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Cryptocurrencies in an uncertain world: Comprehensive insights from a wide range of uncertainty indices

Abstract

This study investigates the impacts of economic policy uncertainty on the Bitcoin market using the monthly data from January 2014 to December 2022. In so doing, six major uncertainty indices (Global Economic Policy Uncertainty, Equity Market Volatility, Twitter-based Economic Uncertainty, Geopolitical risk index, The Cryptocurrency Policy Uncertainty Index, The Cryptocurrency Price Uncertainty Index), and in particular, two novel Cryptocurrency Uncertainty indexes as introduced by *Lucey et al. (2022)* are taken into account. Our findings uncover a negative connectedness between Bitcoin prices and the key selected uncertainty indices, suggesting that higher uncertainties result in lower Bitcoin fluctuation across time and frequency domains. Our results provide valuable information on constructing asset portfolios for investors who have investment strategies entailing Bitcoin since Bitcoin would be a diversifier under economic policy uncertainty shocks. Our results hold robust by using the alternative methodology.

Keywords: Bitcoin; Cryptocurrency policy uncertainty measures; Economic policy uncertainty; Wavelet analysis.

JEL Codes: G15, D81, C22

1. Introduction

"*Risk comes from not knowing what you are doing*".
(Warren Buffet)

In the last couple of years, we have experienced a meteoric increase in Bitcoin prices, a remarkable development in the degree of integration and interconnectedness among cryptocurrency markets and policy uncertainty. During periods of stress, the Bitcoin market has exhibited ups and downs analogous to the macroeconomic indicators, for instance during the European public debt crisis, the Trump Trade War, and the Covid-19 outbreak. There is prima facie evidence of the nexus between Bitcoin and economic outlook (Corbet et al 2020). More importantly, this cryptocurrency spiked in value and gained more ground as many saw it as a shelter from uncertainty surrounding traditional economic and banking systems (Bouri et al., 2017). Fasanya et al. (2021) argue that this increased performance greatly impacts government and financial institutions' likely failure during the Global Financial and European Sovereign Debt crises. Consequently, the Bitcoin-uncertainty nexus has led to higher risk transmission in portfolios and declined the diversification benefit. Recently, several papers have focused on the interlinkage between uncertainties and conventional markets including stock, bond, and foreign exchange markets (see, e.g., Gozgor et al. 2019; Wu et al. 2019; Demir et al. 2018; Panagiotidis et al. 2019; Wang et al. 2019; Bouri et al. 2017). Despite the longstanding debate on uncertainty and its consequences for the economy and financial markets, our understanding of the role of uncertainty and its effects on cryptocurrencies, including Bitcoin is very limited (Lucey et al, 2022; Huynh et al. 2021). Nonetheless, the high levels of uncertainty and economic and financial instability have increased the appetite for alternative assets that can provide a hedge against exposure risk, inflation, and uncertainties to gain the benefits associated with the diversification of portfolios (Fasanya et al., 2021). On this aspect, a number of studies have explored the notion of Bitcoin being a safe haven or a hedge (see, Corbet et al, 2018; Shahzad et al 2019; Bouri et al 2020; Corbet et al., 2020b), however, the nexus between the Bitcoin and remains uncertainty is underexplored in parallel to the some of the research gaps identified in Cryptocurrencies' literature[1]. To address this caveat, we drew on the recent work by Lucey et al. (2022) and aim to analyze the implications of uncertainty for the cryptocurrency market.

The global economy and financial system have suffered from high uncertainties in recent years, particularly the economic and policy-associated uncertainties in advanced and developing

[1] See Corbet et al (2019) for a systematic analysis on the Cryptocurrency and gaps in the existing body of knowledge.

countries (Brexit, Trade War and most recently COVID-19). Some studies explored how uncertainties and risks influence Bitcoin markets (Gozgor et al., 2019). Economic and policy uncertainties play a prominent role in a certain economy's economic growth, and any uncertainty associated with the policies slows down the growth process. Supporting this view, Wu et al. (2019) have argued that Bitcoin is affected by the EPU shocks. In the same vein, Fang et al. (2019) have pointed out that global economic policy uncertainty negatively influences the Bitcoin-bonds relationship. Demir et al. (2018) have reported that the EPU has predictive power on the Bitcoin returns, especially a negative nexus between the EPU and Bitcoin returns. In their study, Wang et al. (2019) asserted that the US EPU and equity market uncertainty indexes significantly influence Bitcoin prices. Bouri and Gupta (2019) reveal that Bitcoin is a hedge against the ability of two measures of uncertainty, namely newspaper-based and internet search-based measures. Among the most recent studies, Fasanya et al. (2021) have investigated the relationship between Bitcoin prices and US economic policy uncertainty and found that the economic policy uncertainty has considerably impacted the interaction between Bitcoin and precious metal markets.

Al-Yahyaee et al. (2019) employed the wavelet analysis to examine the co-movement between Bitcoin and uncertainty indices (US Economic Policy Uncertainty index, the Crude Oil Volatility index, and the Geopolitical Risk index). Their results showed that the Bitcoin-uncertainty indices are dependent on the investment horizon. Similarly, Aysan et al. (2019) reported that GPR has predictive power for both returns and price volatility of Bitcoin and confirmed that Bitcoin can be considered as a hedging tool against global geopolitical risks. However, Su et al. (2020) also pointed out that there are positive and negative impacts of global geopolitical risks on the Bitcoin market. It must be acknowledged that the impact of uncertainty on the Bitcoin market is not always consistent. For instance, Colon et al. (2021) have documented that Bitcoin reacts to uncertainty differently, depending on the kind of uncertainty. Specifically, they found that the Bitcoin market can serve as a strong hedge against geopolitical risks. On the contrary, while investigating whether the volatility of Bitcoin is impacted by global economic policy uncertainty, Fang et al. (2019) have indicated that global economic policy uncertainty has a negative influence on Bitcoin. Concomitantly, the evidence on the impact of uncertainty on the Bitcoin market is not clear, furthermore, the approaches to account for the uncertainty remained limited. In this context, the subject study focuses on the impact of six major uncertainty indices (Global Economic Policy Uncertainty, Equity Market Volatility, Twitter-based Economic Uncertainty, Geopolitical risk index, the Cryptocurrency Policy Uncertainty Index, and The Cryptocurrency Price Uncertainty Index) on Bitcoin prices.

Specifically, the novel *Cryptocurrency Uncertainty Index*, as introduced by (Lucey et al. 2022), is used as an effective measure of uncertainty during the Covid-19 pandemic since these indexes capture uncertainty more distinctively than typical uncertainties such as Economic Policy Uncertainty (EPU) and global EPU. Concomitantly, the objective of this study is to investigate the nexus between Bitcoin and uncertainty indexes across time and frequency domains while employing a comprehensive approach to the latter.

It is vital to note that policy uncertainties in connection with the economy can influence Bitcoin as well. Especially during high-stress periods, uncertainty in the fiscal policy of governments and monetary policy of central banks have demolished the safe-haven characteristics of conventional assets. The recent Covid-19 outbreak crisis shows that uncertainties can considerably impact the cryptocurrency markets (Wu et al. 2021). This study aims to investigate the influences of policy uncertainties on the Bitcoin market using the wavelet framework, specifically, continuous cross wavelet transforms, wavelet coherence, and Rua (2013) cohesion, to gauge the magnitude of the effects that uncertainties have on the Bitcoin market. Our primary hypothesis is that the variations in the uncertainty indices may have a significant influence on Bitcoin prices. We depart from the previous literature by concentrating on four major uncertainty indexes (Global Economic Policy Uncertainty, Equity Market Volatility, Twitter-based Economic Uncertainty, Geopolitical risk index) and two novel measures of the EPU (Cryptocurrency Policy Uncertainty Index and the Cryptocurrency Price Uncertainty Index), which are introduced by Lucey et al. (2022). Our empirical analyses account for the Covid-19 outbreak period. To the best of our knowledge, this is the first study in the literature to look into the impacts of two novel measures of the EPU (UCRYPO and UCRYPR) on the cryptocurrency market using the wavelet analysis, which can explore the causal association between the time series. Our key findings suggest a negative relationship between Bitcoin and the selected uncertainty indices at different time and frequency domains. There are three main contributions this study makes to the existing literature. First, this paper used the wavelet analysis to capture the co-movement between the key uncertainty indices and Bitcoin prices at different time horizons, including short, medium, and long-term, and identify whether these indices co-vary or not. The heterogeneous direction of arrows gives clear evidence that the causal association between the selected variables co-moves through time and frequency domains. Second, based on our empirical findings, we found that the selected uncertainty indices have a negative impact on the Bitcoin market during the period studied, which implies that uncertainty-netted economic policies are associated with a decrease in Bitcoin prices. Finally, our paper extends the literature by investigating the lead-lag relationship between Bitcoin prices and two novel measures of the

EPU (UCRYPO and UCRYPR) proposed by Lucey et al. (2022). These indices can be utilized to evaluate how policy uncertainty impacts Bitcoin prices, which might help systematically understand the behaviour of a wide range of investors in the Bitcoin market.

The rest of the paper is organized as follows. Section 2 briefly introduces the methodology used. Section 3 reports the empirical results, and Section 4 concludes.

2. Methodology

In this paper, we employ a wavelet framework which is a powerful technique to look into the localized frequency elements of a time series without losing time-specific information (Cai et al. 2020). It has significant advantages over fundamental Fourier transform analysis which can decompose the time series into sines and cosines of infinite length, discarding all time-localized information. Previous studies have confirmed that wavelet analysis is efficient in grabbing the true essence of co-movement by taking into consideration the relevance of frequency in determining the extent and intensity of the effect along with the crucial time information. According to Kang et al. (2019), the wavelet approach is developed as a practical framework to explore such ambiguous interlinkage between time series. First, continuous wavelet transform is used to analyze the localized volatility in the selected variables. Second, we utilize cross-wavelet transform, wavelet coherence, and Rua (2013) cohesion to examine the interdependence and lead-lag correlation structure in the nexus between the two series. The application of this set of approaches has been adopted by a few recent studies (Jun et al., 2018; Alam et al., 2019; Kang et al., 2019; Cai et al., 2020; Hung, 2020; Khan et al., 2020).

There are several reasons for our methodological selection for the time-domain analyses of the Bitcoin uncertainty nexus. First, the cross-wavelet transform known as a nonparametric free model allows for an in-depth analysis of potentially non-linear time series properties of aggregates and their lead-lag nexus through various time scales (short, medium, and long horizons). Theoretically, the long-term and short-term relationship may have a polarizing impact on the causal associations' received understanding. Second, the possibility of considering the time series, both time and frequency would be more attractive in finance and economics than either time or frequency alone because the selected variables occasionally rely on regime shifts and structural breaks and outliers and clustering (Tiwari et al. 2019). Third, in the time domain, the applications of various econometric tools and significant tests require the stationarity of the time series. Therefore, we miss the chance of classifying the frequency variations in the selected variables. The wavelet techniques relax the stationary characteristics by giving the chance of observing the variables in both time and frequency domains. More

specifically, this approach allows us to jointly evaluate co-movement and casual associations across time and frequency levels. Furthermore, the use of the wavelet approach to predict the Bitcoin market is a ubiquitous phenomenon in the financial world (Rua, 2013; Jun et al. 2018). Concomitantly, for these reasons, our study explores the nexus between the Bitcoin market and the uncertainty indices based on the chosen set of novel approaches.

3. Data

We employ the monthly frequency data for Bitcoin price (BIT) with six major uncertainty indexes, namely, Global Economic Policy Uncertainty (GEPU), Equity Market Volatility (EMV), Twitter-based Economic Uncertainty (TEU), Geopolitical risk index (GPR), The Cryptocurrency Policy Uncertainty Index (UCRYPO) and The Cryptocurrency Price Uncertainty Index (UCRYPR). The period of the analysis is from January 2014 to December 2022, which is primarily based on the data availability. This period contains financial crises and market turmoils, including the European Debt Crisis (2014-2015), the oil price plunge in mid-2014, the Covid-19 pandemic (2020-2021) and the Russia-Ukraine war. Bitcoin prices are collected from Coindesk.com, while the rest of the other uncertainty indices are obtained from www.policyuncertainty.com. All related variables have been converted into a logarithmic difference series.

The indices of TEU, GEPU, EMV and GPR are constructed by searching for articles containing the words like 'economic,' 'economy' and other words about economic policy from 10 large newspapers in the US and collected from the website (https://www.policyuncertainty.com/). For example, the TEU index is based on keywords in connection with uncertainty in the economy. The global GPR index is based on automated text-search results from the electronic archives of 11 international newspapers (Caldara and Iacoviello, 2018). The GEPU index is a GDP-weighted average of 21 countries' EPU indexes. The newspaper method is also used to create the EMV index (Li et al. 2022). The UCRYPO and UCRYPR indices used in this paper are introduced by Lucey et al. (2022), based on the Lexis Nexis Business Database, which covers a wide range of newspaper news-wire feeds to realize the social aspect of cryptocurrencies. The advantage of the UCRYPO and UCRYPR indexes is that they cover the primary events from 2014 to 2022, namely Covid -19 outbreak, cyberattacks on cryptocurrency exchanges and political elections (Lucey et al. 2022), and they allow us to capture the co-movement between cryptocurrency markets and uncertainty indexes, particularly during turmoil periods. Therefore, this data conveys negative information about the cryptocurrency prospects in its development.

Figure 1 shows the trends of six uncertainty indices from 2014 to 2022. Six uncertainties are generally quite volatile during 2020-2021 due to the COVID-19 outbreak. Specifically, we find that geopolitical risks are at their highest in 2022, a period in which we have Russia-Ukraine war. The other series are fairly unstable, fluctuating within a specific range.

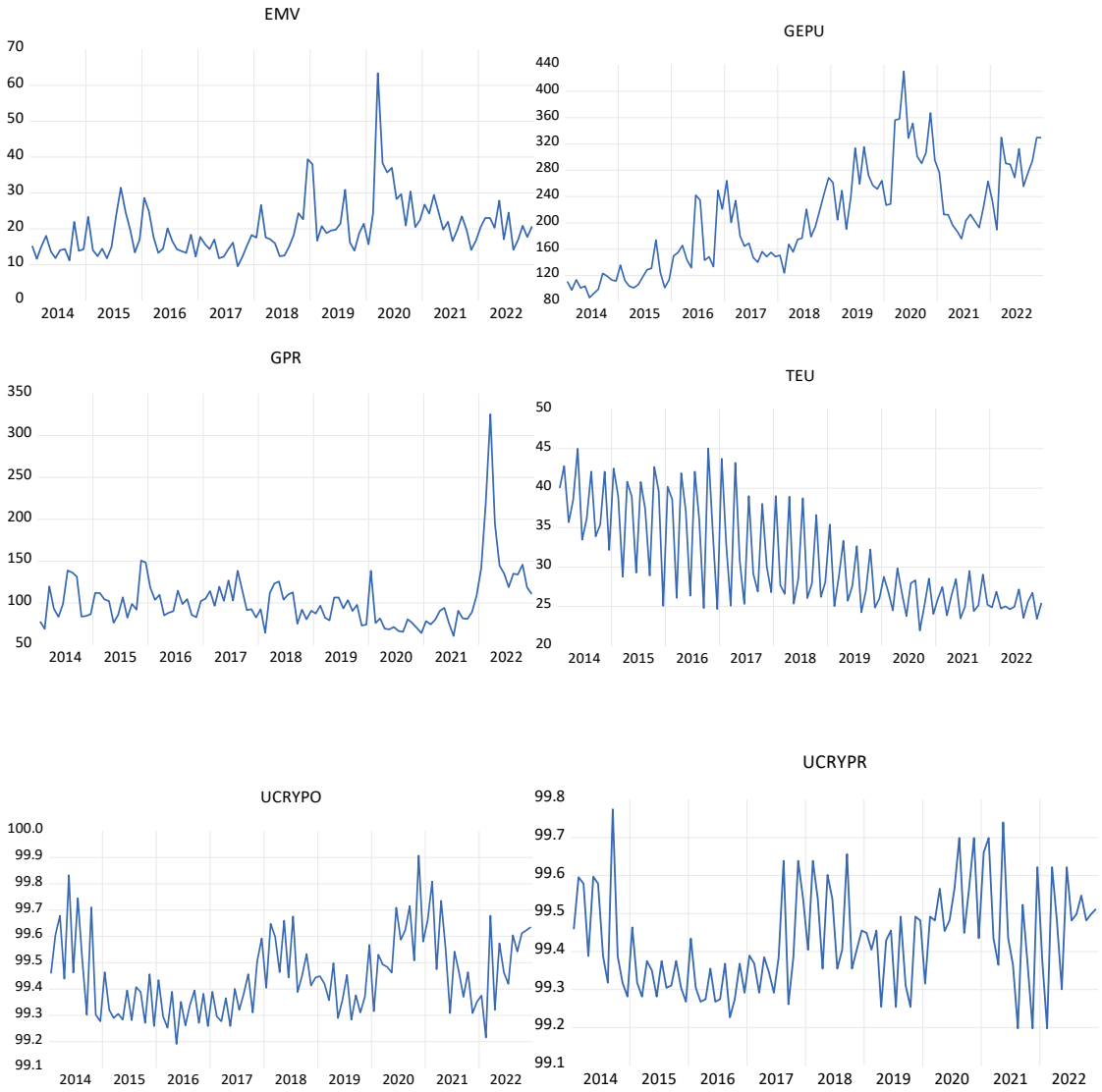

Figure 1. Index of six uncertainties

Descriptive statistics for the variables under examination are given in **Table 1**. These figures reveal that BIT markets appear to be more volatile than uncertainty indices. Interestingly, all mean of the series experience positive values. Furthermore, these indicators are positively skewed, except for BIT, and the value of the kurtosis is higher than two showing that each of the concerned variables has a fat and asymmetric tail. However, it can be noted that all-time series follow normal

Table 1. Summary descriptive statistics for the variables

	GPR	EMV	GEPU	UCRYPO	UCRYPR	TEU	BIT

Mean	4.590986	2.930925	5.248477	4.599662	4.599427	3.412656	7.880828
SD	0.266745	0.327939	0.388438	0.001511	0.001340	0.200633	1.947247
Max	5.785128	4.148892	6.064387	4.604238	4.602915	3.807192	11.02369
Min	4.104322	2.258589	4.457739	4.597046	4.597115	3.089385	3.508556
Skew.	1.132727	0.740191	-0.131019	0.678121	0.481586	0.498770	-0.137568
Kurt.	5.968375	3.795844	1.985504	2.897125	2.504353	1.827445	1.768090
J-B	62.74588***	12.71203***	4.940394*	8.324888*	5.280150**	10.66488***	7.169855**

******* Significance at the 1%, 5% and 10% level.

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distribution. This implies that these indicators are normally distributed. The findings of the Jarque-Bera (J-B) test also tally with the aforementioned deviations from the normal distribution.

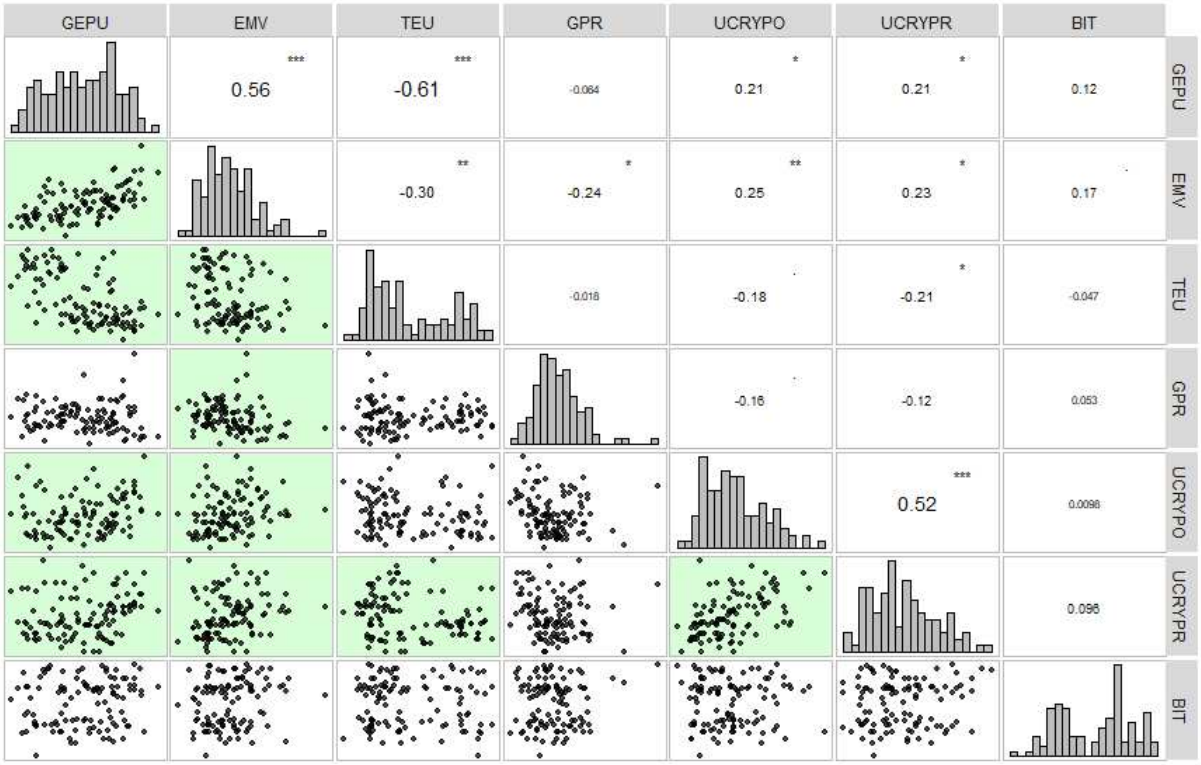


Figure 2. Plots of the distribution and the pair-wise unconditional correlations of BIT and other uncertainty indices.

The overall distribution of the data and the pair-wise correlations between the variables under investigation are shown in **Figure 2**. It is apparent that the data used have a normal distribution. Specifically, the coefficient correlation between BIT and other indicators is not statistically significant, while the highest correlation found between GEPU and EMV is equivalent to 0.56.

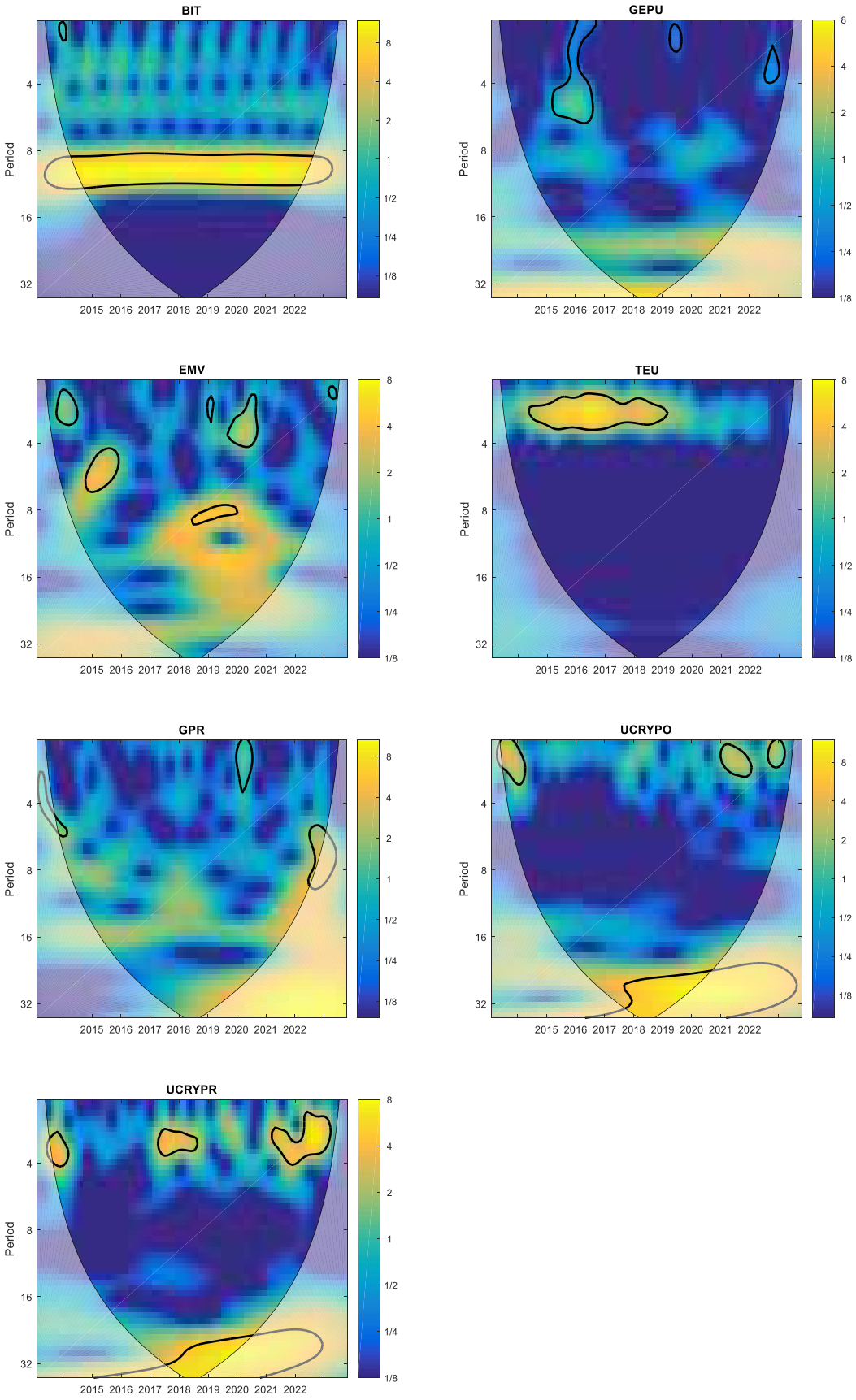


Figure 3. Continuous wavelet power spectrum for Bitcoin and related uncertainty indices (monthly series).

Figure 3 describes the outcomes of the continuous wavelet power spectrum for BIT and other indices under examination. We can easily see that in cases of BIT, GPR, EMV, UCRYPO, and UCRYPR, there are patterns of robust variances in plenty of small, medium, and long-run periods. More importantly, BIT shows a high variance in the medium scale but lacks in the long run. As for GPR, EMV, UCRYPO, and UCRYPR, strong variance mainly exists at a small time scale throughout the sample period. Nevertheless, there seems a significant variance for TEU and GEPU at low and medium frequencies for the whole research period. Obviously, the common regions between the related variables are easily observed from 2015 to 2016 and later in 2019-2022, spanning the so-called European debt crisis and the Covid-19 outbreak. The seven variables exhibit high volatility during the crises. These outcomes also support the studies of Colon et al. (2021), Wu et al. (2021) and Huynh et al. (2021), who call attention to the remarkable rise in Bitcoin prices and other uncertainty indexes during crisis periods.

We employed the continuous wavelet methodology to decompose the data into four levels spanning various holding periods, namely, short-, medium- and long-term investment horizons. **Table 2** reports the wavelet scale for more details, which shows detailed information on the raw data.

Table 2. Corresponding association between time and scale.

Detail	Wavelet Scale	Frequency
D_1	1	2-4 months
D_2	4	4-8 months
D_3	8	8-16 months
D_4	>16	16-32 months

4. Empirical Results

The cross-wavelet transform enables to experience particular high power between Bitcoin-uncertainty pairs in **Figure 4**. The cross-wavelet transform unveils the domestic covariance between Bitcoin and related uncertainty indexes at various scales and periods. The yellow (blue) colours suggest high (low) power, and the yellow (warmer) colours represent that the two variables have high joint power. By contrast, the blue (cooler) colours show BIT and related series have lower power. Besides, arrows show the direction of correlation and lead-lag connectedness. If the arrow points right (left), there exists a positive (negative) relationship between the two series. Arrows pointing up and to the right illustrate BIT leading, and those down and to the right reveal BIT lagging. On the other hand, arrows pointing down and to the left show BIT leading, while those up and left show BIT are lagging.

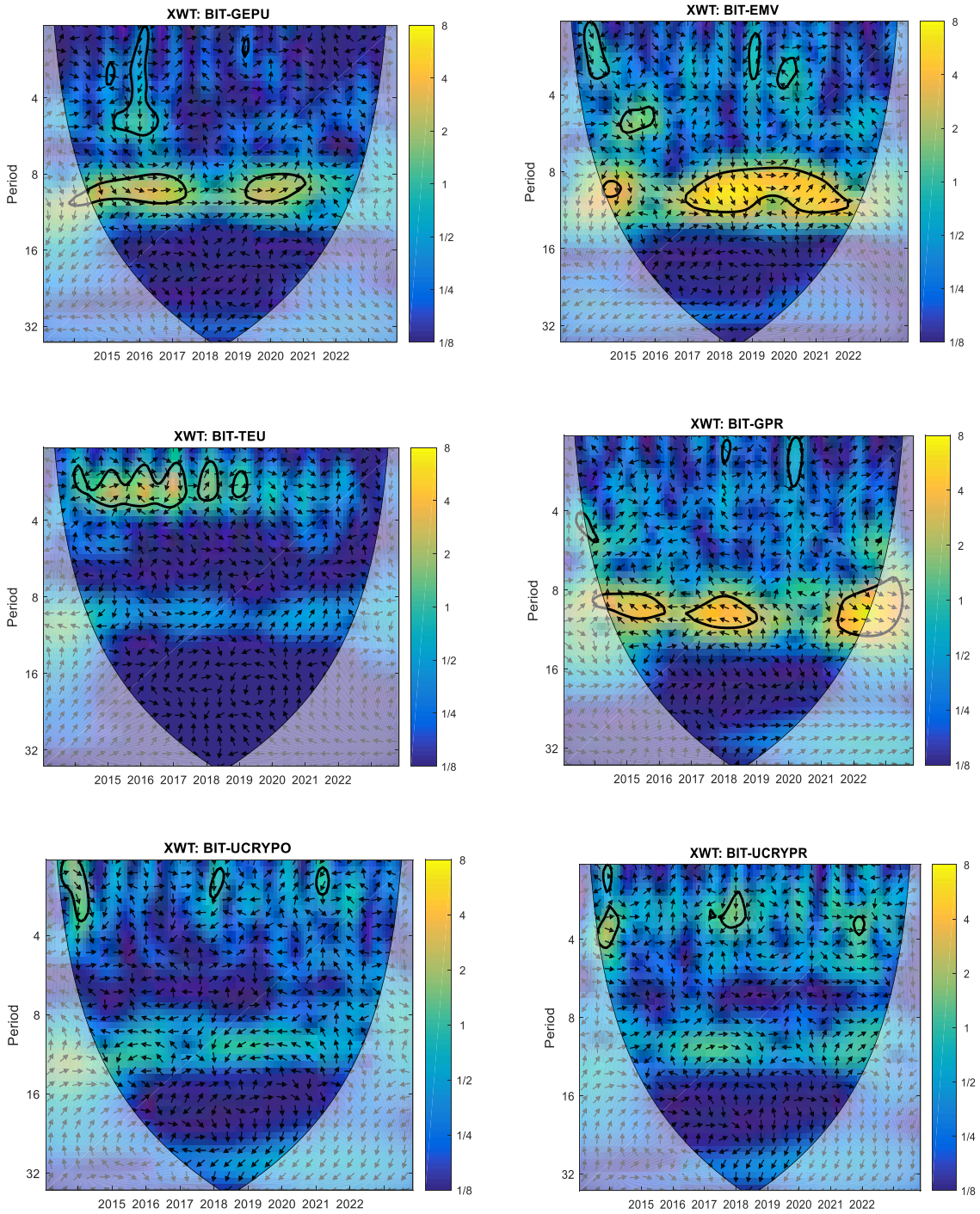
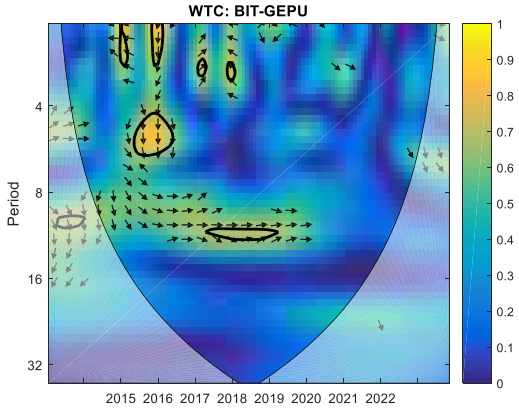
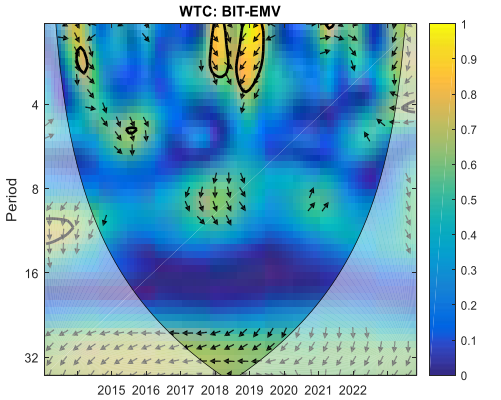


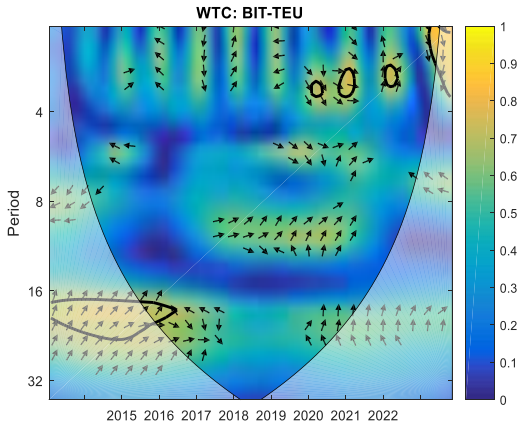
Figure 4. Cross-wavelet transforms between Bitcoin and other uncertainty indices. The arrows demonstrate the relevance direction and lead-lad correlation structure. If the arrow points right (left), the pair has a positive (negative) relationship.

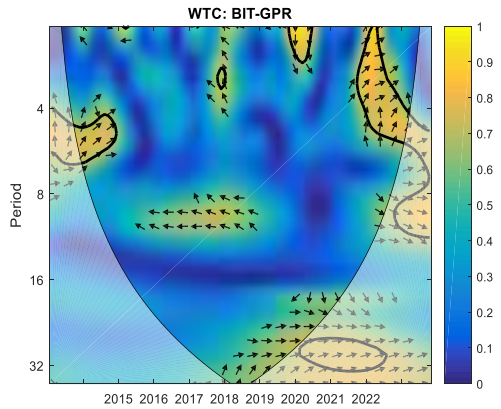
A look at **Figure 4** shows that pairs of BIT-GPR, BIT-EMV, BIT-GEPU, BIT-UCRYPO, and BIT-TEU have significant yellow noise throughout the sample period, which means that there is a robust causal association between the pairs. Putting it another way, the interdependence between BIT and other related uncertainty indices is statistically significant at low and medium frequencies, indicating that the two series have the same variation in the long run, except BIT-

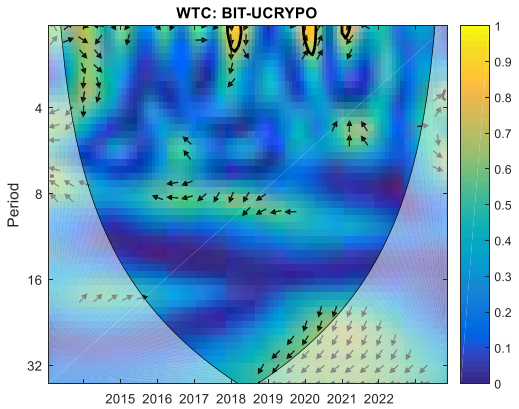
UCRYPR pair. This may reasonably be explained by the unremitting increase in Bitcoin prices during the sample period. Overall, the outcomes uncover that the fluctuation of the time series under consideration exhibited fundamental changes during the period shown, which implies that these pairs are exposed to long-term fluctuation. Besides, even though there is significant interdependence between the variables at different scales, various directions are found with timescale differences, as shown by arrows pointing up, down, right, and left across time and scales, which means that there is a lead-lag connection among the pairs at different time and frequencies.











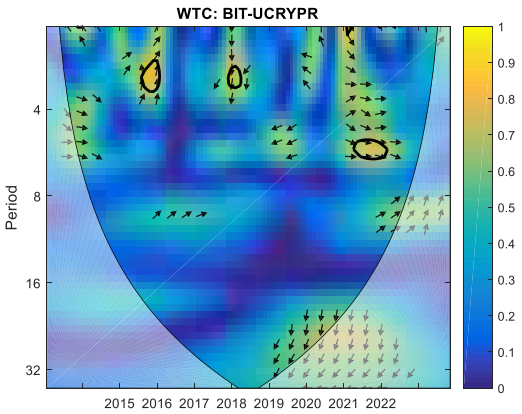


Figure 5. Wavelet transform coherence of BIT and other uncertainty indices. The phase difference arrow is determined by a value greater than 0.5. Island inside the black contour plotted in warmer colour indicate strong interdependence. The arrows pointing right and left and up and down illustrate the correlation direction and lead-lag nexus.

In this section, the co-movements and lead-lag connections between BIT and other related uncertainty indexes are taken into account using pairwise wavelet coherence plots, as shown in **Figure 5**. The thick black contour describes the statistically significant regions at the 5% significant level estimated from Monte Carlo simulations. The colour code for power ranges goes from blue (low power) to yellow (high power). The warmer areas show that the pairs have a strong relationship, while cooler areas represent that the two variables are less dependent. The arrows indicate the phase difference between BIT and related uncertainty indexes. The indicators are in phase if arrows point to the right (positive correlation). The BIT is leading if the arrows point to the right and up. On the other hand, uncertainty indexes are leading if the arrows point to the right and down. Moreover, the time series are out of phase if the arrows point to the left (negative correlation). The BIT is leading if arrows point to the left and up, whilst uncertainty indexes are leading if the arrows point to the left and down.

Figure 5 highlights six various episodes. The graphs' pair of wavelet coherence unveil that BIT and related uncertainty indices under consideration exhibit a statistically significant relationship depending on timescales and periods. More specifically, a somewhat high opposite co-movement between the two variables at low and medium frequencies (2-4 and 4-8) months of the period is dramatically perceived. Furthermore, this negative association occurs in the 2015-2019 sample period. The BIT-uncertainty relationship illustrates high coherence in the cases of BIT-GPR, BIT-GEPU, and BIT- UCRYPO. The casual association between these variables exists at all scales, namely short, medium and long term throughout the sample period. The highest level of coherence was recorded at scales ranging from 8 to 16-month scales over the sample period. The arrows are pointed to the left and down, which indicates BIT and GPR, GEPU, and UCRYPO are anti-phase, showing BIT is leading. The reason behind the opposite association between these variables might be attributed to the influence of the variation of Bitcoin prices on GPR, GEPU and UCRYPO. An intensification of the GPR, GEPU, and UCRYPO results in increases in the Bitcoin market. In the long period, wavelet transform coherence's outcomes failed to represent a conclusive relationship between BIT, UCRYPO, EMV, and TEU. However, there are many significant islands with high wavelet coherence in 2-4-month and 6-8-month scales, corresponding to the periods 2016-2018 and 2019-2020, respectively. The wavelet coherence between BIT, GPR, UCRYPR and GEPU after 2021

revealed that the pairs are in-phase in 2022 in the short and medium run (right-up arrows). In 2022, GPR, UCRYPR and GEPU positively led BIT at 4-8 month and 8-16 month scale, indicating a rise in these uncertainties increases BIT. These outcomes provide a better understanding for investors to offset Bitcoin's influences by manipulating the uncertainties. Nevertheless, in cases of BIT-GEPU, BIT-TEU and BIT- UCRYPO pairs, Figure 4 documents that they are out-phase (left-down arrows) in 2022 at all different frequencies, which implies that uncertainties lead BIT across short-, medium- and long-run investment horizons. Put differently, changes in these uncertainties impact BIT, hence declining Bitcoin's ability to defend against policy innovations, validating BIT as a safe-haven instrument against uncertainties as confirmed by past articles (Bouri and Gupta, 2019). We document the outcomes of the wavelet coherence based on three major periods, namely, short, medium, and long-term, summarized in **Table 3.**

Table 3. Wavelet coherence findings summary

Frequencies	Cross-wavelet coherence
BIT-GPR	
High frequency	↑ *BIT* →↓ *GPR*
Medium frequency	↑ *BIT* →↓ *GPR*
Low frequency	↑ *BIT* →↓ *GPR* ↑ *BIT* →↑ *GPR*
BIT-EMV	
High frequency	↑ *BIT* →↑ *EMV*
Medium frequency	↑ *BIT* →↓ *EMV*
Low frequency	↑ *BIT* →↓ *EMV*
BIT-GEPU	
High frequency	↑ *BIT* →↓ *GEPU*
Medium frequency	↑ *BIT* →↓ *GEPU* ↑ *BIT* →↑ *GEPU*
Low frequency	↑ *BIT* →↓ *GEPU*
BIT- UCRYPO	
High frequency	↑ *BIT* →↑ UCRYPO
Medium frequency	↑ *BIT* →↑ UCRYPO ↑ *BIT* →↓ UCRYPO
Low frequency	↑ *BIT* →↑ UCRYPO ↑ *BIT* →↓ UCRYPO
BIT- UCRYPR	
High frequency	↑ *BIT* →↑ UCRYPR
Medium frequency	↑ *BIT* →↓ UCRYPR
Low frequency	↑ *BIT* →↓ UCRYPR
BIT-TEU	
High frequency	↑ *BIT* →↓ *TEU*
Medium frequency	↑ *BIT* →↓ *TEU*

Low frequency	$\uparrow BIT \rightarrow \uparrow TEU$ $\uparrow BIT \rightarrow \downarrow TEU$

Notes: $\uparrow$ denotes an increase in, $\downarrow$ denotes a decrease in, $\rightarrow$ denotes the variable on the left side of arrow leads the variable on the right side of the arrow.

Our results also confirm the notion that the dynamics of Bitcoin are driven by uncertainties, especially during the times of crisis such as the COVID-19 pandemic (Chen, Liu and Zhao, 2020). Our findings also suggest that the high fear, as well as the uncertainties, could negatively predict Bitcoin trading. More importantly, the recent study by Huynh et al (2021) emphasized the economic mechanism of the widening value in the bid-ask spread. Concomitantly, the pessimistic risk premium and the theory of deteriorating liquidity are the relevant theoretical concepts to explain the changes in Bitcoin returns and trading volumes, which emphasizes in the recently published papers when using the political uncertainties in terms of the US Partisan Conflicts (Umar et al., 2021). It is worth acknowledging that the study by Umar et al. (2021) put solid and sound arguments for using a wavelet-based quantile-on-quantile causal approach; thereby our study takes an inclusive approach by using the novel data as well as more insightful perspectives.

Wavelet-Based Granger Causality

Wavelet-based Granger causality tests are carried out to examine the bidirectional causality between the concerned indicators. The findings of Granger causality tests were based on four frequency domains (D1-D4) documented in **Table 4**. The outcomes suggest that uncertainties under consideration have significant impacts on BIT in the medium and long run. However, BIT has no causal effects on the EMV, GPR in the medium term, and TEU in all frequencies. Overall, there is bidirectional causality between Bitcoin and interested uncertainties in the long run during the sample period, which supports the results of wavelet coherence.

Table 4. Results of Wavelet-based Granger Causality Test at Different Time Scales for Bitcoin and Uncertainties

		Null Hypothesis			
		BIT does not cause Uncertainty		Uncertainty does not cause BIT	
Time domain	Result	F-test	P-value	F-test	P-value
BIT-EMV					
D1	$BIT \rightarrow EMV$	2.89077	0.0601	0.09717	0.9075
D2	**No causality**	0.32902	0.7204	0.05261	0.9488
D3	$EMV \rightarrow BIT$	2.09898	0.1279	21.5726	0.000
D4	$EMV \rightarrow BIT$	2.34620	0.1009	142.856	0.000
BIT-GPR					
D1	$BIT \leftrightarrow GPR$	5.58929	0.0050	3.54793	0.0324

D2	**No causality**	0.17113	0.8430	0.03105	0.9694
D3	$BIT \leftrightarrow GPR$	6.04470	0.0033	27.3260	0.000
D4	$GPR \rightarrow BIT$	1.20961	0.3026	42.2151	0.000
BIT-GEPU					
D1	**No causality**	1.37090	0.2586	1.02981	0.3608
D2	$BIT \leftrightarrow GEPU$	2.85329	0.0623	10.4894	0.000
D3	$GEPU \rightarrow BIT$	1.88526	0.1571	6.38885	0.0024
D4	$BIT \leftrightarrow GEPU$	4.17346	0.0181	283.953	0.000
BIT-TEU					
D1	**No causality**	0.10461	0.9008	0.01829	0.9819
D2	$TEU \rightarrow BIT$	0.34824	0.7068	13.8385	0.000
D3	$TEU \rightarrow BIT$	0.44222	0.6438	32.3941	0.000
D4	$TEU \rightarrow BIT$	0.24848	0.7805	356.271	0.000
BIT- UCRYPO					
D1	**No causality**	0.82415	0.4415	1.92518	0.1512
D2	**No causality**	0.40449	0.6684	0.14687	0.8636
D3	$BIT \rightarrow$ UCRYPO	16.0542	0.000	1.22611	0.2978
D4	$BIT \leftrightarrow$ UCRYPO	2.77426	0.0672	5.14645	0.0074
BIT- UCRYPR					
D1	UCRYPR $\rightarrow BIT$	2.09135	0.1288	3.73135	0.0273
D2	UCRYPR $\rightarrow BIT$	1.18069	0.3113	3.05089	0.0517
D3	$BIT \leftrightarrow$ UCRYPR	10.2679	0.000	3.51601	0.0334
D4	UCRYPR $\rightarrow BIT$	0.88139	0.4174	3.14834	0.0472

5. Robustness Check

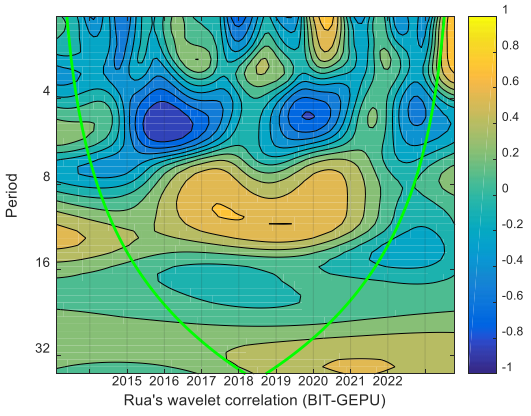
The robustness check is conducted by employing the wavelet cohesion, which is a time-frequency approach introduced by Rua (2013) that measures the cross-wavelet transform correlation to provide more insights with regard to the co-movement between two variables. Rua (2013) developed the correlation intensity measure $\rho_{x,y}$ as the real number on [-1,1] by considering the wavelet cross-spectrum as follows:

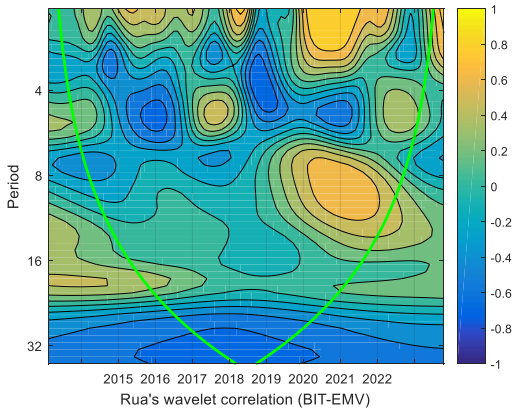
$$\rho_{x,y} = \frac{\Re\left(W_n^x W_n^y\right)}{\sqrt{\left|W_n^x\right|^2 \left|W_n^y\right|}}$$

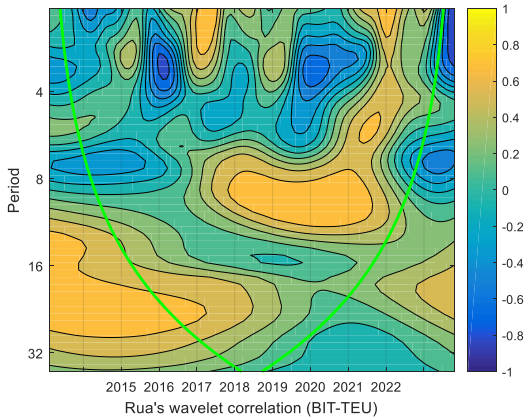
This technique estimates both positive and negative co-movements between Bitcoin prices and other related uncertainty indexes, unlike wavelet coherence transform, falls to extract information about the lead-lag status. **Figure 6** plots the Rua correlation between the Bitcoin market and the related uncertainty indices under examination. The spectra reinforce the initial wavelet coherence transform's results. The negative associations are represented by blue colour

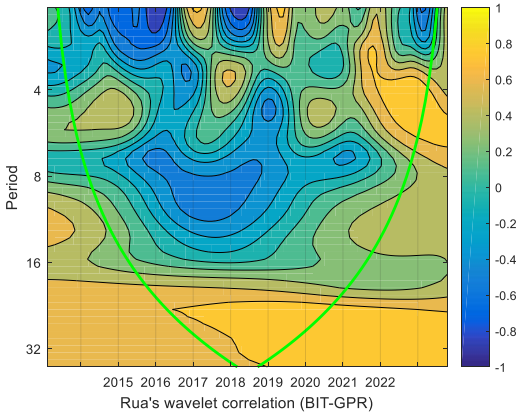
at low and medium frequencies, while the positive connections are found by yellow colour at the long frequency. A similar interpretation holds for all pairs.

We found that the Bitcoin prices and the selected uncertainty indexes significantly correlate in the short and medium-term (lower frequencies), and this relationship persists during the study period. More importantly, the GPR, GEPU, UCRYPO, and EMV have a negative impact on Bitcoin prices at different time and frequency domains; the intercorrelation increases to peak during the Covid-19 outbreak (around 2020-2022). These outcomes are consistent with those of Huynh et al. (2021), and Chen et al. (2020). Furthermore, the lead-lag correlation structure between any of the two pairs is clear. The evidence of unidirectional causality is in line with the scenario that GPR, GEPU, UCRYPO, and EMV indices offer information about Bitcoin markets, which helps the adjustment towards short and medium-term equilibrium and vice versa. The reason behind this situation may be that the increase in the Bitcoin market aggravates GPR, GEPU, UCRYPO, and EMV panic around the world. Furthermore, the Bitcoin market's soaring drives the economic bubble, so the GPR, GEPU, UCRYPO, and EMV are expected to change.









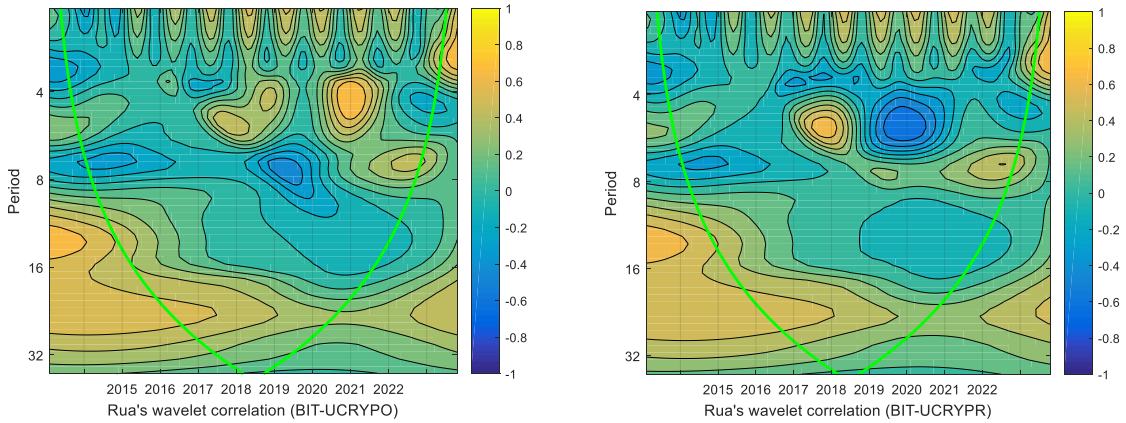


Figure 6. Wavelet-based Correlation

Note: The colour code indicates the degree of correlations, which goes from blue (negatively related) to yellow colour (positively related)

Our findings imply that the selected uncertainty indexes are intrinsically linked to the Bitcoin market in the short and medium run, and the tendency of the Bitcoin prices closely depends on GPR, GEPU, UCRYPO, and EMV indexes, suggesting that BIT leads these indices in the medium run. On the other hand, there is no evidence of a causal association running from the Bitcoin prices to UCRYPR and TEU at mainly higher frequencies. Overall, the results extend the findings of Mokni et al. (2020), Wu et al. (2021), Al-Yahyaee et al. (2019), Aysan et al. (2019), Su et al. (2020), Colon et al. (2021), Huynh et al. (2021) and Fang et al. (2019) with the estimates of reaction of the relationship of Bitcoin to policy uncertainty shocks.

These outcomes have several significant implications for investors interested in Bitcoin. Investors can take into consideration to forecast the variations of the Bitcoin market. More accurately, they should look to adjust their portfolio structure under low, medium, and high frequencies and through time horizons to achieve the optimal decision-making process. In particular, they should observe economic and policy uncertainties to hedge their portfolios against potential risk exposures. For regulators and policymakers, they should consider political instability, Equity Market Volatility, Twitter-based Economic, Geopolitical risk, and Cryptocurrency Policy Uncertainties in the design of reforms and regulations.

6. Conclusion

In this study, we endeavoured to explore the nexus between the uncertainty and the Cryptocurrency market while taking a comprehensive approach to account for the uncertainty. For inclusivity, we drew on the, six major uncertainty indices (Global Economic Policy Uncertainty, Equity Market Volatility, Twitter-based Economic Uncertainty, Geopolitical risk index, The Cryptocurrency Policy Uncertainty Index, The Cryptocurrency Price Uncertainty

Index), and in particular, two novel Cryptocurrency Uncertainty indexes as introduced by Lucey et al. (2022) are taken into account. Our findings lead us to conclude on a negative connectedness between Bitcoin prices and the key selected uncertainties indices, which suggests that higher uncertainties result in lower Bitcoin fluctuation across time and frequency domains. Besides, we identified that GPR, GEPU, UCRYPO, and EMV play a prominent role in the variation in Bitcoin prices, and the intercorrelation increases to peak during the Covid-19 outbreak. Our empirical findings also imply that the resource allocation to Bitcoin to reduce investment risk exposure is not optimal. In this regard, the subject study offers some insightful implications. First, investors should keep tracking the uncertainties, which have been revealed by the news and other social media are associated with the downside shocks on the Bitcoin returns. Since the existing evidence confirms that policy uncertainties could negatively affect other financial assets such as equities (Baker et al., 2016; Baker et al., 2020), investors having a portfolio consisting of Bitcoin and other financial classes should pay more attention to the fluctuations of news regarding uncertainties. Second, during a crisis time, especially an unprecedented event of COVID-19, the indices containing uncertainties could be an indicator to shift the capital flow to a better investment channel.

Future studies may employ different publicly available uncertainty measures to look into how the Bitcoin market reacts heterogeneously to divergent kinds of uncertainty. In terms of methodological approaches, further studies can also employ methods like machine learning or deep learning to further explore the nexus between the uncertainty indexes and the Bitcoin market.

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