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The COVID-19 effects on cryptocurrency markets: robust evidence from time-frequency analysis

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Abstract

This study contributes to the related literature on the COVID-cryptocurrency relationship by examining its dynamics in the time-frequency space. The application of wavelet frameworks to the news-based COVID-19 sentiment index introduced by Buckman et al. (2020) is what distinguishes our approach. Our empirical results suggest a bidirectional relationship between the two variables in the short and medium run. Specifically, negative co-movement between them was found during the COVID-19 crisis. In addition, the COVID-19 sentiment index has a higher causal effect and a significant connection with the selected cryptocurrency prices. News-based sentiment indexes can provide fresh insight into future developments in the cryptocurrency markets.

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1. Introduction

Without a doubt, the COVID-19 pandemic has had a significant impact on the global economy (Hung and Vo, 2021; Pano and Kashef, 2020). In this sense, corporate sales have plummeted, industrial production has reduced, consumer behaviors have changed, businesses have faced serious financial difficulties, and global unemployment rates have grown dramatically. In addition, as the number of positive coronavirus cases has increased, the COVID-19 pandemic has caused panic and the temporary shutdown of enterprises in most nations (Rubbaniy et al. 2021; Demir et al. 2020; Iqbal et al. 2021). COVID-19 has caused dread and concern among individuals and investors in recent years. As a result of this psychological state, behavioral biases such as herding behavior may emerge (Mnif et al. 2020).

The interdependence between the COVID-19 outbreak and oil price variations, corporate performance, insurance markets, stock markets, firm performance, and industrial activities has been extensively researched (Iqbal et al. 2021; Adekoya and Oliyide, 2021; Hung, 2021b). Nevertheless, the COVID-19 link in cryptocurrency markets, on the other hand, remains limited (Sahoo, 2021). Bitcoin and other cryptocurrencies are referred to as financial assets (Umar and Gubareva, 2020) that are highly volatile and have superior hedging capabilities compared to other financial assets like stocks and foreign exchange rate markets (Iqbal et al. 2021). Therefore, investors attempted to diversify their portfolios toward cryptocurrencies in order to profit in the short term during the pandemic (Rubbaniy et al. 2021; Chen et al. 2020; Corbet et al. 2020). Conlon and McGee (2020) uncover that Bitcoin cannot be regarded as a safe haven or a hedge against the extreme bear market of the COVID-19 situation. Further, various researchers have found that the COVID-19 pandemic can negatively impact cryptocurrency markets, which could lead to a halt in active trading and a halt in the cryptocurrency markets. As a result, it is critical to look into the cryptocurrency market conditions during the COVID-19 outbreak.

From an investment perspective, it is necessary to assess how the COVID-19 pandemic affected cryptocurrency efficiency (Pano and Kashef, 2020). The goal of this study is to investigate the causal effects of the news-based COVID-19 sentiment index introduced by the Federal Reserve Bank of San Francisco (Buckman *et al*. 2020) on the five major cryptocurrency markets, including Ethereum (ETH), Bitcoin cash (BCH), Ripple (XRP), Bitcoin (BIT) and Ethereum Operating System (EOS). More accurately, we evaluate the impact of the Covid-19 epidemic on cryptocurrency markets formally and thoroughly. The Covid-19 epidemic is still ongoing, investors and traders still have time to adjust their positions in response to current market changes and significant co-movements. In essence, market participants and policymakers require a preliminary assessment of the current consequences of the COVID-19 outbreak on cryptocurrency prices in order to make better decisions in the immediate term (Lahmiri and Bekiros, 2020).

This study provides evidence on the hedging and safe-haven potential of cryptocurrency markets during the COVID-19 pandemic by focusing on the relationship between cryptocurrencies and COVID-19 sentiment. The implications of such analysis are important not only from the standpoint of portfolio and risk management, but they also provide an opportunity to evaluate the long-term contribution of cryptocurrency markets to sustainable financial markets, particularly during the pandemic's turbulent times. Because the underlying markets can experience diverse conditions at the same time, we use wavelet frameworks to represent the dynamic patterns between the cryptocurrency markets and the COVID-19 sentiment index. The method can be used to calculate the lead-lag relationship between cryptocurrency markets and the COVID-19 sentiment index across different time and frequency domains. Specifically, this approach also predicts the nature of the outcomes and

aids investors in better understanding the dynamic interaction between the time series under consideration under different market conditions.

During the coronavirus outbreak, Rubbaniy et al. (2021) discovered that cryptocurrency markets behave like traditional assets using the global COVID-19 fear index. Chen et al. (2020) also examine the impact of the COVID-19 outbreak on Bitcoin markets, and provide evidence that negative Bitcoin returns and high trading volume can be explained by fear of the coronavirus. According to Lahmiri and Bekiros (2021), cryptocurrency variations exhibit greater volatility and irregularity during the pandemic period than equities. According to Demir et al. (2020), there was initially a negative correlation between Bitcoin and the number of reported cases and deaths; however, the correlation improved over time. Similarly, Sahoo (2021) establishes a unidirectional causal relationship between COVID-19 confirmed and death cases and cryptocurrency price returns.

Some researchers looked into the impact of the epidemic on the cryptocurrency markets and discovered that they performed poorly during the crisis and had a strong association with the equity markets (Iqbal et al. 2021; Pano and Kashef, 2020; Yousfi et al. 2021; Neslihanoglu, 2021; Yousaf et al. 2021; Corbet et al. 2021; Bejaoui et al. 2021; Adekoya and Oliyide, 2021; Le et al. 2021). More so, Sifat (2021) indicates no relationship between cryptocurrencies and global risk, risk aversion, and uncertainty. Umar and Gubareva (2020) highlight some key characteristics of cryptocurrency market behavior that could be leveraged to create efficient cross-currency hedges that can withstand the negative effects of the COVID-19 pandemic.

The ongoing COVID-19 epidemic, as Goodell (2020) points out, is a significant event harming the global economy. Whilst some recent papers have discussed the influence of COVID-19 on cryptocurrency markets around the world (Hung and Vo, 2021; Pano and Kashef, 2020; Rubbaniy et al. 2021; Demir et al. 2020; Iqbal et al. 2021), the majority of these authors ignored the possibility of the time-frequency nature of such an association, as suggested in past studies in connection with cryptocurrencies (Umar and Gubareva, 2020). As a result, small and large changes in COVID-19 intensity (infections and deaths) may affect the returns of digital cryptocurrencies differently at different frequencies. Furthermore, most of these studies focus solely on Bitcoin, ignoring the dynamics of other cryptocurrencies, which now account for a sizable portion of the overall market (Sahoo, 2021). For this reason, with the five major cryptocurrency prices and the news-based sentiment index, we analyze the causal effect between them during the COVID-19 outbreak. As a result, we attempt to fill this research gap by investigating the time-frequency nexus between the COVID-19 outbreak and the returns on cryptocurrencies. We depart from the previous literature by focusing on the news-based sentiment index, which is used to measure market participants' reaction to the COVID-19 pandemic, which was introduced by Buckman *et al*. (2020).

Several contributions to the existing literature can be made as a result of this investigation. Firstly, wavelet analysis was utilized to capture the co-movement between the COVID-19 sentiment and the cryptocurrency markets over various time horizons, including short, medium, and long-term, and determine whether these series vary or not. The arrows pointing in different directions indicate that the causal relationship between the selected variables co-moves over time and frequency domains. Secondly, we show that the COVID-19 has a negative impact on the selected cryptocurrencies over the COVID-19 period, implying that uncertainty shocks in the COVID-19 condition are connected with a decrease in the assessed changes in cryptocurrency values. Finally, our paper extends the literature by examining the lead-lag nexus between cryptocurrency markets and a novel measure of the COVID-19 sentiment proposed by Buckman *et al*. (2020), which evaluates the timing and magnitude of the COVID-

19 pandemic on various aspects of the economy (Van der Wielen and Barrios, 2021; Zhang and Hamori, 2021; Lee, 2020).

The remainder of the research is structured as follows. The data and methodology are described in Section 2. Section 3 discusses the findings, while section 4 concludes the research and offers some policy recommendations.

2. Methodology

We analyze the influence of COVID-19 sentiment on cryptocurrency price variations using wavelet coherence and wavelet-based Granger causality proposed by Olayeni (2016), which was inspired by several wavelet-based studies (Hung and Vo, 2021; Hung, 2021; Umar et al. 2021; Hung, 2021a; Hung, 2022). Using wavelet techniques, we can obtain the form of time-frequency heat maps that include information on both the coherence and time difference of the analyzed pairs of series.

According to Torrence and Webster (1999), the cross-wavelet of two series $x(t)$ and $y(t)$ can be defined as:

$$W_n^{XY}(u,s) = W_n^X(s,\tau)W_n^{Y*}(s,\tau) \tag{1}$$

where u denotes the position, s is the scale, and * denotes the complex conjugate. Consequently, the wavelet coherence can be calculated as follows:

$$R_n^2(s,\tau) = \frac{|S\left(s^{-1}W_n^{XY}(s,\tau)\right)|^2\big)}{S\left(s^{-1}|W_X(s,\tau)|^2\right)S\left(s^{-1}|W_Y(s,\tau)|^2\right)} \tag{2}$$

where S connotes smoothing process for both time and frequency at the same time. $R_n^2(s,\tau)$ is in the range $0 \le R^2(s,\tau) \le 1$.

Causality in continuous wavelet transform

Olayeni (2016) presented the continuous wavelet transform (CWT) for Granger causality, which expands CWT-based correlation measure by Rua (2013). It can be written as

$$G_{Y\to X}(s,\tau) = \frac{\xi\left\{s^{-1}|\Re\left(W_{XY}^m(s,\tau)\right)I_{Y\to X}(s,\tau)|\right\}}{\xi\left\{s^{-1}\sqrt{|W_X^m(s,\tau)|^2}\right\}\xi\left\{s^{-1}\sqrt{|W_Y^m(s,\tau)|^2}\right\}} \tag{3}$$

where $W_Y^m(s,\tau)$, $W_X^m(s,\tau)$ and $W_{XY}^m(s,\tau)$ are the wavelet transformations and $I_{Y\to X}(s,\tau)$ as the indicator function which is defined as

$$I_{Y\to X}(s,\tau) = \begin{cases} 1, & if\ \phi_{XY}(s,\tau) \in (0,\pi/2) \cup (-\pi,-\pi/2) \\ 0, & otherwise \end{cases} \tag{4}$$

3. Data

To capture the causal relationship between COVID pandemic effects and cryptocurrencies, we take into account a sample of the top five cryptocurrencies and COVID-19 sentiment produced by Buckman *et al*. (2020). The five cryptocurrencies are Ethereum (ETH), Bitcoin cash (BCH), Ripple (XRP), Bitcoin (BIT), and Ethereum Operating System (EOS), which were collected from the link www.coindesk.com. The selection of the currencies is motivated by the fact that these five major cryptocurrencies had the highest market capitalizations of all cryptocurrencies in August 2020 (Rubbaniy et al. 2021). The news-based sentiment index is a high frequency measure of economic sentiment based on lexical analysis of economics-related news articles compiled by the news aggregator service LexisNexis from 16 major US newspapers (Lee,

2020). Because the situation is constantly changing, high-frequency data are required to assess the timing and magnitude of the COVID-19 pandemic in many sectors of the economy. Buckman et al. (2020) and Shapiro et al. (2020) provide a detailed description of the sentiment index construction process. The daily data for the selected variables spans from 1 January 2020 to 11 July 2021, leading to a sample size of 558 observations. COVID-19 is evolving and spreading from 1 January 2020 to July 11, 2021 (the most current observation of my data), covering the period from the first lockdown to the first relaxation in most countries' lockdowns. As a result, we can evaluate the evolution of these assets during the pandemic.

Table 1. Descriptive statistics of COVID and selected cryptocurrency returns.

	COVID	BIT	BCH	EOS	ETH	XRP
Mean	-0.189506	0.002512	0.001049	0.000446	0.004783	0.001744
Median	-0.137270	0.002374	0.001718	0.001148	0.004221	0.001801
Maximum	0.167594	0.178685	0.396244	0.447856	0.234784	0.448991
Minimum	-0.652475	-0.480904	-0.616944	-0.546247	-0.592454	-0.541017
Std. Dev.	0.244751	0.043707	0.069792	0.071909	0.060148	0.075546
Skewness	-0.467355	-2.316851	-1.174640	-0.903192	-1.867264	-0.192833
Kurtosis	1.866877	30.21561	19.90088	16.91331	22.49389	15.66811
J-B	50.075***	17688.47***	6757.31***	4568.40***	9143.12***	3727.95***

Notes: *** represents the 1% significance level.

Table 1 reports the main characteristics of the descriptive statistics of the series under investigation. Most cryptocurrency prices had positive mean growth during the sample period. The most volatile time series is COVID, and the cryptocurrencies experience similar degrees of volatility, as reflected in their standard deviations. The distribution shape estimations (skewness, kurtosis, and, the Jarque-Bera statistic) uncover that these series are likely to have nonlinear dynamics. Furthermore, Figure 1 plots the evolution over time of the five cryptocurrencies and COVID-19 sentiment under study.

Figure 1 shows that all cryptocurrencies, ETH, BCH, XRP, BIT and EOS, exhibit a very similar time pattern at different frequencies during the COVID-19 period. The swings in the five cryptocurrency prices, which increased considerably in the high and medium run after the middle of 2020, spanning the so-called Covid-crisis period, are plainly visible. The COVID-19 sentiment index also represented high volatility during the COVID-19 outbreak. Several outcomes of Iqbal et al. (2021), Pano and Kashef (2020) and Yousfi et al. (2021) draw attention to the rise in cryptocurrency prices during the COVID-19 period.

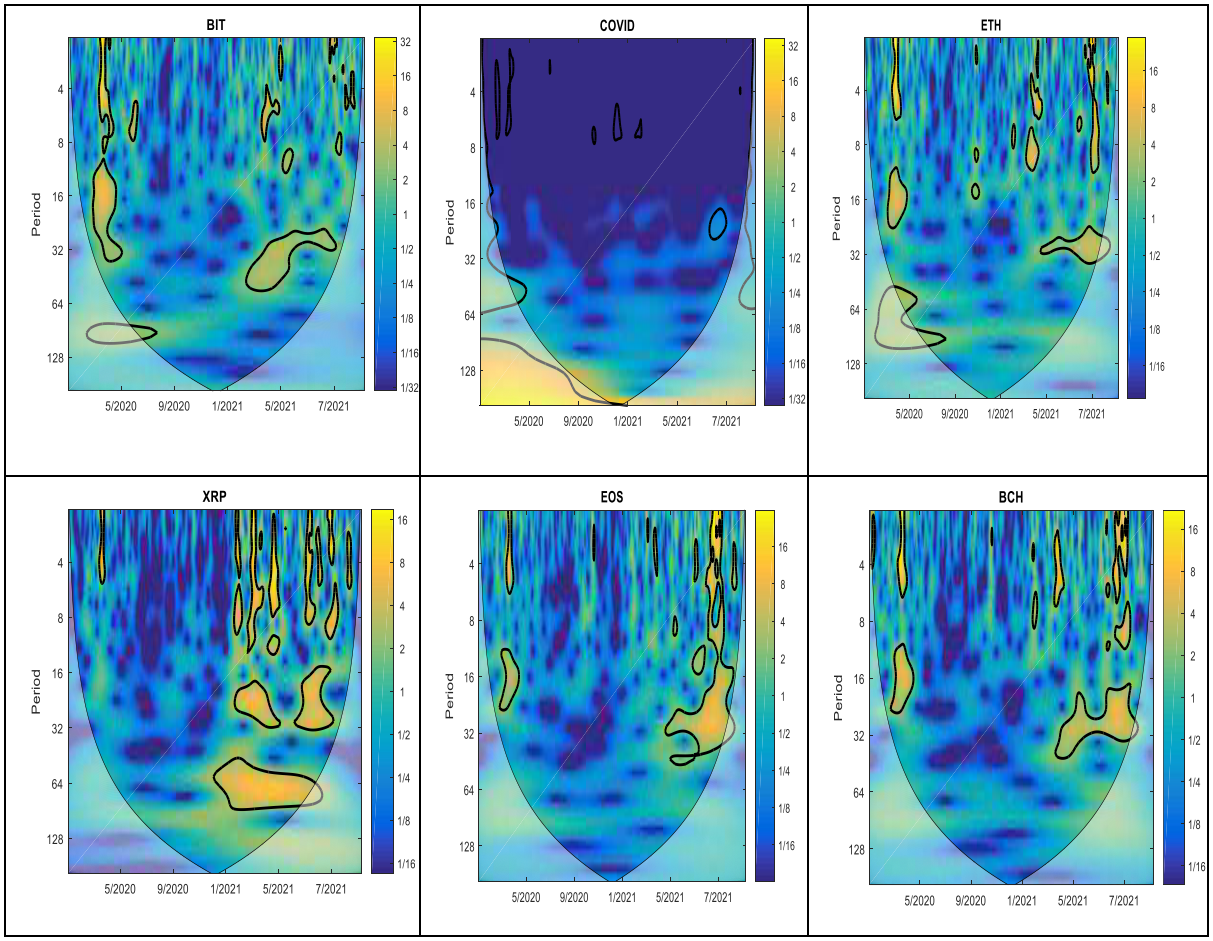
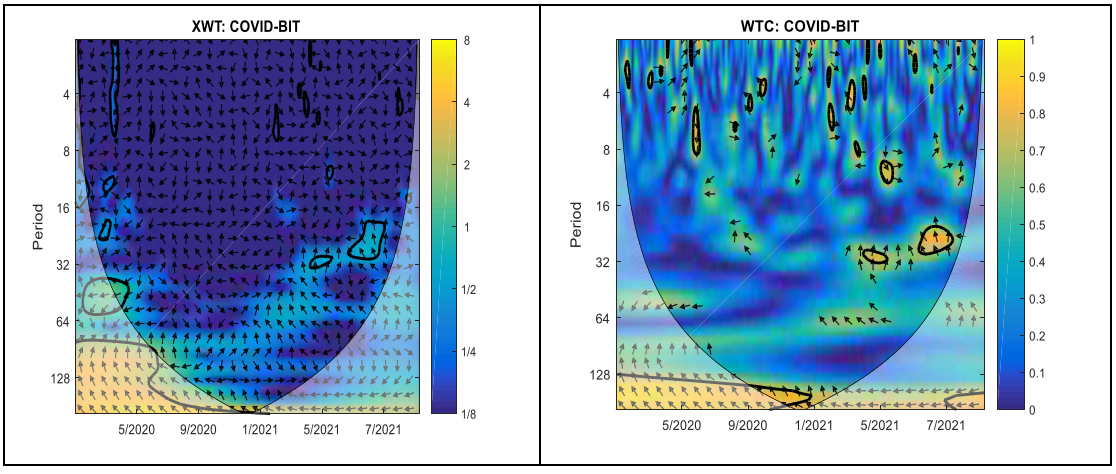


Figure 1. The continuous wavelet power spectrum of individual series.

4. Empirical results

The results of cross-wavelet transform (XWT) and wavelet coherence (WTC) explaining the coherence plots between COVID and the five cryptocurrencies are presented in Figure 2. The outcome of XWT is shown on the left-hand side, while that of WTC is on the right-hand side. The horizontal axis shows time, the vertical axis represents frequency. The shaded contours unveil islands with significance at the 5% level. The cone of impact, indicated by a solid curved line, shows the zone affected by edge effects. Warmer (cooler) color tones show high (low) power. The color codes, which co-vary from blue to yellow, highlight the range of coherence values from zero to one.



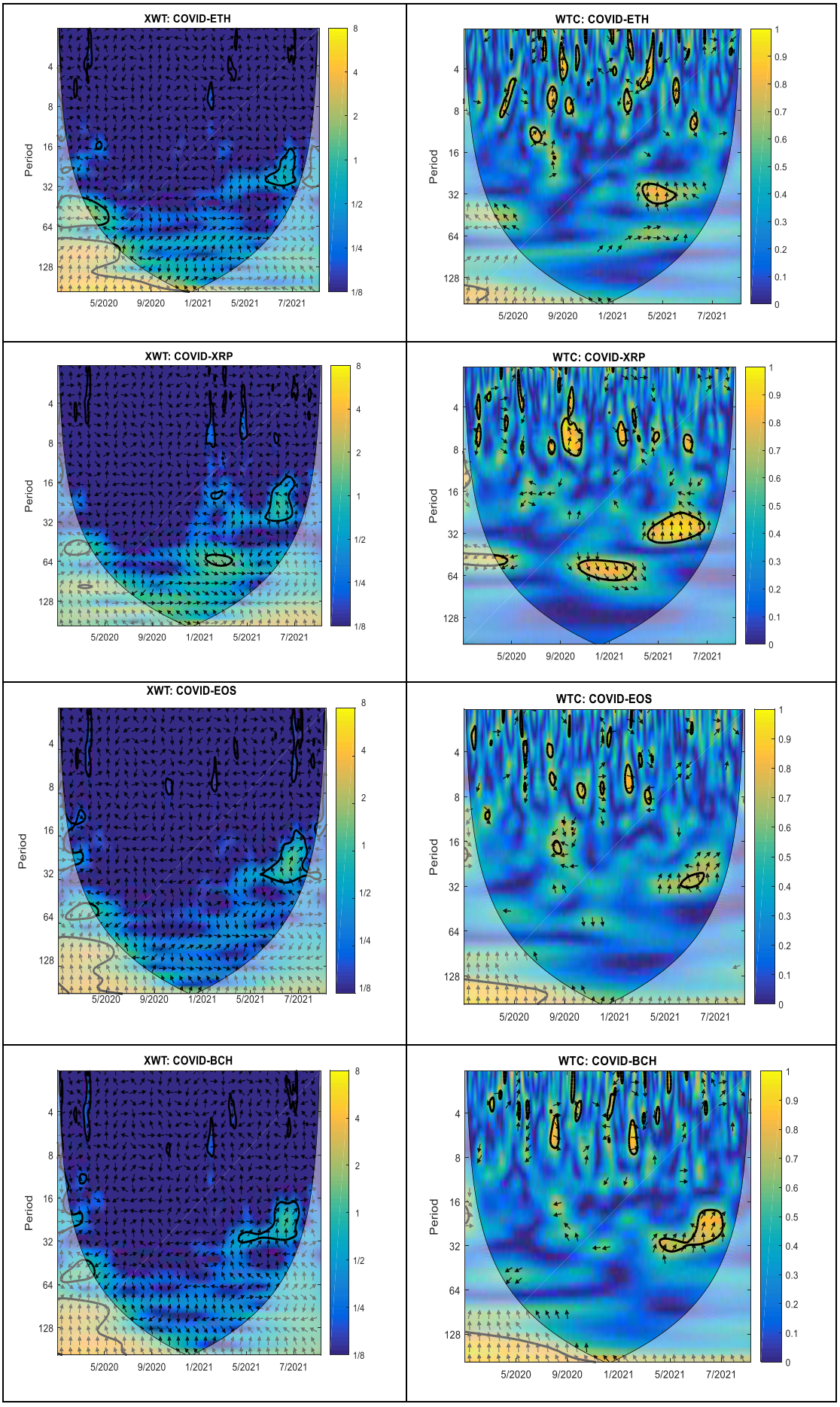
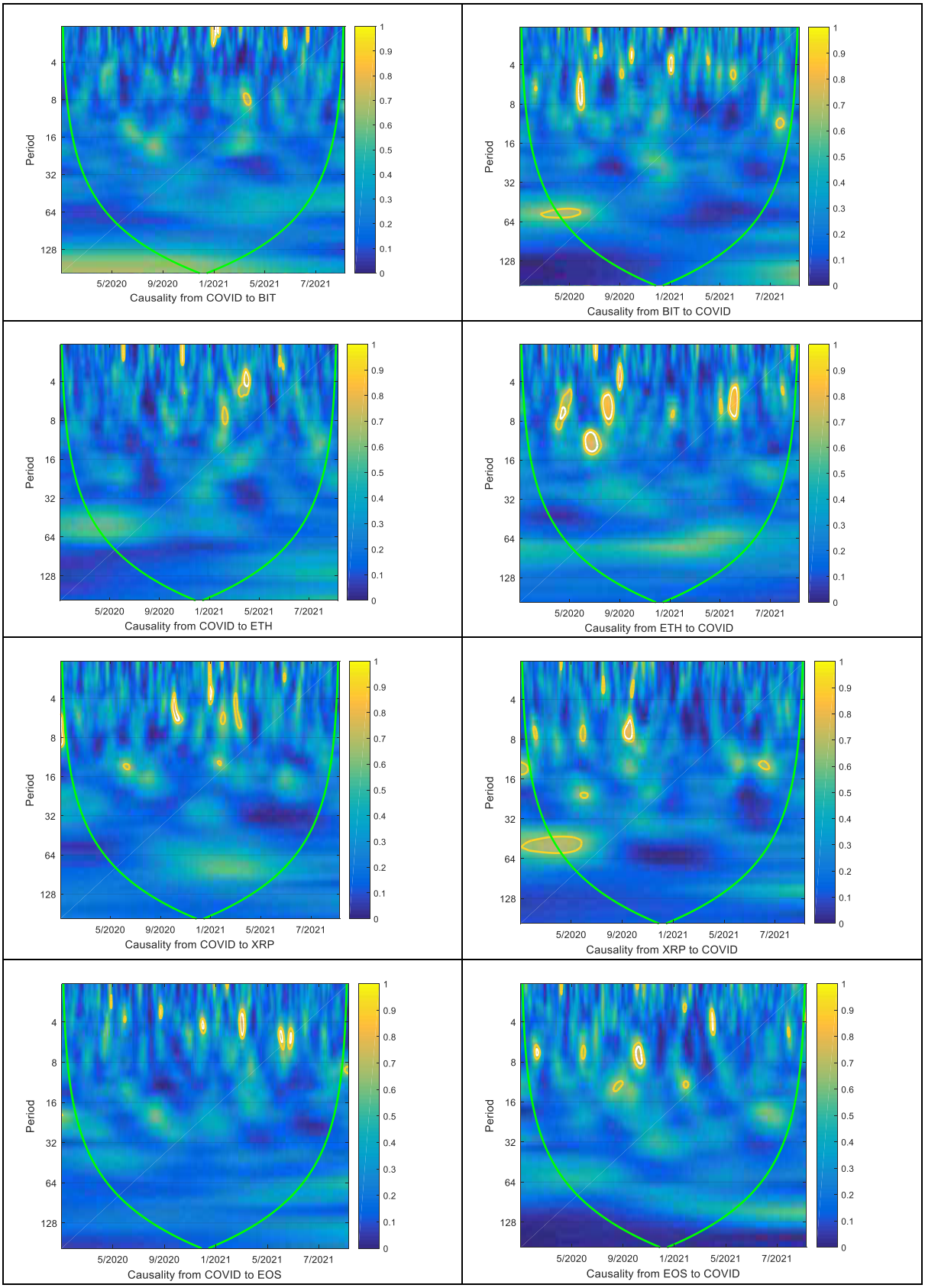

XWT: COVID-ETH
WTC: COVID-ETH
XWT: COVID-XRP
WTC: COVID-XRP
XWT: COVID-EOS
WTC: COVID-EOS
XWT: COVID-BCH
WTC: COVID-BCH
Period
4
8
16
32
64
128
5/2020
9/2020
1/2021
5/2021
7/2021
8
4
2
1
1/2
1/4
1/8
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

Figure 2. Cross-wavelet transform (XWT) and wavelet coherence (WTC) between COVID and cryptocurrency markets.

The outcomes of the cross-wavelet transform between COVID and the selected cryptocurrency indices reflect the local covariance between the two-time series in different time and frequency domains. These figures uncover that covariance eventually increased with scale, which means that the interdependence between COVID and cryptocurrencies was more impacted by long-run and persistent changes than by short-lived shocks. Specifically, the low frequency can be identified when cross-wavelet coherence was relatively high for all pairs during the COVID-19 period shown, while cross-wavelet coherence was lower and short-lived. In addition, information on the phases (shown by the arrows) indicates that the nexus between COVID and cryptocurrencies was not homogeneous through scales, as arrows point up, right, and left through short time scales.

A time-varying wavelet coherence (WTC) and phase difference between COVID-19 sentiment and the examined cryptocurrency prices are displayed in Figure 2. Just like the cross wavelet transform, the WTC is portrayed across a contour plot. The coherence values between the selected pairs co-move through time and frequency, as we can observe intuitively. Overall, both coherence and phase discrepancies are more volatile at higher frequencies and medium-run scales, but they are more stable at the lower frequencies of the 64-128-day scale. More importantly, the largest coherences are found at the medium frequencies of the 16-32-day scale, implying that the COVID-19 sentiment index is most strongly linked to cryptocurrency markets in the short and medium-term, especially in the cases of COVID-XRP and COVID-BIT. This implies that the short and medium-run cryptocurrencies depend strongly on Covid-19 sentiment in unstable periods, but at the beginning of 2021, the long-term correlation decreased, which is consistent with the studies of (Chen et al. 2020; Lahmiri and Bekiros, 2021; Demir et al. 2020). Significant interdependence between COVID-19 sentiment and cryptocurrency markets increased at the 16-32-day scale in the cases of COVID-ETH, COVID-XPR, COVID-BCH, and at the 8-16-day scale for COVID-BIT and COVID-EOH pairs during the COVID-19 outbreak. In terms of arrow direction, we notice that most arrows point up and left or down and left at varying frequencies throughout the crisis time, indicating a negative relationship between the two variables while their lead-lag relationship co-varies over time and across timescales, and cryptocurrencies are leading. Put differently, extreme price fluctuations in all cryptocurrency markets are caused by the COVID-19 sentiment index. This occurs because severe negative sentiment, such as COVID-19, causes major price drops, whereas increases in the sentiment index, particularly in the positive value range, lead cryptocurrency prices to rise. Our findings reveal that COVID-19 sentiments accurately reflect the economy's general health and so contain much substance to explain large swings in significant economic variables.


Period
4
8
16
32
64
128
5/2020
9/2020
1/2021
5/2021
7/2021
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Causality from COVID to BIT
Causality from BIT to COVID
Causality from COVID to ETH
Causality from ETH to COVID
Causality from COVID to XRP
Causality from XRP to COVID
Causality from COVID to EOS
Causality from EOS to COVID

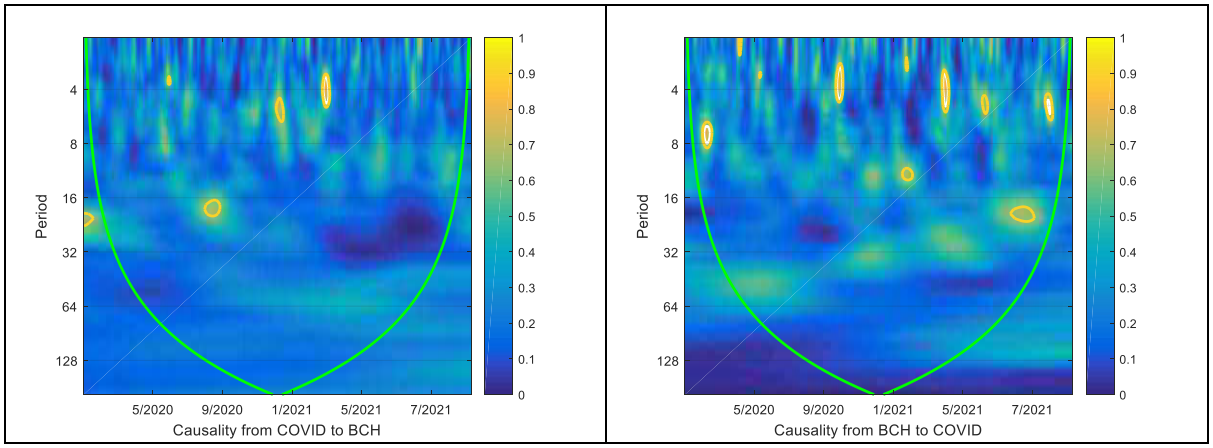


Figure 3. Wavelet based causality from COVID to cryptocurrencies and cryptocurrencies to COVID

Figure 3 depicts the outcomes of the CWT-based Granger causality method of Olayeni (2016) between the COVID-19 sentiment and each of the five cryptocurrency markets. Causal associations are demonstrated across contour plots as three dimensions are involved: frequency, time and magnitude of the causal relationship. More precisely, the strength of causal relationships between the two indices is expressed by a colour code, which spans from dark blue (lack of causal influence) to dark yellow (strong causal influence). The left-hand side of Figure 3 refers to the causal effects of the COVID-19 sentiment on the cryptocurrency markets, whereas the opposite direction is reported on the right-hand side. These plots reveal that the COVID-19 sentiment index has a higher causal effect on the cryptocurrency markets during the research period shown. The strongest causal association with those cryptocurrencies occurred at low and medium frequencies during the COVID-19 crisis. We also find scattered long-run causal relationships from COVID-19 sentiment to all cryptocurrencies through the whole sample period of 64-128 days, which supports the study of Rubbaniy et al. (2021). In addition, the feedback causal association with the COVID-19 sentiment index from the cryptocurrency markets is also evident and significant. Such an outcome is vital since previous studies assumed a unidirectional spillover from COVID-19 sentiments to financial markets, while we unveil that fluctuations in cryptocurrency markets also induce fear in market participants. Extreme sentiments (either positive or negative) cause increased market volatility, which complements the results of the lead-lag relationship. As a result, COVID-19 not only caused a crash in cryptocurrency prices, but also increased market risk.

Overall, we can observe that the COVID-19 sentiment index has a significant relationship with cryptocurrency returns. High positive correlations occurred within the cone of impact in the low and medium run over the COVID-19 crisis. Other than these small patches, the relationship between COVID-19 sentiment and the cryptocurrencies is significantly negative in the medium to long run (64-128 days). It suggests that increases in COVID-19 sentiment are thought to predict higher returns in crisis conditions and lower returns in normal time. This supports the findings of Lahmiri and Bekiros (2021), Sahoo (2021) and Umar and Gubareva (2020), who demonstrate that the COVID-19 sentiment index and cryptocurrency returns have remarkable connections during the COVID-19 outbreak.

5. Conclusion

COVID-19, which was labeled a pandemic on March 11, 2020, halted the global economic activity**.** The essence of this paper is to determine whether the news-based COVID-19 sentiment index introduced by Buckman *et al*. (2020) has any causal association with

cryptocurrency market returns. Our findings uncover a bidirectional relationship between the two variables in the short and medium run. Specifically, negative co-movement between them was found during the COVID-19 crisis. In addition, the COVID-19 sentiment index has a higher causal effect and a significant connection with the five selected cryptocurrency prices. We further find that the feedback causal association on the COVID-19 sentiment index from the cryptocurrency markets is also evident and significant. The possible explanation for this scenario is that governments are imposing more restrictions as the number of reported cases and deaths rises, and these restrictions are likely to increase demand for non-traditional assets. Major cryptocurrencies and blockchain technology have the potential to mitigate some of the challenges that have arisen as a result of the pandemic's new realities. Depending on the COVID-19 cases, investors should take into account the inclusion of cryptocurrencies in their portfolios. They offer benefits in terms of pandemic hedging, but they can also be used as payment and money transfer instruments (Demir et al., 2020). As a result, extreme sentiments cause high price fluctuations in the cryptocurrency markets. Policymakers should be aware that cryptocurrency markets are particularly vulnerable to events such as pandemics. News-based sentiment indexes can provide insight into future developments in the cryptocurrency markets. This study gives cryptocurrency market participants new insights to help them make investment decisions and avoid under or over-investment. The negative impact of the COVID-19 on the selected currencies under study means that the higher volatility of the COVID-19 index reduces the cryptocurrency returns. To put it another way, investors must seek out other investment options that can serve as safe havens during such volatile times. Furthermore, they can use COVID-based sentiment at different time intervals to hedge risk and diversify their portfolios across industries. Future research can look into the COVID-19 transmission channels to financial equity prices.

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Appendix: Robustness analysis

The robustness test is carried out by using wavelet cohesion, a time-frequency approach introduced by Rua (2013) that measures the cross wavelet transform correlation to provide more insights into the co-movement of two variables. He developed the correlation intensity measure $\rho_{x,y}$ as the real number on [-1,1] by considering the wavelet cross spectrum as follows:

$$\rho_{x,y} = \frac{\Re\left(W_n^x W_n^y\right)}{\sqrt{\left|W_n^x\right|^2 \left|W_n^y\right|}}$$

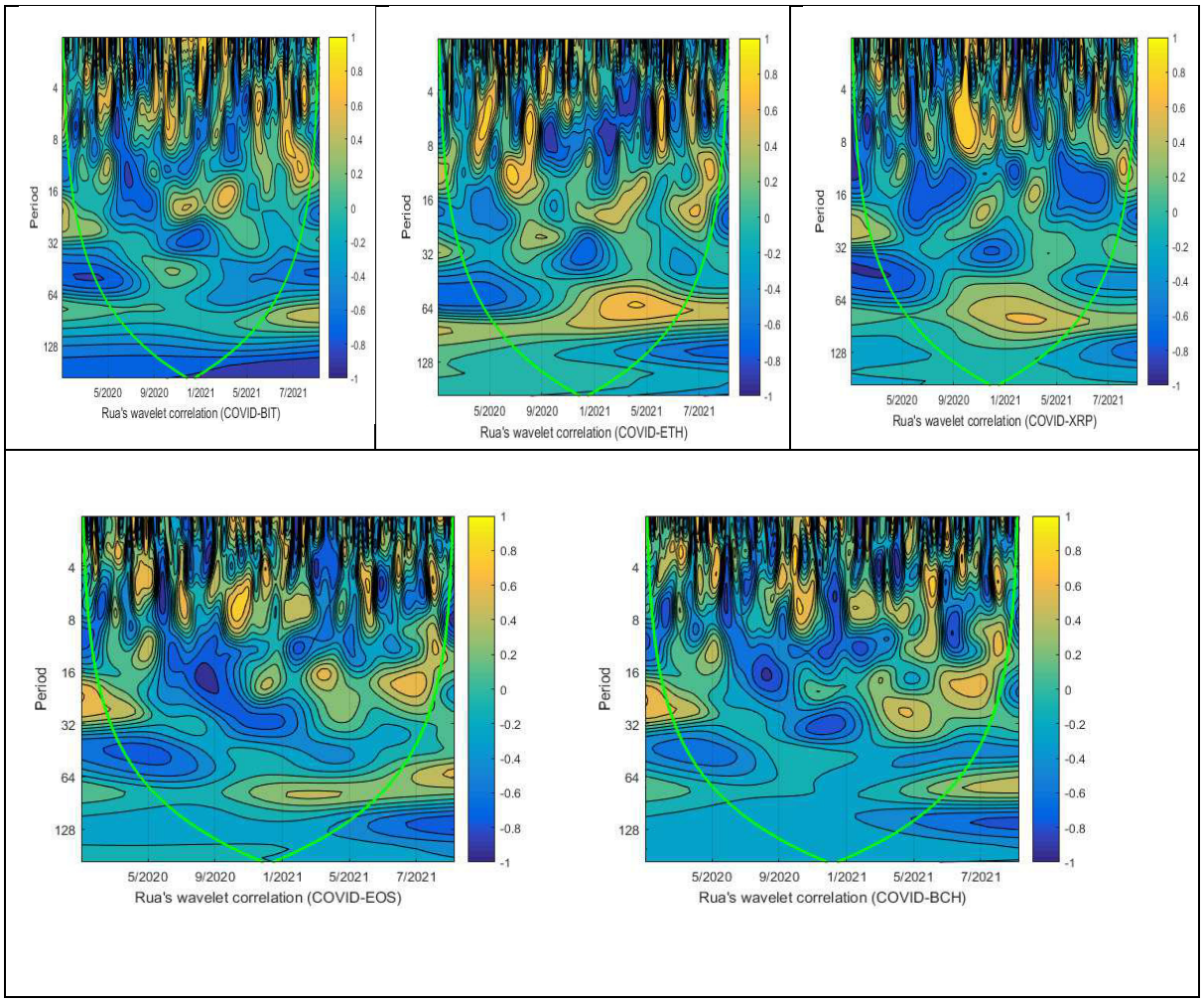

Figure 4. Wavelet-based correlations (Rua, 2013).

In this section, we investigate the robustness of our wavelet-based estimates across the frequency domain causality framework of Rua (2013). Figure 4 shows the link between the COVID-19 sentiment index and the cryptocurrencies under investigation. This technique measures both positive and negative co-movements between COVID and the cryptocurrency

markets, unlike the wavelet coherence transform. It also extracts data on the lead-lag situation. The spectra back up the initial wavelet coherence transform results. At low and medium frequencies, negative connections are blue, whereas positive ones are yellow at long frequencies. All of the pairs have the same interpretation. Wavelet coherence and cross wavelet transform causality conclusions are frequently supported by the plots. In sum, these findings are consistent with what we found using wavelet-based correlation and causality analyses. The COVID-19 sentiment index is seen to cause cryptocurrency markets in the short and medium-term, and vice versa.