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Abstract: The purpose of this study is to explore the co-movement between COVID-19 cases and eight cryptocurrencies. Cryptocurrencies (Bitcoin, Ethereum, Tether, Binance Coin, Dogecoin, Ripple, USD Coin and Bitcoin Cash) are selected based on their market capitalisations. Daily data is considered from 30 January 2020 to 19 May 2021. The continuous wavelet transform (wavelet coherence) is used to determine the time-varying co-movement between COVID-19 instances and cryptocurrencies in this research. COVID-19 and cryptocurrency prices are interlinked, as found using the wavelet method. Similar results were discovered for Tether, Binance Coin, and Ripple. Although this seems to be the case, Dogecoin appears to be an alternative investment during COVID-19. The research is unique and adds to the existing body of knowledge, even though some of the results address the function of cryptocurrencies in times of crisis. The research findings indicate that investors and crypto enthusiasts should keep an eye out in the scenario of COVID-19 scenarios when making investments in cryptocurrency marketplaces.

Keywords: COVID-19; cryptocurrencies; Bitcoin; wavelet.

JEL codes: C58, F37, G10.

Biographical notes: Saeed Sazzad Jeris is a young researcher who works with financial stability, economic growth, economic policy uncertainty, cryptocurrency, etc. He already published few articles in SCOPUS, Web of Science, ABDC, and ABS indexed journals in his short career. He also presented a paper in a conference organised by Bangladesh Institute of Bank Management and won several competitions in Bangladesh.

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sustainable marketing. He has published a number of refereed research papers in globally recognised journals, including Elsevier, Springer, Inderscience, and presented his numerous papers in international conferences in the UK, the USA, and South Korea.

1   Introduction

China spotted a viral pneumonia outbreak in Wuhan (Hubei Province) on 31 December 2019. Due to social connections during intimate contact, this isolated virus known as COVID-19 has rapidly spread worldwide. Thus, the epidemic was designated an international public health emergency concern on 30 January 2020, and a pandemic on 11 March 2020. One of the biggest problems for the world economy since the Second World War has emerged from the global health catastrophe produced by the COVID-19 epidemic. In particular, the widespread suspension of industrial operations and the travel restrictions resulting from restrictive measures have led to an unprecedented decline in global demand for crude oil, leading to a substantial decline in crude oil prices and increasing financial risk levels (Albulescu, 2020; Jeris and Nath, 2020; Urom et al., 2020). As a result, the market return on most financial assets has fallen precipitously, as investors attempt to assess the severity of the epidemic and its effect on the global economic and financial markets. Several works address the effects of COVID-19 on the financial system, such as stock market performance (Ali et al., 2020; Mazur et al., 2021; Topcu and Gulal, 2020), banks (Jeris and Nath, 2021), commodity prices (Corbet et al., 2020; Salisu and Vo, 2020), and the tourism and leisure sectors (Ghosh, 2020).

The danger of the COVID-19 pandemic is also expected to have significant consequences for hedge fund operators, cryptocurrency markets, and individual traders. A slew of new cryptocurrencies has emerged since the inception of Bitcoin. Many reasons have led to the phenomenal development of the cryptocurrency industry, including the usage of intelligent innovations, the digital revolution, the recognition of cryptocurrencies as a legal currency in many states, and the acceptance of cryptocurrencies by significant corporations. It is thus critical to grasp the characteristics of the Bitcoin market, mainly when the industry is in a period of turmoil. When volatility is moved from one cryptocurrency to another during a crisis, professional investors and authorities must alter their investment strategy and rules to mitigate the risk of contagion.

As a consequence, information transmission (return and volatility) across cryptocurrencies, particularly during a crisis, may provide critical insights into investment decisions, optimal hedging, effective pricing, risk mitigation, and so on. A little research has explored the fluctuation and return correlation between different cryptocurrencies (Ji et al., 2020). For instance, Ji et al. (2020) investigated the return and volatility economic consequences, which that Bitcoin and Litecoin are the net receivers of volatility spillovers and Ethereum is the net sender of the spillovers.

Few studies have explored the influence of the COVID-19 cases on cryptocurrencies. However, the situation with COVID-19 is changing. Specifically, in Asia, the cases and deaths of COVID-19 again increased significantly at the beginning of 2021. The prices of cryptocurrencies could be volatile again, affecting the whole economy and the financial sector. It is required to assess the co-movement between cryptocurrencies and

COVID-19, increasing cases and deaths, as things can change quickly. In addition, in the event of a crisis, it is critical to investigate safe-haven assets. This study analysed the co-movement between COVID-19 cases and eight cryptocurrencies by considering a significant period of COVID-19. The safe assets are identified using the wavelet results, and the impact of changes in COVID-19 on cryptocurrency prices is also evaluated. Other studies only considered Bitcoin and a few other cryptocurrencies. However, in this study, we considered a few additional cryptocurrencies because they can also serve as a safe asset during a crisis.

The remainder of the paper proceeds in the following manner. Section 2 provides an overview of the study's literature. The data and methods are presented in Section 3. The results are discussed in Section 4. Section 5 highlights the results of this research. The last section discusses policy implications, limits, and future research agendas.

2   Literature review

On a global basis, large players like the USA and China have led the way in cryptocurrency proliferation, although several small nations have had similar success (Goundar et al., 2021a). Goundar et al. (2021b) further noted that cryptocurrencies have created new horizons for e-commerce via decentralisation, relying on blockchains; improved anonymity and virtualisation of coinage allow users to trade anonymously on the internet.

Investigations have been made into cryptocurrencies, particularly Bitcoin, and the financial literature has examined their efficiency, performance, hedging characteristics, and connection to conventional financial assets. More than 1,600 cryptocurrencies have been launched since the launch of Bitcoin in 2009, with the bulk of them achieving commercial success (Goundar et al., 2021c). Similarly, research examining the effect of the current pandemic on cryptocurrency has proliferated in the aftermath of COVID-19's breakout. With a focus on security haven assets like Bitcoin, Ethereum, and Tether during the pandemic, Conlon et al. (2020) discovered that Bitcoin and Ethereum are unsafe hedges because these cryptocurrencies may raise the down-side risk. Conlon and McGee (2020) found that Bitcoin was not a haven against the S&P 500 severe global recession caused by the COVID–19 epidemic. Additionally, Corbet et al. (2020) explored the contagion effects of the COVID-19 pandemic on gold and cryptocurrencies and noted a short-term and significant association between Chinese capital markets and Bitcoin after the COVID-19 outbreak. The significance of safe havens is observed to be lower by Ji et al. (2020), although gold and soybean commodities have remained resilient as safe-haven assets throughout the outbreak. Using the COVID-19 coronavirus epidemic as an example, Grobys (2020) gained fresh insights about the dynamic link between Bitcoin and US inventories, whereby Bitcoin cannot address the enormous threshold risk in US stocks. By applying the wavelet coherence method, Goodell and Goutte (2021) assessed the time-varying effect of Bitcoin and COVID-19 and found an increase in Bitcoin prices after the first week of April 2020. Furthermore, Kristoufek (2020) argues that the outbreak of COVID-19 might be regarded as a chance to examine Bitcoin's haven. The quantitative connections between Bitcoin and the S&P 500 or the VIX do not support Bitcoin's haven history, whereas gold is considered to be a far more secure shelter in the epidemic.

The performance of cryptocurrencies is compared to the world stock market in COVID-19 by Lahmiri and Bekiros (2020). They noticed that the epidemic affects cryptocurrencies more than the global stock markets. In comparison with the equity market, there is more turbulence and irregularities in the cryptocurrency market.

Demir et al. (2020) considered three cryptocurrencies to find their association with COVID-19 and results from the Wavelet coherence analysis evidenced a causal correlation between COVID-19 and cryptocurrency prices. Yarovaya et al. (2020) analysed crowding in the cryptocurrency markets during the COVID-19 outbreak and pointed out that COVID-19 did not enhance herding considerably in the cryptocurrency sector. More recently, Khelifa et al. (2021) evaluated the connections between cryptocurrencies and hedge funds amid the COVID-19 crisis and reported that cryptocurrency and traditional hedge funds had substantive interactions. COVID-19 does not affect the link involving hedge funds in cryptocurrency and Bitcoin, and Ethereum (Khelifa et al., 2021). Mariana et al. (2021) found some essential findings. One of those is that Bitcoin and Ethereum exhibit short-term safe-haven properties. They further mentioned Ethereum as a potentially better haven than Bitcoin.

Since there is a conflict between the findings of the role of cryptocurrencies as a haven, it is required to explore for a considerable period by considering more cryptocurrencies. This study is a timely contribution to the literature.

3 Data and methodology

3.1 Data

This study gathered daily data from 30 January 2020 to 18 May 2021, to investigate the co-movement between COVID-19 and cryptocurrencies. Based on the market capitalisation on 18 May 2021, this study considered the closing price of eight top cryptocurrencies, i.e., Bitcoin (BTC), Ethereum (ETH), Tether (USDT), Binance Coin (BNB), Dogecoin (DOGE), Ripple (XRP), USD Coin (USDC), and Bitcoin Cash (BCH). The cryptocurrency data is derived from coinmarketcap.com, and all prices are in US dollars. Data for COVID-19 confirmed cases are employed from John Hopkins' database on COVID-19. Several studies (see Demir et al., 2020; Sarkodie et al., 2021) used COVID-19 data from John Hopkins' database.

3.2 Methodology

This CWT (wavelet coherence) method will allow understanding the time-varying effects between COVID-19 and cryptocurrencies. The method is also more applicable in measuring daily data. Thus, for assessing the lead-lag correlation between COVID-19 and cryptocurrencies, The CWT (wavelet coherence) technique is used to investigate the local association of two-time series in a time-varying region. Even though CWT (wavelet coherence) is extensively used in scientific research (Alexandridis and Zapranis, 2013), It has recently developed a reputation for dependability in banking and the economy. (Vacha and Barunik, 2012; Ko and Lee, 2015; Jeris and Nath, 2021). Construct the continuous waveforms of the signals $x(\cdot)$ and $y(\cdot)$ · $|W_{xy}| = |W_x W_y|$ will be the cross-wavelet intensity, showing the two-time series' spatial covariance at each frequency and scale (Hudgins et al., 1993). When two tends powerfully respond to each

other, coherence is defined as the wavelet cross-spectrum modulus stretched to a single spectrum.

A continuous wavelet transform (CWT) may divide a continuous-time matrix into wavelets in general. The continuous transformation of the wavelet can produce a time and frequency picture of a message that allows the frequency and time location to be vital. This approach encompasses both frequency and time when it localises a continuous wavelet transformation since it has a minimal border for the uncertain product. Gencay et al. (2002) highlighted CWT's main advantage, namely that the time (Δt) or frequency ($\Delta \omega$) or both may be determined by identifying CWT. In addition, the minimum limit for an unsafe product requires both Δt and $\Delta \omega$ to be evaluated appropriately. We examined the Morlet wavelet in this research since it is a prominent wavelet widely utilised in recent years. Because this method can give both frequency components and a local assessment of the phase delays, this concept is highly well-suited for finding the number of cycles in the phase delay and the correlations between the fluctuations of the two series over time. Depending on which way the arrow points, the phase information is determined. This is the definition of the Morlet wavelet equation as given by Torrence and Compo (1998), which is as follows:

$$\psi_0(\eta) = \pi^{-1/4} e^{i\omega_0 \eta} e^{-\left(\frac{1}{2}\right)\eta} e^{-\frac{1}{2}\eta^2} \tag{1}$$

where time = η and dimensionless frequency = ω_0. In addition to providing a good balance between frequency localisation and time, the Morlet wavelet (with $\omega_0 = 6$) method also makes it an excellent choice for feature extraction.

This technique is motivated by the fact that It can be used to filter time series data as a band-pass filter. It is possible to stretch a wavelet in time by changing its scale (s), so that = $\eta = s \cdot t$ and then normalises it to have a unit value. (δ_t, ..., $n = 1$, ..., N) is measured based on xn and the scaled and normalised wavelet. It is as follows:

$$W_n^x(s) = \sqrt{\delta t / s} \sum_{n'=1}^{n} x_n \psi_0 \left[n' - n\left(\frac{\delta t}{s}\right) \right] \tag{2}$$

Monte Carlo techniques were used to determine the wavelet coherence's statistical significance level. The 5% level of significance against the null hypothesis of red noise is shown by the thick black contour, while the thin black line represents the cone of effect. Arrows pointing right-down or left-up indicate that the first variable is influencing the second. Arrows pointing right-up or left-down indicate that the second variable is connected to the first.

4   Results and discussion

4.1   Descriptive statistics

Table 1 presents the descriptive statistics of COVID-19 daily cases and eight cryptocurrencies. It has been discovered that the average number of daily global COVID-19 cases is 344,072.6, ranging from 380 to 905,992. The standard deviations for the expected change in prices in Binance Coin (BNB) and Dogecoin (DOGE) are higher than their mean, indicating a higher level of risk in these two cryptocurrencies. As shown

by the Jarque-Bera statistics, the probability of this series is asymmetric and leptokurtic, which contradicts the normal condition. We believe that wavelet analysis is the most suitable technique for this problem since the series is asymmetric and leptokurtic. When doing wavelet analysis, rather than evaluating an average statistical connection, it is essential to consider co-movement across time as well as with frequency. The time series trend of the variables utilised in this research is shown in Figure 1.

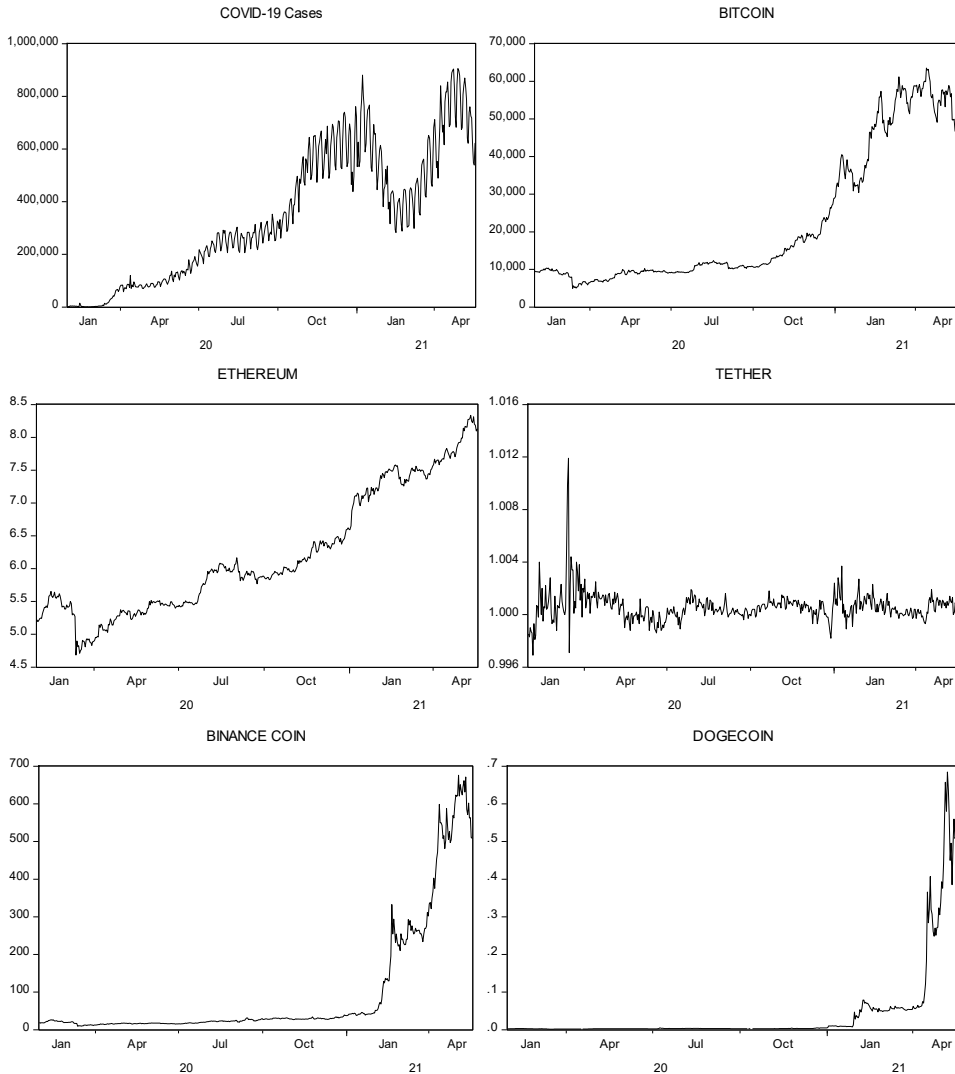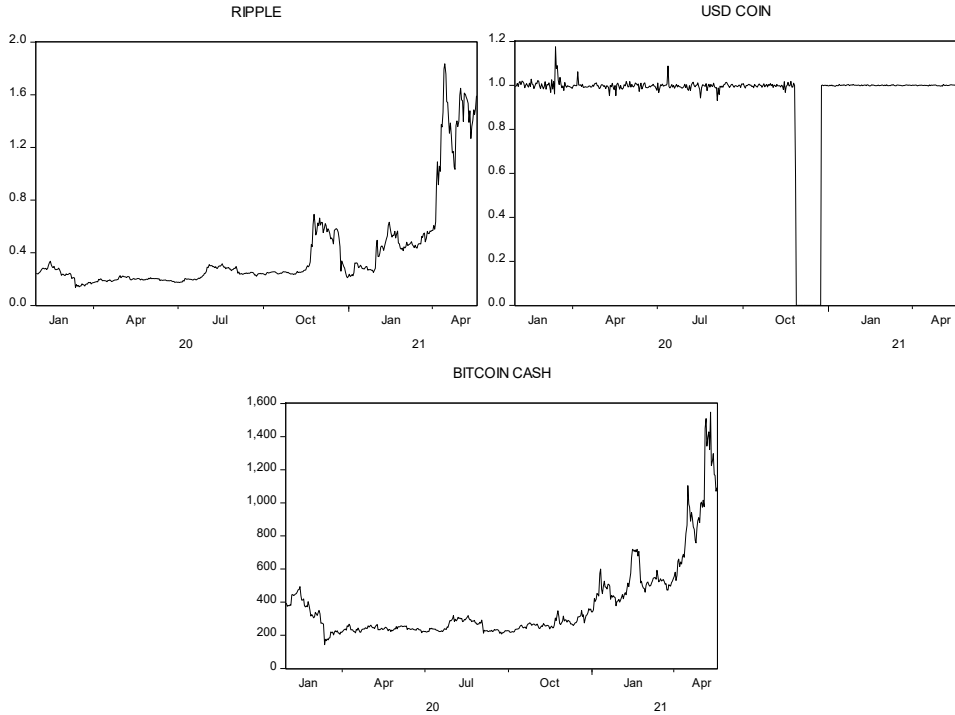**Figure 1** Time series trend of COVID-19 cases and eight cryptocurrencies

Figure 1   Time series trend of COVID-19 cases and eight cryptocurrencies (continued)

4.2   *Wavelet results and discussion*

Wavelet coherence was used in this research to investigate the connection between the variables. Figures 2, 3, 4, 5, 6, 7, 8, and 9 illustrate wavelet coherence plots (WTC). The co-movement of eight cryptocurrencies with COVID-19 instances was examined in this research up to a time frame of 128 days. The *x*-axis represents the investors' holding period for their investment horizon, while the line represents the trading days between 30 January 2020 and 19 May 2021.

The wavelet coherence between the COVID-19 cases and Bitcoin values is shown in Figure 2. During the first 100 days of the timeframe (until April 2020), most arrows point right downward, indicating that COVID-19 is outperforming Bitcoin prices. Following that, in the short and medium-term, COVID-19 cases drove Bitcoin values. After November 2020, it seems that the co-movement between COVID-19 cases and Bitcoin prices will continue with a high degree of regularity if not more regularity than before. The result is consistent with Demir et al. (2020) and Goodell and Goutte (2021), where they regarded Bitcoin as a safe hedge at the time of COVID-19.

The wavelet coherency between the Ethereum and COVID-19 instances is shown in Figure 3. In comparison to Bitcoin, the correlation between Ethereum and COVID-19 instances seems to be somewhat weaker. However, a modest degree of dependence is evident throughout the timeframe, and most of the arrows are positive, indicating that Ethereum served as a hedge throughout the COVID-19 epidemic. Demir et al. (2020) also reached a similar conclusion, although with a shorter sample period.

Table 1   Descriptive statistics

	COVID cases	Bitcoin	Ethereum	Tether	Binance Coin	Dogecoin	Ripple	USD Coin	Bitcoin Cash
Mean	344,072.6	22,256.04	6.21	1	98.42	0.04	0.39	0.94	382.48
Median	291,728.0	11,518.00	5.96	1	27.06	0.00	0.26	0.99	276
Max.	905,992.0	63,518.00	8.34	1.01	676.12	0.68	1.84	1.18	1,548
Min.	380	4,927	4.68	0.99	9.28	0.00	0.14	0.00	144
Std. dev.	249,478.2	18,176.27	0.94	0.00	163.87	0.11	0.35	0.23	237.45
Ske.	0.35	1.03	0.57	3.44	2.17	3.7	2.41	–3.77	2.38
Kur.	2	2.43	2.1	32.57	6.49	16.51	8.05	15.34	9.25
Jarque-Bera	29.51	90.42	42.11	18,243.97	613.09	4,655.97	965.32	4,139.68	1,255.79
Prob.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Obs.	475	475	475	475	475	471	475	475	475

Figure 2   WTC between COVID cases and Bitcoin (see online version for colours)

WTC: COVID CASES-BITCOIN
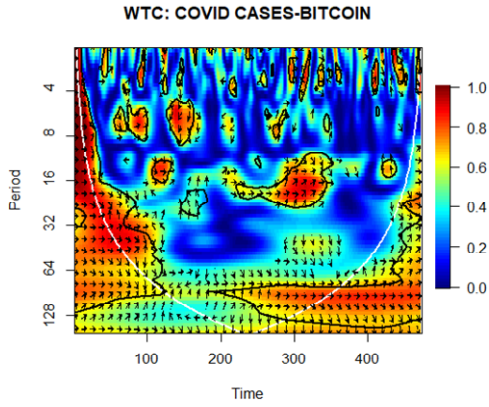
Figure 3   WTC between COVID cases and Ethereum (see online version for colours)

WTC: COVID CASES-ETHEREUM
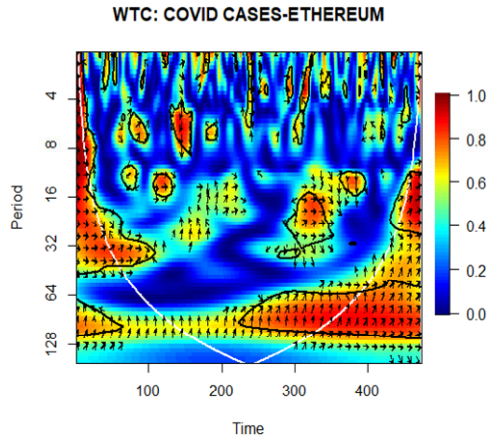
Figure 4   WTC between COVID cases and Tether (see online version for colours)

WTC: COVID CASES-TETHER
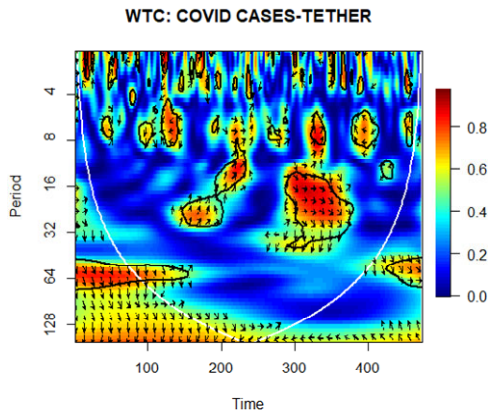
Figure 5 WTC between COVID cases and Binance Coin (see online version for colours)
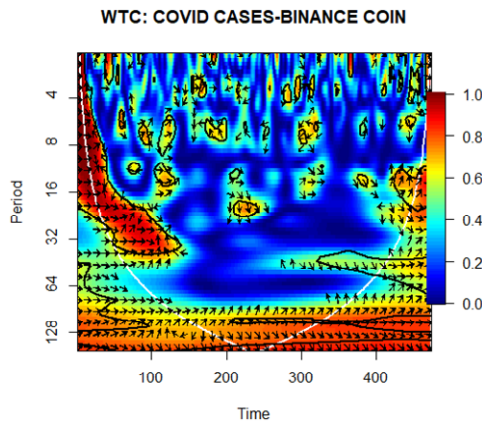

Figure 6 WTC between COVID cases and Dogecoin (see online version for colours)
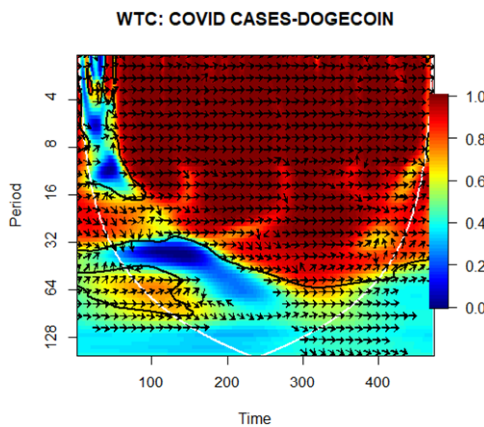

Figure 4 illustrates the relationship between COVID-19 instances and Tether. The finding indicates that the variables, in this case, are less dependent on one another than Bitcoin and Ethereum were throughout the research period. However, the most significant correlation was found at the sample period's midpoint. Between November 2020 and March 2021, most arrows headed right-down, indicating that COVID-19 cases influenced the Tether pricing. After a slight pause, COVID-19 seems to have regained its price edge against Tether in the later section of the study. COVID-19 outbreaks spread around the world, notably in Asia, around the beginning of 2021, as the consequences of the virus worsened. While a strong economy like India was experiencing a big setback, it is possible that the price of cryptocurrencies such as Tether was negatively affected.

Figure 5 illustrates the wavelet coherence between COVID-19 instances and Binance Coin. Even though most of the arrows were positive, a significant correlation between Binance Coin and COVID-19 instances was discovered during the first six months of the period. Following that, a tiny island of high dependency was seen throughout the research period. The dependence is mainly between the frequency bands of 4 to 8 days and 8 to 16 days. However, in the latter half of the research period, the effects on frequency bands

ranged from 16 to 128 days. Most arrows point to the right and upward, indicating that Binance Coin values began to fall in response to COVID-19 instances at that time. As with Tether, COVID-19 influenced the pricing of Binance Coin during that period.

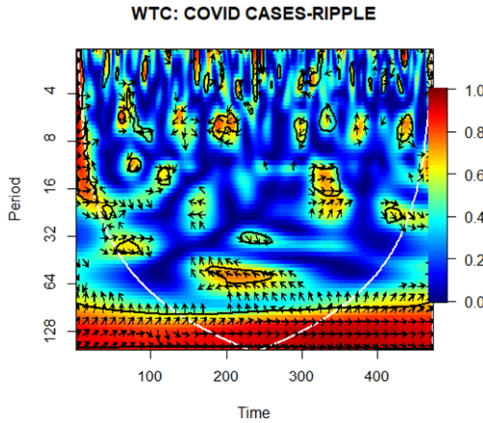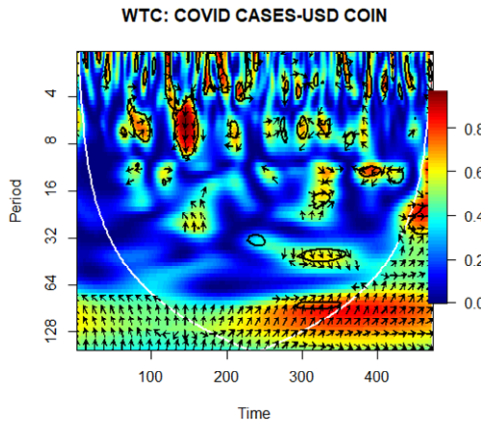**Figure 7**   WTC between COVID cases and Ripple (see online version for colours)

Figure 8   WTC between COVID cases and USD Coin (see online version for colours)

The wavelet coherence graphs between global COVID-19 instances and Dogecoin prices are shown in Figure 6. During the first five months of 2020 (January to May 2020), it has been noticed that COVID-19 cases influence Dogecoin pricing since the majority of arrows point to the right and down. Afterward, a statistically significant positive long-term dependency was seen throughout the period, demonstrating that Dogecoin functioned as an effective hedge during the COVID-19 epidemic.

Figure 7 shows the WTC plots for the COVID-19 cases and Ripple. It is worth noting that the correlation between these two is very modest in comparison to other cryptocurrencies. However, a minor degree of dependence is observed over time (mostly 2–4, 4–8, and 8–16 days). The most significant motions are seen in the study's initial, middle, and final sections. Moreover, most significantly, most of the arrows at these times point right-down or left-up, indicating that COVID-19 instances outperform Ripple

prices. Demir et al. (2020) revealed that, in comparison to other cryptocurrencies, Ripple has a low intensity. This study, on the other hand, believes that Ripple's price will be influenced starting in 2020.

Figure 9 WTC between COVID cases and Bitcoin Cash (see online version for colours)
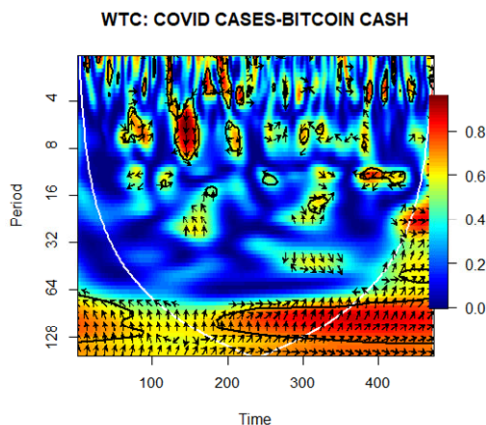

Figure 8 illustrates the co-movements of the COVID-19 cases and the USD Coin. In comparison to other cryptocurrencies, the COVID-19 cases had little effect on the price of USD Coin since just a few modifications happened throughout the time. However, according to the findings of the last phase of the investigation, the COVID-19 occurrences are now outpacing the USD Coin price. In the case of the relationship between COVID-19 and Bitcoin Cash, very similar patterns can be seen (see Figure 9).

5 Implications and conclusions

This research presents new insights as well as practical policy and implementation consequences. The possibility has been opened of examining the impact of a pandemic and a financial crisis on cryptocurrency values and how they change during such a crisis. Cryptocurrency price activity serves as an early indication for those who regulate, govern, and engage in academic study. More government limitations lead to increased demand for non-traditional assets. In theory, blockchain and Bitcoin technology may reduce some of the new problems that have emerged due to the rise of the global pandemic. Cryptocurrencies should be part of an investor's portfolio, based on their COVID-19 stages. As a hedge against the epidemic and as a money transfer and payment system, cryptocurrencies may provide both advantages.

The findings of this research should be interpreted cautiously since they are based on worldwide cryptocurrency pricing circumstances. Additional research may be conducted to investigate the correlation between the movement of conventional financial assets and the pandemic and to compare the results to the situation of cryptocurrency. Additionally, the effect of COVID-19 on other commodity prices should be investigated since this epidemic will very certainly impact them. Additionally, as time passes, the number of observations will grow, providing fresh insights about the behaviour of cryptocurrencies throughout the pandemic's later phases.

This research looks at how COVID-19 instances are correlated with cryptocurrencies (Bitcoin, Ethereum, Tether, Binance Coin, Dogecoin, Ripple, USD Coin, and Bitcoin Cash). The continuous wavelet method (wavelet coherence) has been used to investigate the circumstances of cryptocurrencies in the COVID-19 time, based on daily data taken from 30 January 2020 to 19 May 2021. It may be concluded that COVID-19 and cryptocurrency prices are interlinked, as shown using the wavelet method. Similar results were discovered for Tether, Binance Coin, and Ripple. Although this seems to be the case, Dogecoin appears to be an alternative investment during COVID-19. This follows other research, which shows that Bitcoin effectively reduces uncertainty (Demir et al., 2020; Goodell and Goutte, 2021).

Figure 10   A diagram of the whole work
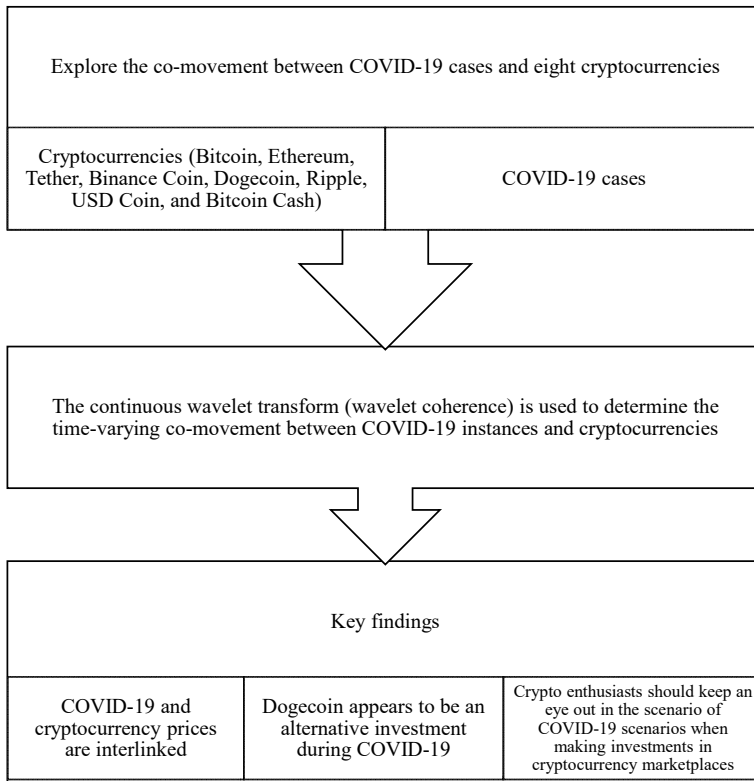
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