the findings point out that both Bitcoin and Ether price movements are more sensitive to changes in bond yields and stock market prices when accounting for the number of COVID-19 daily new cases as benchmark variable than for daily deaths at global level. The results remain robust when including one day lagged covariates in the baseline specification instead of contemporary covariates. In this way the hypothesis is confirmed.

In addition, when discriminating between upturns and downturns in the percentage change of new cases periods characterized by a decreasing number of daily cases witness more statistically significant relationships between the explanatory variables and cryptocurrencies' price. Results obtained are in line with the conclusion of Drożdż, Kwapień, Oświęcimka, Stanisz and Wątorek (2020) who analyzed the correlation of Bitcoin and Ether price with oil and gold markets and with the American stock indices and uncovered that the cryptocurrency market was only temporarily correlated with these traditional markets during several periods in the first half of 2020.

As regards the relationship between sustainable stock market indices and cryptocurrencies it is only present in times of pandemic downturns and always exhibits a positive sign suggesting the diversifier role fulfilled by cryptocurrencies against responsible investments. A similar idea is formulated by Treiblmaier (2018) who analyzes the potential of cryptocurrencies and of the mechanism on which they are based against the wider societal objectives and sustainability standards. The author suggests that cryptocurrencies can improve economic growth and facilitate the transition to a sustainable economy by shifting the

Table 7. Synthesis of the safe haven or diversifier features exhibited by each determinant variable (conditioned by the evolution of COVID-19 daily cases)

Covariates	Bitcoin		Ether	
	Region 1	Region 2	Region 1	Region 2
BY_US	safe haven	safe haven	safe haven	safe haven
BY_CHN	safe haven	–	safe haven	–
BY_UK	safe haven	–	safe haven	–
BY_GER	–	safe haven	–	safe haven
Nikkei225	–	safe haven	–	–
SP500	safe haven	–	safe haven	–
DAX	diversifier	–	diversifier	–
SP500ESG	diversifier	–	diversifier	–
Brent OIL price	–	–	diversifier	–
Gold price	–	–	–	diversifier

Source: Own work.

Table 8. Synthesis of the safe haven or diversifier features exhibited by each determinant variable (conditioned by the evolution of COVID-19 daily deaths)

Covariates	Bitcoin		Ether	
	Region 1	Region 2	Region 1	Region 2
BY_US	safe haven	–	–	–
BY_CHN	safe haven	–	safe haven	–
BY_UK	safe haven	safe haven	safe haven	–
BY_GER	–	safe haven	–	safe haven
Nikkei225	–	safe haven	–	–
SP500	–	–	–	–
DAX	–	diversifier	–	diversifier
FTSE100	–	–	safe haven	–
SP500ESG	–	–	–	–
DJS Emerging markets	–	–	safe haven	–
DJS Europe	–	–	diversifier	–
Brent OIL price	–	–	–	–
Gold price	diversifier	–	diversifier	–

Source: Own work.

demand for money and financing the economy. In a complementary fashion. Arps (2018) questions how sustainable cryptocurrencies and their digital ecosystems are and approaches cryptocurrencies from an environmental, societal, economic and technological perspective. It even proposes the development of an index for the accurate measurement of the durability of cryptocurrencies called the Cryptocurrency Sustainability Index.

Tables 7 and 8 aggregate the previous findings in order to delineate between diversifiers, safe havens and hedges and summarize the circumstances under which each cryptocurrency serves as safe haven or diversifier.

The findings in Table 7 show that when the pace of the pandemic is slowing down (corresponding to values below the threshold for the number of daily COVID-19 new cases) both cryptocurrencies exhibit safe haven or diversifier roles against a variety of financial assets (bond yields, stock indices). This is not the case in times when the pandemic seems to escalate (region 2 columns), the safe haven relationship holding only for some bond yields.

The previous conclusion seems to hold also when considering as the threshold the number of daily COVID-19 new cases (see Table 8). Most of the time both cryptocurrencies act as safe havens for the UK bond yields. For Chinese bond yields they behave as safe havens only for the time periods included in region 1 characterized by a number of daily deaths below the threshold while for the German bond yields they are safe havens only for region 2 time periods. The diversifier role is present for DAX only in times of daily deaths exceeding the estimated threshold (region 2), and for gold in times of daily deaths below the estimated threshold (region 1).

Conclusions

The purpose of the paper is to highlight the response of Bitcoin and Ether cryptocurrencies in the context of the current pandemic crisis to gain insights in the attitude of investors and their preference for taking advantage of the safe heaven, hedge or diversifier features of the most representative cryptocurrencies against the background of a severe and surrounded by uncertainty health crisis.

A major finding common to both cryptocurrencies is that in times characterized by an increasing number of COVID-19 daily cases and deaths the statistical relationship between cryptocurrencies and main financial market determinants weakens being most of the time non-statistically significant. Indeed, contrary to conventional wisdom stated in the literature during periods of increased turmoil the cryptocurrencies' evolution seems not to be so closely related to the events from financial markets worldwide.

Both cryptocurrencies are more sensitive and show significant correlations in relation to the number of COVID-19 cases compared to the indicator number of deaths. The analysis according to the number of COVID-19 cases shows that both Bitcoin and Ether are statistically significant correlated with nine variables, predominantly financial, for the lower threshold region and in correlation with only four variables for the upper threshold region.

Compared to Bitcoin there is a sensitivity of Ether to the price of real assets represented by oil and gold. The positive correlation of Bitcoin and Ether with gold means that cryptocurrencies have behaved like a traditional and reliable financial instrument and that the safe haven asset status of these currencies has had the same trend as goal, which could be an expression of the maturity of the cryptocurrency market.

Negative correlations with stock market indices regardless of geographical area confirm the conclusions of Umar, Thai, Chen, Iqbal and Jebran (2020) who claim that there is a conditional correlation between most cryptocurrencies and stock market indices and that negative shocks amplify the magnitude of these correlations. The correlations are also important from the perspective of investors providing information on the potential for hedging and diversification of portfolios composed of conventional financial assets and cryptocurrencies.

Moreover, the results here are in line with Barbu, Boitan, Petrescu and Cepoi (2021) or Dyhrberg (2016) which revealed that Bitcoin exhibits hedge capabilities and may be used as a hedge against FTSE index and US dollar fluctuations, S&P Index or Shanghai Index.

From the perspective of the relationship between cryptocurrencies' price and bond yields there is a negative correlation for all bonds included as variables except those issued by Germany which are characterized by maintaining constant bond yields pending decisions taken by the European Central Bank (ECB). In general, the yield on government securities declined significantly during the timeframe considered in our study, their evolution in the context of the pandemic being closely related to the stimulus measures adopted by central banks, the Fed and the ECB through the Pandemic Emergency Purchase Program and the specific monetary and fiscal policies adopted as a reaction to the pandemic. The reduction in bond yields has led investors to focus on better performing assets such as cryptocurrencies which once again confirm their quality as a safe haven financial asset.

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