Insights into Cryptocurrency Market Prices Fluctuation Correlated to COVID-19 Pandemic spillovers: Whether Bitcoin Can Act as a Safe Haven

Maoyuan Wu[1,a,*]

[1]*Nanjing University, 210023, PR China*
a. wmy_NJU@aliyun.com
*corresponding author

Abstract: In this article, I examine the relationship between COVID-19 daily additional cases and Bitcoin daily closing prices by applying Quantile-on-Quantile Regression (QQR) approach. The results reveal that the changing intensity level of COVID-19 does have an impact on Bitcoin prices. What's more, my research captures the dependence between the distribution of Bitcoin prices and the severity of the COVID-19 pandemic. Levels of COVID-19 cause a rise in Bitcoin prices. I give a fresh look at combining every day confirmed number of new infections of COVID-19 and behavioral economics with fluctuating daily Bitcoin prices. And as the confirmed case has stabilized, although it is still at a relatively high position, investors would develop speculative psychology and take abnormal and seemingly inexplicable actions, e.g., they prefer to invest in Cryptocurrency rather than hold US dollars cash. Bitcoin offers a relatively steady performance in enduring the pandemic shocks; thus, it can be considered a safe-haven asset.

Keywords: COVID-19, Bitcoin, Quantile-on-Quantile Regression, Safe haven

1. Introduction

In previous experiments, Tversky and Kahneman[1] demonstrate that acute losses, instead of gains, have a stronger impact on investors. Berkelaar[2] says this incentive let investors seek optimal portfolio choice, which contains several asset classes to diversify risks. But the diversification benefits have been witnessed by Campbell[3] to diminish in times of high market volatility. Smith[4] estimated that in 2003 the SARS, a severe acute respiratory syndrome, cost a \$30–100 billion loss globally. Baur and Lucey[5] believe such risk aversion pushes investors to look for assets that during periods of market turmoil, are uncorrelated or negatively correlated with traditional assets. Many researchers according to Corbet[6] have been inspired to study safe haven properties such as gold in [7], which has a natural hedge against the market disasters in [8], and its universal equivalent in history makes it a safe haven asset in[9]. When comparing the correlation between Bitcoin and famous financial assets such as the US dollar, and major stock market indices, the result is that the correlation is weak or negative. Bitcoin thus has the potential to reduce portfolio risk in [10]. Bitcoin is even described by Shahzad[11] as "digital gold" when it confronts the extreme downside risk of the global stock market and displays safe-haven properties. Baur and Lucey[5], Baur and McDermott[12], Bredin[13], O'Connor[14], Raza[15] all held a belief that Bitcoin may

have hedging properties like gold. Certainly, there are different characteristics between these two assets. Gold is mainly influenced by the uncertainty of economic policy in [15] while Kurka[16] finds whether there are shocks occurring has an influence on the relationship between Bitcoin and other assets. Shahzad et al[17] find that compared with Bitcoin, gold has an indisputably safe-haven property than Bitcoin. According to Matkovskyy and Jalan[18], during crisis periods, risk-averse investors assume Bitcoin is riskier and they choose to abandon Bitcoin. Guesmi et al[19] find that a portfolio which comprises gold, oil, and emerging market stocks except Bitcoin can reduce portfolio risk considerably. Nevertheless, the increasing search interest in COVID-19 is an explanation for market volatility, since the volatility is usually exacerbated by fear sentiment in[20]. Coronavirus gives a rise to fear sentiment which may be the result of Bitcoin's negative returns and high trading volume.

2. Literature and theory

Before the COVID-19 epidemic outbreak, Klein, Thu, and Walther [21] put Bitcoin and other asset classes together and through portfolio statistical properties analysis, which suggests that Bitcoin is incapable to be a safe-haven asset and fails to hedge against risk, even in developed markets. Shahzad et al[22] define safe-haven characteristics using an across quantilogram approach and declare a time-varying behavior that not only Bitcoin but also gold, and the commodity index are all weak safe-havens. Bitcoin is thought to be a speculative investment instead of a currency considering its extreme volatility in[23][24]. Smales[25] denies that Bitcoin is a potential safe asset, Bitcoin is not a new gold [21]. Many studies are managing to figure out how market pricing, and how volatility and bubble related to crypto-assets affect researchers' understanding in[26][27][28]. Pre-pandemic research presents scholars' doubt about Bitcoin's capability to act as a safe-haven asset.

The main decisive factors of bitcoin prices are a fundamental supply and demand factor in[29]; investors' interest in[30]; financial developments and macroeconomics in[31]; together with technological elements in[32]. But all these factors above are heavily affected by black swan events. The market has witnessed an increasingly panicked and rapidly deteriorating condition as Coronavirus transfers from epidemic to pandemic in[33]. McGee[34] shows that during the COVID-19 crisis, Bitcoin has actually been a poor hedge against the S&P500. Except for the US treasury bonds, the financial market has observed a negative return, and high volatility, indicating the COVID-19 outbreak creates investor sentiment and perceived uncertainty in[33]. We have witnessed some acute changes in dynamic behaviors of the periods both before and after the COVID-19 pandemic. Evidence shows elevated correlations within the assigned Chinese exchanges, floating from +0.889 to +0.967 as the market situation began to exacerbate in[6], which suggests of COVID-19 has a powerful positive influence on the volatility of each exchange. Treasure bill, together with soybean commodity futures and gold obtained positive average returns. Among them, only soybean commodity futures' Sharpe ratios is positive within the sample period in[8]. It seems that cryptocurrencies lose their edges when compared with traditional commodities, let alone Bitcoin, which has negative skewness compared to Ethereum, only Tether's dollar peg turns out to act as a safe haven during the COVID-19 crisis in[34].

Former researchers mainly discuss the comparisons of Bitcoin with other assets, while they neglect the peculiarity of Bitcoin, which although it has high price volatility it's decentralized and is less affected by the financial market, and that's why Bitcoin wins such huge popularity and worth so much. Goodell and Goutte[35] research COVID-19 global deaths and Bitcoin every day closing prices from 31st December 2019 to 29th April 2020, and find that levels of COVID-19 cause a rise in Bitcoin prices. I give a fresh look at combining daily numbers in addition to infection of COVID-19 and behavioral economics with fluctuating daily Bitcoin price.

Goodell and Goutte[35] find there is a negative co-movement of Bitcoin prices and COVID-19. But their research overlooks what investors may be insensitive to as the raging pandemic has entered the life of people for some time. And as the confirmed case has stabilized, although it is still at a relatively high position, investors would develop speculative psychology and take abnormal and seemingly inexplicable actions, e.g., they prefer to invest in Tether rather than hold US dollars cash [34].

The above literature are instructive, it is worthwhile to examine whether the COVID-19 pandemic causes the cryptocurrency market to fluctuate over a long period, and I try to find and explain the reason behind Bitcoin price movement correlated with the daily addition of new infections worldwide.
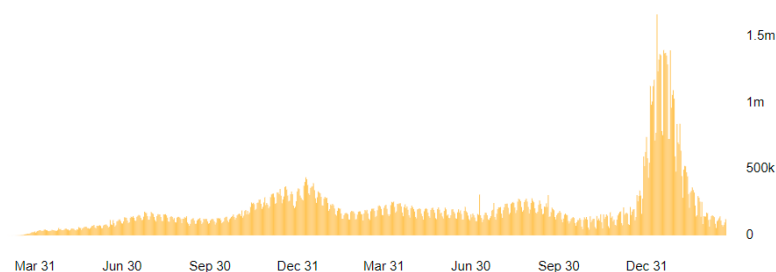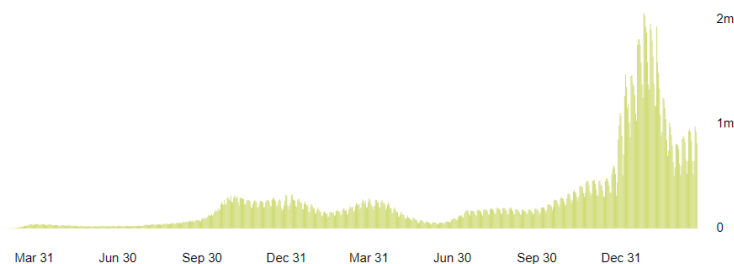

Figure 1: Daily confirmed cases since the beginning of the COVID-19 pandemic.

3.   Data and methodology

This study applies the quantile-on-quantile regression method to daily confirmed data of COVID-19 worldwide confirmed case and Bitcoin prices from 3rd January 2020 to 21st March 2022.

3.1. Data

I collect the daily prices of Bitcoin according to the current market capitalization in[36]. The data containing global newly confirmed numbers of COVID-19 is collected from World Health Organization in[37]. I normalize values in this case according to the advice of the QQR methodology in[36]. The historical data for Bitcoin is the real closing price of the cryptocurrency

market. Additionally, I use the "daily confirmed cases" as a substitution agent for the condition of the virus to examine my results' robustness.

The Sample period starts from 3rd January 2020 to 21st March 2022. A time series plot of these series which are originally measured is shown in Figure 2 and Figure 3. Then I normalize these data for analysis. Table 1 shows the total data of two core variables in this process: the number of Worldwide COVID-19 newly confirmed cases and Bitcoin's historical price. The QQR approach proposed in this paper gives us an insight into how the Bitcoin prices and the severity of the COVID-19 are related at their various quantile

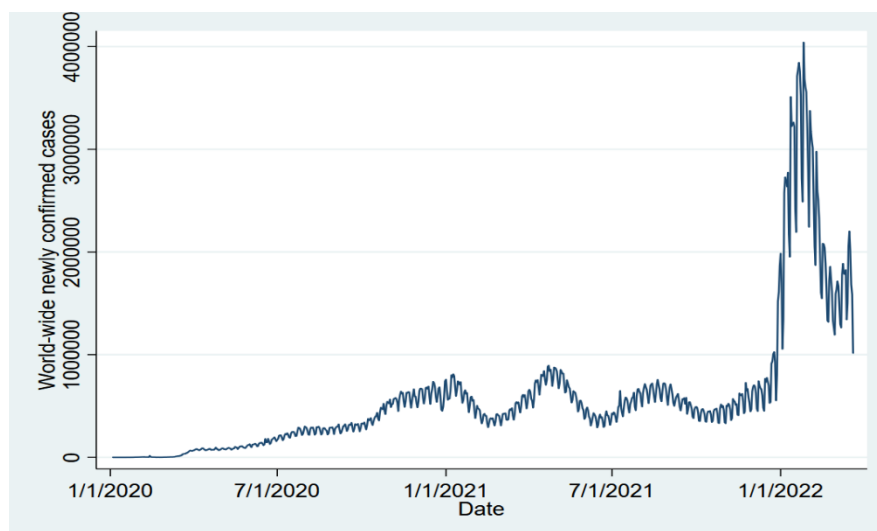

Figurg 2: Historical data for Bitcoin (US dollars)

Figure 3: Worldwide newly confirmed cases

Table 1: Summary statistics.

	Worldwide newly confirmed cases	Bitcoin historical price
Mean	0.14	0.41
Standard deviation	0.16	0.30
Minimum	0.00	0.00
Maximum	1.00	1.00
Correlation	-	0.40

3.2. Methodology

I have employed an effective technique in[38] in checking asymmetric nexus related to economic studies. The quantile-on-quantile regression approach focuses on how the Bitcoin closing price and daily COVID-19 infected numbers are correlated at their various quantiles. The nonparametric quantile regression is defined below.

$$Bitprice_t = \beta^\sigma(COV19_t) + \epsilon^\sigma \tag{1}$$

Where $Bitprice_t$ is a given Bitcoin closing price in time t, $COV19_t$. Denotes worldwide daily new addition cases. Assigning the σ superscript to denote the quantile of the Bitcoin daily closing price, $\beta^\sigma(.)$ is a feature that is yet not identified function since we assume there is no connection between $Bitcoin_t$ and $COV19_t$. ϵ^σ is a quantile error term when the ϵth quantile is zero.

Next is investigating the connections between σth quantile of $Bitprice_t$ and τth quantile of $COVID19_t$, we apply first-order Taylor expansion of $\beta^\sigma(.)$ to extend the basic regression function as below.

$$\beta^\sigma(COV19_t) \approx \beta^\sigma(COV19_t) + \beta^{\sigma\prime}(COV19^\tau)(COV19_t - COV19^\tau) \tag{2}$$

With Eq. (2), $\beta^\sigma(COV19_t)$ and $\beta^{\sigma\prime}(COV19^\tau)$ can be redefined as $\beta_0(\sigma, \tau)$ and $\beta_1(\sigma, \tau)$ respectively. Hence, combined Eq. (1), and Eq. (2) can be rewritten as under.

$$Bitprice_t \approx \underbrace{\beta_0(\sigma, \tau) + \beta_1(\sigma, \tau)(COV19_t - COV19^\tau)}_{*} + \epsilon^\sigma \tag{3}$$

I describe the part $\beta_0(\sigma, \tau) + \beta_1(\sigma, \tau)(COVI19_t - COV19^\tau)$ as (*), part (*) is the σ conditional quantile of the Bitcoin closing price and τ-quantile of COVID-19 newly confirmed cases, where β_0 and β_1 are dual index in σ and τ. Part (*) thus can capture the overall dependence relationship between $Bitprice_t$ and $COV19_t$ due to their respectively independent distributions.

To estimate coefficients in Eq. (), I minimize the problem by using local linear regression. Where b_0 and b_1 estimate the values of β_0 and β_1, $\widehat{COV19}_t$ is the estimated counterpart of $COV19_t$, $\widehat{COV19}^\tau$ is the empirical quantile of $COV19^\tau$ as in[38]. Then, solving the below equation $min_{b_0, b_1} \sum_{i=1}^{n} \rho_\sigma[Bitprice_t - b_0 - b_1(\widehat{COV19}_t - \widehat{COV19}^\tau)] K(\frac{F_n(\widehat{COV19}_t) - \tau}{h})$ to obtain the estimates $\widehat{\beta_0(\sigma, \tau)}$ and $\widehat{\beta_0(\sigma, \tau)}$. $\rho_\sigma(.)$ is a quantile loss function while $K(.)$ is a Gaussian kernel function.

It is essential to carefully select bandwidth when applying kernel regression. A large bandwidth brings about greater variances but smaller estimates bias while a small bandwidth gives a low variance but increased bias of the estimates. According to [38], the current plugin bandwidth is h=0.05.

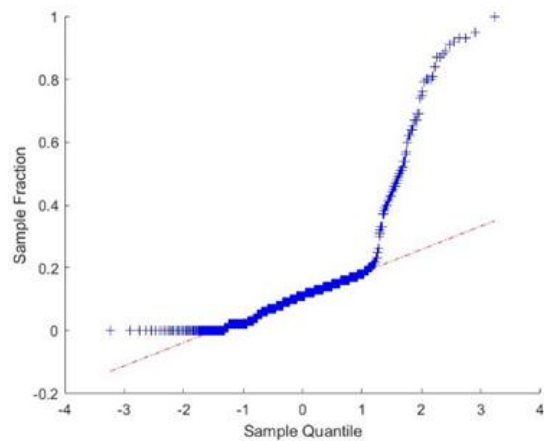## 4.   Result and discussion

4.1. QQR results

To get an idea of the shape of these quantiles, Figure 4(a) draws a plot of the quantile of Bitcoin's daily closing price and tells us that the Bitcoin price below the 46th quantile is negative. Hence, lower quantiles of Bitcoin prices indicate a tough cryptocurrency market, and the reverse held true as well. Where Fig. 4(b) is a plot for the COVID-19 pandemic influence, which is similar to the previous plot. Because I have standardized the number of pandemics newly confirmed cases, any fluctuation that is above(below) the median is positive(negative). Instead say, positive pandemic shocks are above the median, and vice versa.

Figure 5 shows the outcomes of the QQR approach applied in researching the number of everyday additional COVID-19 confirmed numbers and the everyday closing price of Bitcoin according to how the market capitalizes.
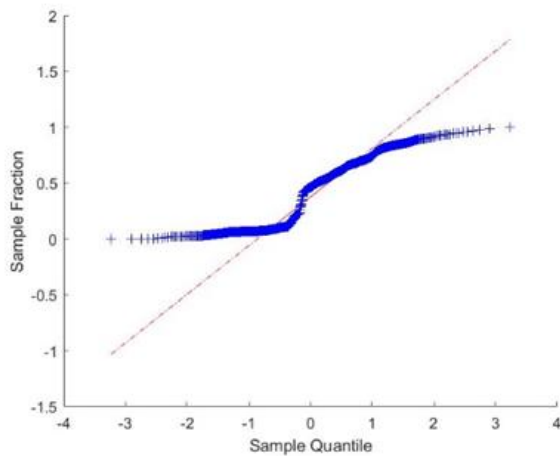
(a) Quantile of Bitcoin Closing Price   (b) Quantile of COVID-19 daily additional cases

Figure 4: Quantile plots.

To the right of this *3D* graph is a vertical bar that shows the direction, magnitude, and scale of the β coefficients. The *z*, *y*, and *x*-axis are $\widehat{\beta_0(\sigma, \tau)}$, the quantiles of Bitcoin and quantiles of COVID-19, respectively. The color shifts from red (upward) to blue (downward), respectively as the value of coefficient and the relationships between variables shift from higher and positive to lower and negative.

In Figure 5 the correlation between Bitcoin and COVID-19 is mainly negative as the graph is filled by a mostly blue and black color, while there is a certain amount of yellow and light green color present. Although an acute decline is witnessed as Bitcoin's value shifts from red to light green and yellow at the onset of COVID-19, the following situation doesn't deteriorate in that the quantiles (20th to 95th) of COVID-19 and green or yellow color represent the lower-middle to upper-middle quantiles (48th to 62nd) of Bitcoin, saying a weak positive association while the upper quantiles of Bitcoin (95th to 100th) are weak positive links as presented by light blue color and it remains such situation since then. This means that following a shrink of Bitcoin market value during the initial stage of COVID-19 is an incredible withstand of the inflation and shock of the pandemic, and it quickly regains the lost value as represented in the raised part in the middle of the graph.
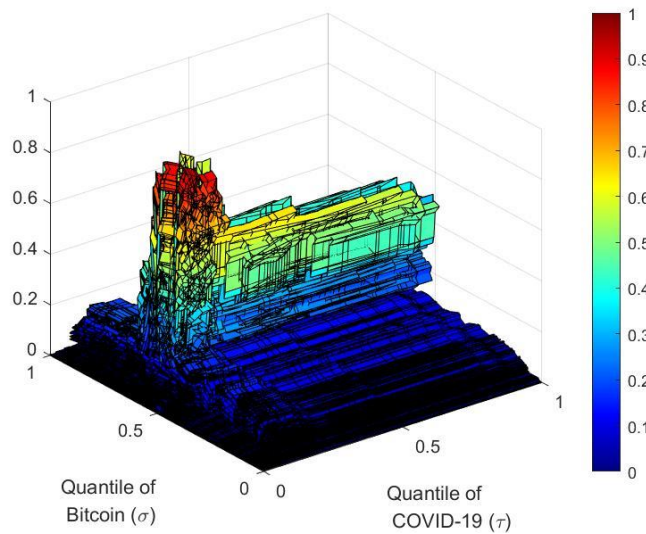

Figure 5: QQ estimate, $\widehat{\beta_0(\sigma, \tau)}$.

4.2. Compared to checking for the QQR approach

In the QR approach, the coefficient is indexed by σ only, since it explains the regression of the σ-quantile of the COVID-19 everyday infection cases on Bitcoin price shocks. While QQR methodology regresses both σ-quantile of the COVID-19 daily infection cases and τ-quantile of Bitcoin daily closing prices, in other words, the QQR approach contains more detailed information about the COVID-19-Bitcoin association than the QR method would, due to the property of potential heterogeneous across τ inherited by the QQR approach. The single efficient σ of the QR method can be generated by the binary parameters σ and τ from the QQR model, by averaging the dual parameters, which is shown in the below equation:

$$\gamma_*(\sigma) \equiv \overline{\overline{\beta}}_*(\sigma) = \frac{1}{S}\sum_\tau \overline{\overline{\beta}}_*(\sigma, \tau) \tag{4}$$

Where S = 809 is the number of quantiles, τ is given in the above paragraphs. QQR parameters in (4) are indexed by σ and τ while the QR method only has parameter σ. Fig.6 shows the plot of QQR and QR estimates of $\gamma_*(\sigma)$. From the plot, we can see, that these two lines coincide near zero or one, but the QQR line is above the QR line and it increases more rapidly. This is a tally with the

discussion above that the QQR approach contains more localized information than QR does. It shows that other aspects have an influence on Bitcoin's closing price during the pandemic panic period, in other words, COVID-19 is not the dominant factor that influences Bitcoin's prices. Weather in[39], for example, refers to not only the state of the atmosphere but also investors' moods. Figure 6 provides an explicit comparison of the QQR methodology, which demonstrates QR estimates' core factors could be revealed by summing up the more separate distribution included in the QQR estimates.
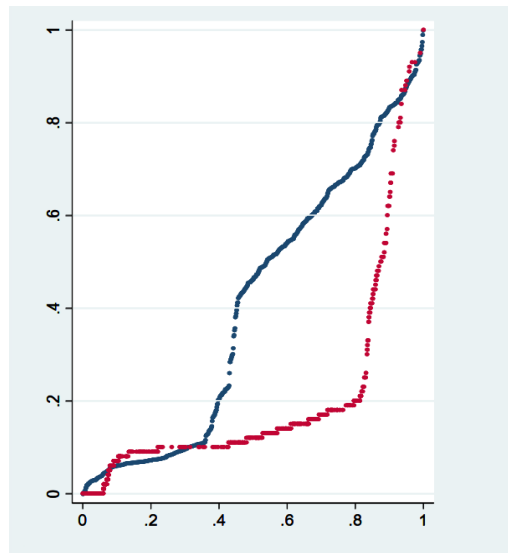

Figure 6: Comparisons of the QR and the QQR estimates.

Note: This graph indicates how valid the QQR estimates is through the comparison of the range of parameters from quantile-on-quantile regression and quantile regression. The blue line indicates the QR coefficients while the red line shows the QR coefficients. The x and y-axis are the quantile (0-1) and coefficients of Bitcoin.

4.3. Discussion

Based on these selected data, the identification of fear-induced, important directional volatility spillovers from investors' worries about whether Bitcoin could hedge risks and those users owning many Bitcoins, along with numerous behavioral observations relating to investors is extremely significant. The COVID-19 pandemic performs a black-swan event characteristic, inadequate anticipation and preparation are observed when the global financial market confronts such international shock. The severity of the upcoming pandemic is underestimated, which results in huge financial market inflation and a sharp decline in every cryptocurrency price. The most interesting thing Is the relationship between the outbreak of the COVID-19 pandemic and the price changes in the Bitcoin market. Once the Bitcoin price exceeded $10,000 in October 2019, the world community was optimistic about the prospect of Bitcoin, and believe blockchain technology could provide potential help to reduce risk. De facto, Bitcoin lives up to the hype, it performs independent movements during the COVID-19 crisis and achieve historic high several times (see Fig.2 and Fig.3). I also observe a rapid increase in the Bitcoin price albeit the existence of the COVID-19 pandemic, which is also an indication of the Bitcoin's safe-have asset characteristic.

Until today, however, the pandemic is still raging and causing thousands of people to die each day. Since the world community has not come up with an effective vaccine and fails to control the momentum of the pandemic, my analysis may be classified into short-term research. No one has an

idea about the ending of the COVID-19 pandemic considering there are already several variations of this coronavirus, and neither is the trend of Bitcoin prices yet. I hope Bitcoin will continue going gangbusters and COVID-19 and its mutant virus will vanish soon.

5.   Conclusion

In this paper, I apply the QQR approach to examine the dependence correlation between Bitcoin daily closing prices and COVID-19 daily additional cases. QQR approach is very suitable for checking how little and huge growth in the intensity of a pandemic affects the ability of Bitcoin to function as a safety-haven asset. Among OLS or quantile regression, and the QQR approach, the last one provides the most information possible about the relationship between Bitcoin prices and COVID-19 new cases. De facto, through the QQR approach, I have got an idea about how complex this relationship would be. I find that a severe situation can improve the prices of Bitcoin, but the explanation of mild pandemic infection condition is always weak. QQR approach can recover the subtle behavior directly, however.

According to my research, Bitcoin offers a relatively steady performance in enduring the pandemic shocks, with neither huge fluctuation nor a downward trend, mostly due to its independence. My research is robust to reflect the severity of the pandemic (Daily newly confirmed cases or daily death numbers). What's more, these results have vital implications for investors and monetary policymakers. Particularly in understanding the behavior of Bitcoin price in periods of disease, and giving investors more comprehensive consideration. Governments and regulators can gain a positive perspective and hence take stabilized formulate to the steady financial market.

References

[1]   Tversky, A., Kahneman, D., 1991. Loss aversion in riskless choice: areference-dependent model. Q. J. Econ. 106 (4), 1039–1061.

[2]   Berkelaar, A., Kouwenberg, R., Post, T., 2004. Optimal portfolio choice under loss aversion. Rev. Econ. Stat. 86 (4), 973–987.

[3]   Campbell, R., Koedijk, K., Kofman, P., 2002. Increased correlation in bear markets. Financ. Anal. J. 58 (1), 87–94.

[4]   Smith, R. D. (2006). Responding to global infectious disease outbreaks: Lessons from SARS on the role of risk perception, communication and management. Social Science & Medicine, 63, 3113–3123.

[5]   Baur, D., Lucey, B., 2010. Is gold a hedge or a safe haven? an analysis of stocks, bonds and gold. Financ. Rev. 45 (2), 217–229.

[6]   Corbet, S., Larkin, C., Lucey, B., 2020. The contagion effects of the COVID-19 pandemic: evidence from gold and cryptocurrencies. Finance Res. Lett. 35, 101554.

[7]   Conlon, T., Lucey, B., Uddin, G., 2018. Is gold a hedge against inflation? A wavelet time-scale perspective. Rev. Quant. Finance Account. 51 (2), 317–345.

[8]   Ji, Q., et al. (2020). Searching for safe-haven assets during the COVID-19 pandemic. International Review of Financial Analysis, 101526.

[9]   Fernandes, N. (2020). Economic effects of coronavirus outbreak (COVID-19) on the world economy. (SSRN 3557504).

[10] Dyhrberg, A. 2016. Bitcoin, gold and the dollar – A GARCH volatility analysis. Finance Research Letters 16:85–92.

[11] Shahzad, J., E. Bouri, D. Roubaud, L. Kristoufek, and B. Lucey. 2019. Is bitcoin a better safe-haven investment than gold and commodities? International Review of Financial Analysis 63:322–30.

[12] Baur, D.G., McDermott, T.K., 2010. Is gold a safe haven? international evidence. Journal of Banking and Finance 34 (8), 1886–1898.

[13] Bredin, D., Conlon, T., Potì, V., 2015. Does gold glitter in the long-run? Gold as a hedge and safe haven across time and investment horizon. Int. Rev. Financ. Anal. 41, 320–328.

[14] O'Connor, F.A., Lucey, B.M., Batten, J.A., Baur, D.G., 2015. The financial economics of gold a survey. International Review of Financial Analysis 41, 186–205.

[15] Raza, S.A., Shah, N., Shahbaz, M., 2018. Does economic policy uncertainty influence gold prices? evidence from a nonparametric causality-in-quantiles approach. Resources Policy 57, 61–68.

[16] Kurka, J., 2019. Do cryptocurrencies and traditional asset classes influence each other? Finance Research Letters 31, 38–46.

[17] Bouri, E., Shahzad, S., Roubaud, D., Kristoufek, L., & Lucey, B. (2020). Bitcoin, gold, and commodities as safe havens for stocks: New insight through wavelet analysis. The Quarterly Review of Economics and Finance. 156-164.

[18] Matkovskyy, R., Jalan, A., 2019. From financial markets to bitcoin markets: A fresh look at the contagion effect. Finance Research Letters 31, 93–97.

[19] Guesmi, K., S. Saadi, I. Abid, and Z. Ftiti. 2019. Portfolio diversification with virtual currency: Evidence from bitcoin. International Review of Financial Analysis 63:431–37.

[20] Conghui Chen, Lanlan Liu & Ningru Zhao (2020) Fear Sentiment, Uncertainty, and Bitcoin Price Dynamics: The Case of COVID-19, Emerging Markets Finance and Trade, 56:10, 2298-2309

[21] Klein, T., Thu, H. P., & Walther, T. (2018). Bitcoin is not the new gold-A comparison of volatility, correlation, and portfolio performance. International Review of Financial Analysis, 59, 105–116.

[22] Shahzad, F., Shahzad, U., Fareed, Z., Iqbal, N., Hashmi, S. H., & Ahmad, F. (2020). Asymmetric nexus between temperature and COVID-19 in the top ten affected provinces of China: A current application of quantile-on-quantile approach. Science of The Total Environment, 139115.

[23] Cheah, E. T., and J. Fry. 2015. Speculative bubbles in bitcoin markets? An empirical investigation into the fundamental value of bitcoin. Economics Letters 130:32–36.

[24] Yermack, D. 2015. Is Bitcoin a real currency? An economic appraisal. Handbook of Digital Currency 31–43.

[25] Smales, L. A. (2019). Bitcoin as a safe-haven: Is it even worth considering? Finance Research Letters, 30, 385–393.

[26] Chu, J., Chan, S., Nadarajah, S., & Osterrieder, J. (2017). GARCH modelling of cryptocurrencies. Journal of Risk and Financial Management, 10(4), 17.

[27] Fry, J., & Cheah, E. T. (2016). Negative bubbles and shocks in cryptocurrency markets. International Review of Financial Analysis, 47, 343–352.

[28] Shen, D., Urquhart, A., & Wang, P. (2019). A three-factor pricing model for cryptocurrencies. Finance Research Letters., 34, Article 101248.

[29] Kristoufek, L. 2015. What are the main drivers of the Bitcoin price? Evidence from wavelet coherence analysis. PLoS One 10 (4):e0123923.

[30] Ciaian, P., M. Rajcaniova, and D. A. Kancs. 2016. The economics of Bitcoin price formation. Applied Economics 48 (19):1799–815.

[31] Panagiotidis, T., T. Stengos, and O. Vravosinos. 2019. The effects of markets, uncertainty and search intensity on bitcoin returns. International Review of Financial Analysis 63:220–42.

[32] Adjei, F. 2019. Determinants of Bitcoin expected returns. Journal of Finance and Economics 7 (1):42–47.

[33] Ali, M., Alam, N., & Rizvi, S. A. R. (2020). Coronavirus (COVID-19)–an epidemic or pandemic for financial markets. Journal of Behavioral and Experimental Finance, 100341.

[34] Conlon, T., Corbet, S., McGee, R.J., 2020. Are cryptocurrencies a safe haven for equity markets? an international perspective from the COVID-19 pandemic. forthcoming Research in International Business and Finance.

[35] John W. Goodell, Stephane Goutte. 2021. Co-movement of COVID-19 and Bitcoin: Evidence from wavelet coherence analysis, Finance Research Letters, 101625.

[36] https://coinmarketcap.com/

[37] https://www.who.int/

[38] Sim, N., & Zhou, H. (2015). Oil prices, US stock return, and the dependence between their quantiles. Journal of Banking & Finance, 55, 1–8.

[39] Iqbal, N., Fareed, Z., Shahzad, F., He, X., Shahzad, U., & Lina, M. (2020). Nexus between COVID-19, temperature and exchange rate in Wuhan City: New findings from partial and multiple wavelet coherence. Science of the Total Environment, 138916.