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Cryptocurrencies Investment Properties against Economic Policy Uncertainty: A Wavelet Analysis before, during and post COVID-19

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Abstract

Purpose – Analyze and characterize the major cryptocurrencies' relationship with EPUs and assess these relationships in the context of pre-COVID, COVID and post-COVID periods.

Design/methodology/approach – The authors used the wavelet methodology based on a cross wavelet transform and wavelet coherence to analyze relationship between economic policy uncertainty and major cryptocurrencies.

Findings – Results present some new insights on the relationships between EPU's and major cryptocurrencies with the distinction that our analysis is divided into pre-COVID, COVID and post-COVID periods. The cross wavelet transform analysis reveals that both Bitcoin and Ethereum are predominantly characterized as diversifiers across all periods. The wavelet coherence analysis reveals that both Bitcoin and Ethereum are in many cases also characterized as a diversifier across all periods. However, the wavelet coherence analysis also highlights that, in general over the post-COVID period there were mostly positive correlations, suggesting the ability of both Bitcoin and Ethereum to act as hedgers or safe-haven instruments against uncertainty. On the other hand, over the pre-COVID and COVID period, there were mostly negative correlations, suggesting the inability of both cryptocurrencies to act as hedgers or safe-haven instruments against uncertainty.

Research limitations - authors highlight that despite being a previously identified literature gap, the use of a monthly frequency in the study may be seen as a limitation since it has less observations.

Practical implications – This study informs investors, so they can better construct their investment portfolios, minimizing risks and maximizing returns against uncertainty. Also, the EPU´s effects provide insights for policymakers and regulators to adequate regulate these digital assets.

Originality/value – This study contributes to the literature by presenting an early study that uses a wavelet-based methodology on the analysis and characterization of the major cryptocurrencies' relationship with EPUs, assessing COVID-19 impact through a pre-COVID, COVID and post-COVID period distinction on these relationships.

Keywords EPU; Cryptocurrency; Bitcoin; COVID-19; Wavelet

JEL Codes D81, G01 G11, G15, G18

Paper type Research paper

1. INTRODUCTION

The world economic and monetary system by which we are governed has already demonstrated numerous failures over time (Gonçalves et al., 2022). These flaws, lead world economies to high uncertainty levels such as the ones felt upon the 2008 financial crisis; the European sovereign debt crisis of 2010-2013 (Chen et al., 2021); and more recently the COVID-19 pandemic.

In this context of uncertainty and distrust in the existing international financial system, cryptocurrencies emerge as a new and alternative monetary system (Nakamoto, 2008). Cryptocurrencies are defined as decentralized digital currencies that do not involve third parties, such as credit institutions, and are not controlled by any governmental organization (Almeida & Gonçalves, 2022). Therefore, since cryptocurrencies may act as an alternative means of payment and an alternative investment asset, totally out of the state's reach, it is important to understand how this digital currency reacts to the risks and uncertainties that prevail in the traditional economic and monetary system (Ali et al., 2022).

To date, existing literature provides quite different conclusions regarding how cryptocurrencies act in the face of economic policy uncertainty. Some studies indicate that cryptocurrencies inability to act as safe-havens (Demir et al., 2018; Long et al., 2021; Mokni et al., 2022) others, point the opposite (Al-Yahyaee et al., 2019; Bouri et al., 2017; Das et al., 2018); others still, show that there is no influence of economic policy uncertainty on the cryptocurrency market (Wang et al., 2019). Fewer show COVID-19 impact (Chen et al., 2021; Elsayed et al., 2022; Wu et al., 2021). In addition, in a systematic literature review by Haq et al. (2021), 4 important literature gaps are identified: the need to further investigate multiple cryptocurrencies and EPUs; to use wavelet approaches; expand sample size to cover the consequences of during and post Covid-19 periods; and to consider monthly data for both EPU and cryptocurrencies considering COVID-19 periods. Similarly, Jalal et al. (2021) calls for additional research on diversification using cryptocurrencies as financial assets, extending previous data and methodologies. We answer those calls.

Accordingly, the objective of this study is threefold: assess the relationship between the major cryptocurrencies (Bitcoin and Ethereum) and seven economic policy uncertainty indices (Global, USA, China, Europe, Germany, UK and France) in a monthly basis; characterize cryptocurrencies as hedging, safe-haven or diversifier instruments of portfolio investment; and classify them over pre-COVID, COVID and post-COVID periods.

Consequently, we contribute to the current literature on cryptocurrencies relationship with uncertainty by addressing important literature gaps and presenting an earlier assessment regarding the pre, during, and post-COVID period analysis. Additionally, it also provides new empirical evidence on the impact of major world economic powers' uncertainty over the most important cryptocurrencies.

Unlike previous studies (Elsayed et al., 2022; Mokni et al., 2022; Shaikh, 2020; Wang et al., 2022; Wu et al., 2021), our study present some new insights on the relationship between EPU's and major cryptocurrencies with the distinction that our analysis is divided into pre-COVID, COVID and post-COVID periods. Our results reveal that both Bitcoin and Ethereum are in many cases characterized as a diversifier across all periods. Nonetheless, they also highlight that, in general over the post-COVID period there were mostly positive correlations, suggesting the ability of both Bitcoin and Ethereum to act as hedgers or safe-haven instruments against uncertainty. However, over the pre-COVID and COVID periods, there were mostly negative correlations, suggesting the inability of both cryptocurrencies to act as hedgers or safe-haven instruments against uncertainty.

The remainder of the study is organized as follows: Section 2, presents the literature review. Section 3 presents the data and outlines the empirical methodology, while Section 4 presents the main empirical results and their discussion. Finally, in section 5, we provide concluding remarks and future venues of research.

2. LITERATURE REVIEW

The literature examining cryptocurrencies' relationship with EPUs is growing (Haq et al., 2021). Previous research showed that during extreme market conditions EPU improves the prediction of Bitcoin returns in the majority of countries (Mokni, 2021). It is evidenced that for both the US and Japan, a significant rise in uncertainty levels results in a decrease in Bitcoin volatility, confirming Bitcoin's hedging ability from 2015 until 2018 (Matkovskyy et al., 2020), and from 2011 until 2019 (Al-Yahyaee et al., 2019; Ali et al., 2022). This is also true for Bitcoin and Litecoin against the China's EPU from 2014 until 2019 (Yen & Cheng, 2021). In addition, it is evidenced that Bitcoin can also act as a safe-haven against Chinas' uncertainty, as well as for US and Japan's (Shaikh, 2020). Furthermore, it is also evidenced that Bitcoin has no significant relationship with US EPU from 2010 until 2018. Hence, also evidencing Bitcoin's ability as a diversifier (Wang et al., 2019). Regarding US EPU relationship with Bitcoin, evidence reveals a mixed effect, in different quantiles, from 2010 until 2020; showing that when a positive impact is observed, Bitcoin present safe-haven properties against US EPU (Umar et al., 2021; Paule-Vianez et al., 2020; Wu et al., 2019). These properties are also evidenced from 2010 until 2018 against US trade policy uncertainty (Gozgor et al., 2019).

Further evidence reveals a positive correlation in the short-term, between Bitcoin and Global EPU, suggesting that Bitcoin may act as a hedge against global uncertainty (Bouri et al., 2017). Moreover, results show a medium and long-term positive correlation from 2010 until 2017, suggesting that Bitcoin may act as a diversifier in the short-term, and as a hedger on the medium- and long-term (Das et al., 2018).

In addition, there is also evidence suggesting that China's EPU has the ability to predict Bitcoin returns (Cheng & Yen, 2020). However, the same is not true for the EPU of US, Japan and Korea (Cheng & Yen, 2020).

On the other hand, it is also shown that Bitcoin does not act as a hedge against the EPU in normal market conditions (Demir et al., 2018), and that Bitcoin is unable to serve as a safe-haven against uncertainty (Long et al., 2021). Further evidence also reveals a negative correlation between Bitcoin and the global EPU between 2010 and 2020, indicating that Bitcoin is not a safe-haven instrument (Wang et al., 2022).

Additionally, previous research also analyzed cryptocurrencies' relationship with EPUs addressing COVID-19 impact. For instance, evidence reveal that during COVID, the US EPU drives Bitcoin price volatility (Elsayed et al., 2022). Regarding Chinas' EPU, evidence reveals a positive impact in Bitcoin returns, thus supporting Bitcoin's ability to act as a hedger during COVID (Chen et al., 2021). Also, Bitcoin, Stellar, Litecoin, Ripple, Ethereum and Monero seem to present good hedging abilities when EPU values are low (Jiang et al., 2021). On the other hand, there is also evidence showing that during the pre-COVID period Bitcoin acts as a safe-haven instrument (Raheem, 2021). However, during COVID period it loses this ability (Raheem, 2021). Further evidence suggest that during the COVID period, Bitcoin, Ethereum, Tether, Ripple and Bitcoin Cash are unable to act as safe-haven and hedgers against EPU (Mokni et al., 2022). Moreover, there is no evidence of a relationship between EPU indices and cryptocurrency returns during the COVID period (Wu et al., 2021). Therefore, it is evidenced that cryptocurrencies do not present any hedging ability against changes in EPU during the COVID period (Wu et al., 2021).

Consequently, extant literature shows that the hedging, safe-haven and diversification properties of cryptocurrency vary across time, methodologies used, and uncertainty measures

considered. We also observe that most of the studies mentioned so far used methodologies such as the OLS regressions, BGSVAR (Bayesian Graphical Vector Autoregressive), NARDL (Nonlinear Autoregressive Distributed Lag), GARCH (Generalized Autoregressive Conditional Heteroskedacity), MVQM (Multivariate quantile model). Very few studies examine cryptocurrencies' relationship with EPUs using a wavelet-based approach. In addition, most studies use daily frequencies. These findings are in line with the findings by Haq et al. (2021), who highlight 4 important literature gaps: the need to further investigate multiple cryptocurrencies and EPUs; to use wavelet approaches; expand sample size to cover the consequences of during and post Covid-19 periods; and to consider monthly data for both EPU and cryptocurrencies spanning COVID-19 periods. Similarly, Jalal et al. (2021) calls for additional research on diversification using cryptocurrencies as financial assets, extending previous data and methodologies.

Therefore, in other to contribute to the literature and address this literature gaps, we present an early study that uses a wavelet-based methodology on the analysis and characterization of the major cryptocurrencies' investment properties with EPUs, assessing COVID-19 impact through a pre-COVID, COVID and post-COVID period distinction on these relationships.

3. DATA AND METHODOLOGY

This study uses monthly data for Bitcoin (BTC) and Ethereum (ETH) prices, and for seven major economic policy uncertainty indices, namely the Global (GEPU), USA (USEPU), China (CEPU), Europe (EUEPU), Germany (GEREPU), France (FREPU) and United Kingdom (UKEPU). The uncertainty indices used in this study are based on the work developed by Baker et al. (2016). Baker et al. (2016) explains that the Global EPU index, is built from the average of the EPU indices recorded in several countries, including those under study. The EPU index of each country is obtained through the volume of newspapers and magazines that denote subject matters where the terms "uncertainty", "economy", "politics", among others, such as "legislation" or "regulation" are included. It also clarifies that the European index (EUEPU) is built from the average of the EPU indices registered in 5 European countries (Germany, Spain, France, Italy and the United Kingdom), where two main newspapers in each country are considered (Baker et al., 2016).

To examine the relationships between economic policy uncertainty and major cryptocurrencies over the pre, during and post COVID-19 periods, we consider data from January 1st, 2018, until April 30th, 2022, resulting in 52 months of analysis. This period is further divided into pre-COVID (January 2018 – November 2019), COVID (December 2019 – September 2021), and post-COVID (October 2021 – April 2022). These dates are established based on the world vaccination rate (Our World in Data, 2022).

It was decided to collect data only from the beginning of 2018, because on this date the prices of BTC and ETH suffered a sharp drop and the number of investors in this market increased significantly (Howell et al., 2020). Additionally, from this date forward, countries began to address cryptocurrencies with due attention, publishing various laws to regulate the cryptomarket (Howell et al., 2020).

Similar to Aharon & Demir (2022), Cheng & Dai (2020) and Matos et al. (2021), cryptocurrency data was retrieved from www.investing.com. While the EPU index information was retrieved from the www.policyuncertainty.com.

We chose to use monthly data for the economic policy uncertainty indices and for cryptocurrencies attending an identified literature gap. In the case of the indices, they are available in a monthly frequency. However, for data synchronization purposes, in the case of cryptocurrencies we considered that the value of a one-month cryptocurrency corresponds to the value recorded at the end of the last day of the respective month.

To investigate the relationship between cryptocurrencies and the different economic policy uncertainty indices, we used the wavelet functions methodology. Wavelet functions consist of an analysis performed through wave functions, where time series are transformed into frequency and time components (Phillips & Gorse, 2018). The graphical analysis of these functions focuses on wave oscillations that, at first, have an amplitude equal to zero and vary over time, always returning to zero amplitude at the end of the considered time interval (Phillips & Gorse, 2018).

A wavelet function takes the following form (1):

$$\psi_{u,s}(t) = \frac{1}{\sqrt{s}}\,\psi\left(\frac{t-u}{s}\right) \quad (1)$$

In this formula, the mother wavelet, ψ, represents the information related to the frequency of a given time series (Firouzi & Wang, 2019). The *u* component refers to the location of the wavelet (Phillips & Gorse, 2018). Component *s* refers to the width of the wavelet, indicating how stretched or contracted the function is, always maintaining the same wave shape (Phillips & Gorse, 2018). That is, the width of the wavelet increases with high levels of *s*, making possible to observe more time series data (Phillips & Gorse, 2018). While reduced scales have a high frequency and allow for short-term analysis, the high scales have a lower frequency and allow for long-term dynamic analysis (Phillips & Gorse, 2018).

There are different types of wavelets, and each one has different features suitable for different purposes (Dogra et al., 2016). As in Phillips & Gorse (2018) and Aloui & Hkiri (2014) the wavelet used in this study is the Morlet Wavelet defined by (2):

$$\psi^{M}(t) = \frac{1}{\pi^{\frac{1}{4}}} e^{-i\omega_0 t} e^{\frac{-t^2}{2}} \quad (2)$$

In this case, ω_0 is the central frequency of the wavelet. According to Grinsted et al. (2004), this variable assumes the value 6, since it offers a good balance between the location of time and frequency on the chart. One of the main parameters of this wavelet is based on the width of the Gauss curve (Aloui & Hkiri, 2014).

To evaluate the existence of a relationship between cryptocurrencies and economic policy uncertainty, we will start by considering the **Continuous Wavelet Transform**. This allows to obtain a complete representation of the wavelet by varying the width and location parameters in a continuous way (Alharbey et al., 2022). It is possible to obtain different periods, ups and downs, where they are decomposed into sub wavelets and then reconstructing the time series (Alharbey et al., 2022; Vacha & Barunik, 2012). The Continuous Wavelet Transform is defined by (3):

$$W_x(u,s) = \int_{-\infty}^{+\infty} x(t)\,\frac{1}{\sqrt{s}}\psi^{*}\left(\frac{t-u}{s}\right)dt \quad (3)$$

In this type of wavelet, the ψ^* parameter represents the conjugated version of the mother wavelet, ψ (Alharbey et al., 2022). The purpose of the mother wavelet is to offer a new version of the wavelet "daughters", which are just the mother wavelet by changing only the location and width parameters (Alharbey et al., 2022).

From the Continuous Wavelet Transform, it will be used the **Cross Wavelet Transform**, which was developed to investigate the relationship between two non-stationary time series and to determine their powers and differences within the time and frequency domain (Alharbey et al., 2022). Additionally, Yu & Lin (2015) state that this type of analysis is used to define the covariance between two time series. Thus, considering two time series *x(t)* and *y(t)* and their wavelet transforms W_x and W_y, respectively, the Cross Wavelet Transform is defined by (4):

$$W_{xy}(u,s) = W_x(u,s)\, W_y^*(u,s) \quad (4)$$

Here, *W*y* is the conjugated version of *Wy*, where the variance of a time series, as well as its power, are obtained through the spectrum of wavelet power, $|W_x|^2$. The covariance between the two time series is determined by $|W_{x,y}|$(Firouzi & Wang, 2019).

Subsequently, we performe the **Wavelet Coherence** analysis, which allows us to capture the locations of the correlation coefficients of two time series that contain non-stationary data for numerous frequencies (Kumar & Anandarao, 2019). We, then, obtain information about the dependence and correlation between the observed time series (Ahn & Park, 2016). Wavelet Coherence is defined as follows (5):

$$R_{xy}(u,s) = \frac{|S(W_{xy}(u,s))|}{\sqrt{S(|W_x(u,s)|^2)\,.\,S(|W_y(u,s)|^2)}} \quad (5)$$

The *S* factor represents a smoothing operator applied to both time and frequency, and R_{xy} assumes values between 0 and 1, where values closer to 1 indicate a stronger correlation and values closer to 0 indicate a weaker correlation (Firouzi & Wang, 2019).

The results output is presented under scalograms with the horizontal axis representing the temporal space analyzed, and the vertical axis the number of periods of time (Phillips & Gorse, 2018). On the top of the vertical axis are the areas with low periods (zone with high frequencies) that are of interest for short-term investors, while in the bottom of the vertical axis are the areas with high periods (low frequency zone) that are of interest for long-term investors (Phillips & Gorse, 2018). Consistently, we considered that the short, medium, and long-term time horizons focus respectively on the range of periods between 0 and 4 months, 4 to 8 months, and 8 to 16 months (Phillips & Gorse, 2018). For the horizontal axis, the beginning of the analyzed time frame is at the leftmost point of the scalogram, so its end is at the farthest point of the graph (Phillips & Gorse, 2018). In this axis, since we use monthly observations, the years 2018, 2019, 2020, 2021 and 2022 correspond respectively to the intervals 1 to 12, 13 to 24, 25 to 36, 37 to 48, and 49 to 52.

The scalograms present a range of colors in the scale chart, from the coldest (blue) to the hottest (red) (Phillips & Gorse, 2018). In this context, the warmer colors represent greater covariance between the time series, in the case of Cross Wavelet Transform, or a greater correlation between, in the case of the Wavelet Coherence (Al-Yahyaee et al., 2019; Phillips & Gorse, 2018). The colors used in this study vary between dark blue and red, so in the case of Cross Wavelet Transform, the scale ranges from 1/8 (dark blue) to 8 (red), and in Wavelet Coherence varies between 0 (dark blue) and 1 (red) (Phillips & Gorse, 2018).

The analysis of the arrows define two aspects: co-movement and the lead/lag effect (Phillips & Gorse, 2018). As it can be seen in Figure 1, a left-oriented arrow represents an out-phase movement between the two time series, evidencing opposite movements (Phillips & Gorse, 2018). On the other hand, a right-oriented arrow represents in-phase movements between the two time series, evidencing similar movements (Phillips & Gorse, 2018).

From another perspective, a left-down-oriented arrow indicates a leading effect, to the extent that the first time series bears a predictive power over the value of the second time series. Conversely, lagging effect expresses a delay of the second time series compared to the first time series (Phillips & Gorse, 2018). On the other hand, a left-upward-oriented arrow indicates that lagging effect, to the extent that the first time series is lagging behind the second time series. In opposition, the lead effect demonstrates that the second time series bears a predictive power over the value of the first time series (Phillips & Gorse, 2018). For right, upward and downward oriented arrows, the interpretation is inverse.

For simplification purposes, the first time series in all scalograms will be the EPU and the second the cryptocurrency, BTC or ETH, respectively.

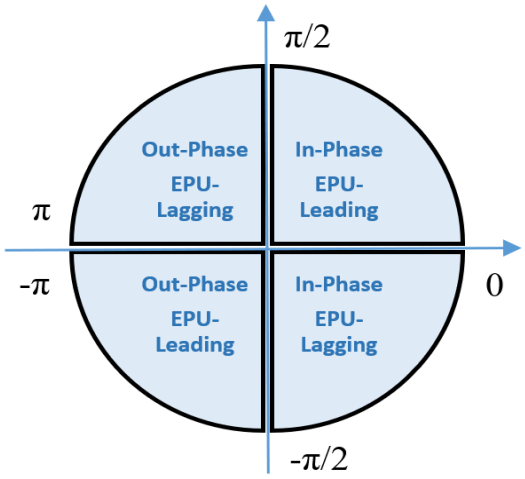


Figure 1- Phase-difference circle

Regarding the time series, the information contained in each observation uses information from neighboring observations (Phillips & Gorse, 2018). But since all the time series used in this study are finite, the data placed at their beginning and end, will not have all the necessary information, especially in areas of high periods (long-term horizon) (Phillips & Gorse, 2018). As this is a recurrent problem, the cone of influence (COI) is used, dividing the less reliable data from the more accurate data (Phillips & Gorse, 2018). Hence, the observations outside the COI represent unreliable data, whereas the effectively reliable data is within the COI (Phillips & Gorse, 2018). Finally, the bold dashed surrounded areas are areas of statistically significant co-movement, based on the Monte Carlo simulation, at a 5% confidence level (Li et al., 2021; Phillips & Gorse, 2018).

4. EMPIRICAL FINDINGS AND DISCUSSIONS

Descriptive Statistics

Variables	Average	Median	Maximum	Minimum	Std. Deviation	Skewness	Kurtosis
GEPU*	246.016	235.900	430.200	123.900	64.200	0.602	0.106
USEPU*	207.800	176.000	504.000	109.700	87.800	1.606	2.355
CEPU*	325.500	319.200	661.800	149.600	106.300	1.118	1.915
EUEPU*	231.700	227.000	391.300	135.200	52.600	0.779	1.027
GEREPU*	276.400	226.900	785.000	97.500	140.600	1.606	3.007
UKEPU*	313.900	318.300	542.500	111.100	108.800	-0.002	-1.004
FREPU*	272.200	263.000	432.700	159.800	62.400	0.673	0.237
BTC (USD)	20400.500	9594.400	61309.600	3437.200	18261.300	0.949	-0.651
ETH (USD)	1100.900	390.200	4628.900	106.700	1289.100	1.247	0.257

* Unit of measure – Number of newspapers and magazines that present subject matter where the terms "uncertainty", "economy", "politics", "legislation" or "regulation".

Table 1 - Descriptive statistics of the EPU's and the cryptocurrencies under study.

Table 1 shows the descriptive statistics of the time series of the economic policy uncertainty indices and the cryptocurrencies under study. It highlights that the CEPU presents the highest average value (325.50), conversely, the USEPU presents the lowest average value (207.80). The GEREPU exhibits maximum (785.50) and minimum (97.50) values. Hence, it also presents the highest standard deviation. With regard to cryptocurrencies, it is highlighted that BTC presented an average value of USD 20,400.50, and ETH an average value of USD 1,100.90. BTC presented much higher volatility compared to ETH. All variables present a

leptokurtic curve with distribution curves concentrated around the mean and right fat tails, with the exception of the UKEPU.

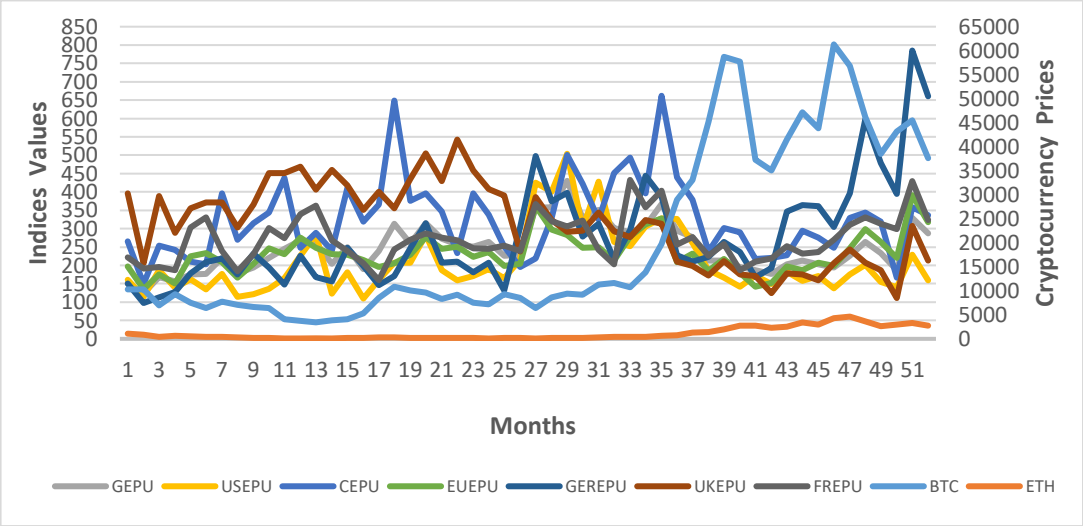


Figure 2 – Evolution of variables under study along the studied period.

Figure 2 shows the evolution of the time series along the studied period. In the beginning of 2018, BTC suffered a drop in its prices from approximately USD 10,300 to around USD 3,400. However, from the end of 2020 it recovered, reaching an all-time high above USD 61,300. ETH prices oscillated between USD 333 and USD 4,600. Regarding the EPU indices, in the beginning of 2018 the UKEPU presents the highest value, followed by the CEPU, nonetheless, at the end of the analyzed period the GEREPU followed by the FREPU are the economic policy uncertainty indices with higher values.

Cross Wavelet Transform

The cross wavelet transform results, presented in figure 3, show short-term relationships with in-phase movements from the beginning of 2021 onwards (COVID and post-COVID periods), for BTC relationships with the GEREPU, CEPU and EUEPU indices, where the indices are leading. Our results for the CEPU – BTC relationship complement the findings by Cheng & Yen (2020) and Chen et al. (2021) and highlight Bitcoin's ability as hedger or safe-haven against the CEPU, GEREPU and EUEPU over the COVID and post-COVID periods. Similar to the findings by Wang et al. (2019), our results reveal no relationship between USEPU, GEPU, UKEPU and FREPU, and BTC. Hence, evidencing Bitcoin's diversification ability against these indices over the pre-COVID, COVID and post-COVID periods.

As far as ETH is concerned, only the GEREPU and EUEPU indices present short-term relationships with it. Results reveal that from mid-2021 onwards (COVID and post-COVID periods), the variables present in-phase movements, and the indices are leading. This result seems to contradict the findings by Wu et al. (2021), where, between 2019 and 2020, it was evidenced a positive relationship between USEPU and ETH.

Although we found evidence of covariance between CEPU and BTC, we could not find any relationship on a global scale. Similarly, with regard to ETH, although we evidence covariance with EUEPU, a global scale relationship is not evident. Both these covariances are dissipated when combined with the constituent countries of the Global index.

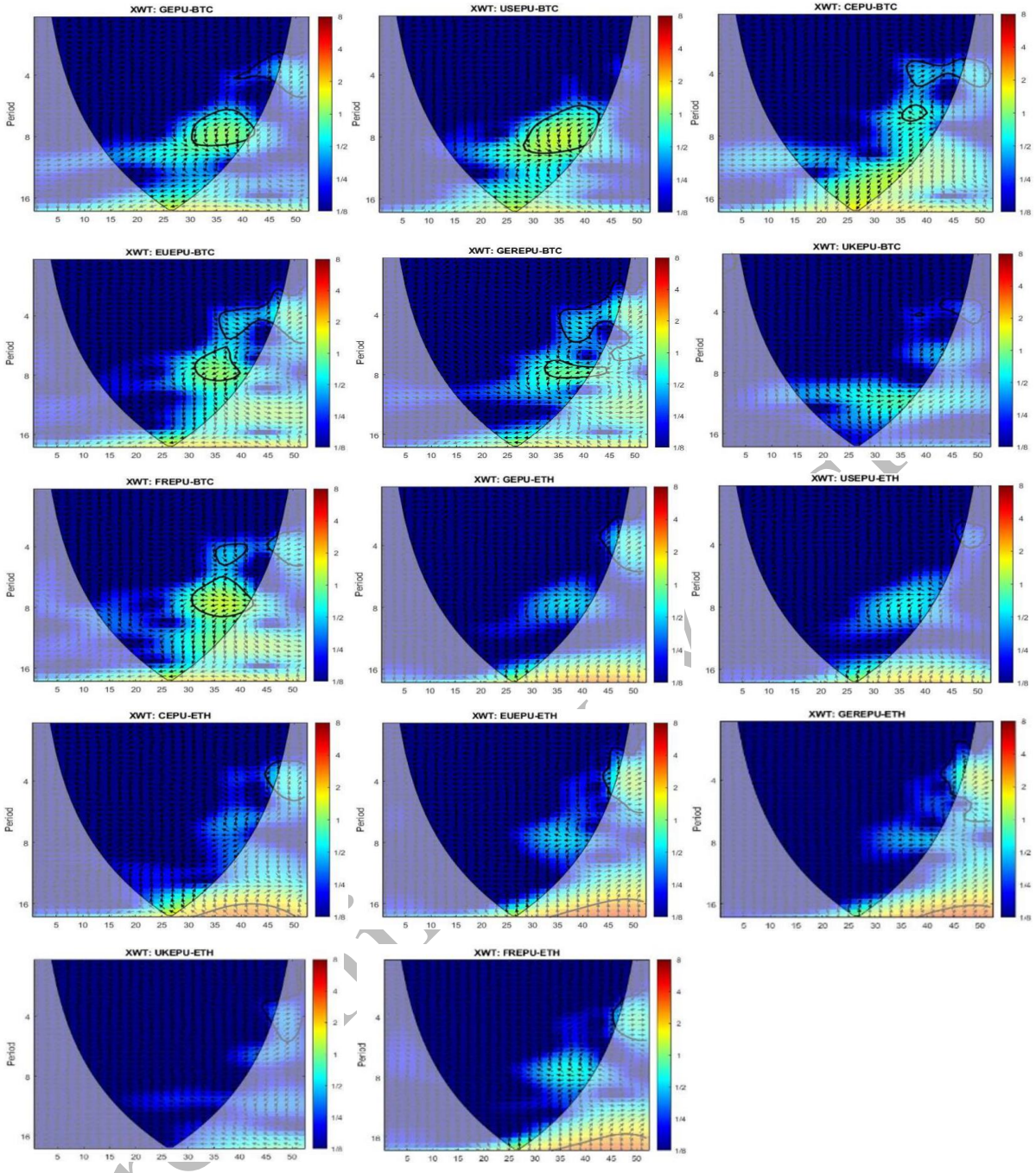


Figure 3 – Cross Wavelet Transform scalograms between the different economic policy uncertainty indices (GEPU, USEPU, CEPU, EUEPU, GEREPU, UKEPU, FREPU) and the two cryptocurrencies (BTC and ETH).

Regarding the medium-term, we evidence relationships between BTC and all economic policy uncertainty indices (GEPU, USEPU, CEPU, EUEPU, GEREPU and FREPU), except for UKEPU. Results reveal out-phase movements for BTC relationships with USEPU, GEPU, GEREPU, FREPU and EUEPU between mid-2020 and mid-2021 (COVID period). In BTC relationships with USEPU, GEPU and GEREPU, indices are leading. However, in BTC relationships with FREPU and EUEPU, BTC is leading. Furthermore, results also reveal out-phase movements between the early 2021 and the beginning of 2022 (COVID and post-COVID periods) for the relationships between BTC and CEPU, where BTC is leading. These results complement the findings by Chen et al. (2021), and , however, contradict Cheng & Yen (2020) and Mokni et al. (2022) findings, by highlighting Bitcoin's inability to act as a hedging, safe-

haven or diversifier tool against USEPU, GEPU, GEREPU, FREPU, EUEPU and CEPU uncertainty indices during COVID and post-COVID.

Additionally, results also highlight in-phase movements from end 2020 until mid-2021 (COVID period) for BTC relationships with FREPU, where BTC is leading; and from 2021 onwards (COVID and post-COVID periods) for the relationship between BTC and GEREPU, where BTC is leading. Therefore, for these specified times, Bitcoin may be seen as a hedging or safe-haven asset.

Our results reveal that there are no relationships between ETH and economic policy uncertainty indices in the medium term. Hence, ETH may be seen as a diversifier over the entire sample period. This result contradicts the findings by Jiang et al. (2021) , which found a positive impact of CEPU over ETH between 2015 and 2020.

The covariances between Bitcoin and the Germany's and France's economic policy uncertainty indices were somewhat reflected in the European index. The same can be said for a Global scale, where the Global index reflected Bitcoin's relationship with the US, China, and Europe uncertainty indices.

In long-term analysis we only evidence BTC relationships with CEPU and USEPU. Results reveal out-phase movements between the end of 2019 and mid-2021 (COVID period) for BTC relationship with CEPU, where CEPU is leading. These results contradict the findings by Cheng & Yen (2020) and Shaikh (2020) and imply that Bitcoin may not be seen as a good hedge, safe-haven or diversifier against the CEPU during the specified times over the COVID period.

Additionally, our results also reveal in-phase movements between early 2020 and mid-2021 (COVID period) for BTC relationship with USEPU, where BTC is leading. These findings contradict those of Mokni et al. (2022) suggesting that Bitcoin may be seen as a hedger or a safe-haven against USEPU during the specified times over the COVID period.

Regarding ETH, our results do not reveal any long-term relationship with the economic policy uncertainty indices. Thus, ETH may be seen as a diversifier over the entire sample period. Similarly, as in the medium-term analysis, also in the long-term analysis, our results contradict the findings by Jiang et al. (2021).

While there is covariance between Bitcoin and US's and China's economic policy uncertainty indices, this is not reflected at a Global level.

Wavelet Coherence

In the wavelet coherence results, presented in figure 4, we found evidence of short-term relationships with out-phase movements: in mid-2018 (pre-COVID period), BTC relationships with EUEPU, UKEPU and FREPU show BTC leading; between mid-2019 and during 2020 (pre-COVID and COVID periods), BTC relationships with GEREPU and CEPU show BTC leading, while relationships with FREPU and UKEPU show the indices leading, whereas relationships with USEPU show no leading/lagging effect; from 2021 onwards (COVID and post-COVID periods), BTC relationships with GEPU, CEPU, and USEPU, show the indices leading. These results complement the findings by Demir et al. (2018), Wang et al. (2022), Bouri et al. (2017), Gozgor et al. (2019), however contradict Chen et al. (2021) findings, by highlighting that Bitcoin fails to act as a hedger, safe-haven or diversifier against all the uncertainty indices under study during the specified times over the pre-COVID, COVID and post-COVID periods.

We also evidence short-term relationships with in-phase movements: in mid-2018 (pre-COVID period), BTC relationships with GEPU, show the index leading, while relationships with USEPU, show BTC leading; between mid-2019 and during 2020 (pre-COVID and COVID periods), BTC relationships with EUEPU show the index leading, while relationships with UKEPU show BTC leading; from 2021 onwards (COVID and post-COVID periods), BTC

relationships with USEPU and UKEPU show the indices leading. These results add to the findings of Cheng & Yen (2020), Jiang et al. (2021) and Shaikh (2020) that Bitcoin may be seen as good hedger or safe-haven against GEPU, USEPU and UKEPU indices, during the the pre-COVID, COVID and post-COVID periods.

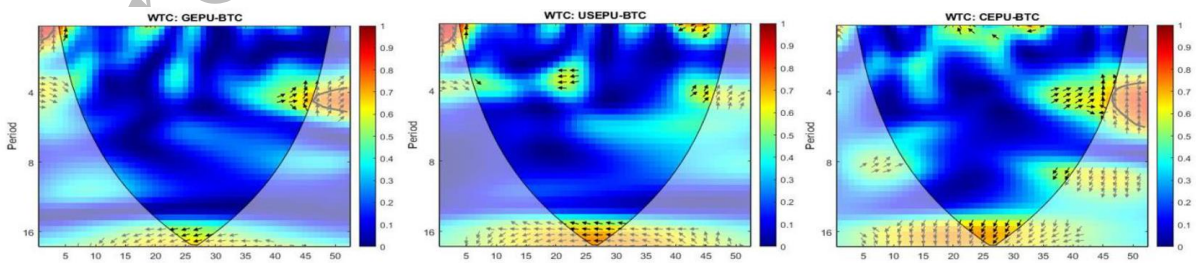
Additionally, results reveal no short-term relationships between BTC and EUEPU GEREPU and FREPU. Thus, evidencing Bitcoin's ability to act as a diversifier against these indices in the post-COVID period.

Regarding ETH, results reveal short-term relationships with out-phase movements: in mid-2018 (pre-COVID period) ETH relationships with GEPU, USEPU, UKEPU, show the indices leading, while relationships with EUEPU and FREPU, show ETH leading; between early 2019 and along 2020 (pre-COVID and COVID periods), ETH relationships with EUEPU, FREPU and UKEPU, show the indices leading, while relationships with GEPU, USEPU, CEPU, GEREPU and FREPU show ETH leading. These results contradict the findings by Shaikh (2020), Jiang et al. (2021) and Mokni et al. (2022), by revealing that Ethereum cannot be considered as a hedger or safe-haven against all the uncertainty indices under study during the specified times over the pre-COVID and COVID periods.

Also, in the case of ETH, we evidence short-term relationships with in-phase movements: in early 2019 (pre-COVID period), ETH relationships with EUEPU show the index leading, while relationships with UKEPU show ETH leading; in the end of 2020 and early 2021(COVID period), ETH relationships with GEPU, EUEPU and UKEPU show ETH leading; from mid-2021 onwards (COVID and post-COVID periods), ETH relationships with GEPU and USEPU show the indices leading, while relationships with UKEPU show ETH leading. These results supplement the findings by Shaikh (2020), however contradict Mokni et al. (2022) findings by showing that Ethereum may be seen as good hedger or safe-haven against GEPU, EUEPU, USEPU and UKEPU indices, during pre-COVID, COVID and post-COVID periods.

Additionally, results reveal no short-term relationships between ETH and CEPU for pre-COVID period, and between ETH and EUEPU and FREPU for post-COVID period. Hence revealing Ethereum's ability to act as a diversifier against these indices over these periods.

In the graphs shown in Figure 4, some red areas were identified, representing a strong and significant correlation between cryptocurrency and uncertainty index for a given period. Regarding Germany's EPU index, the red zone is between 2019 and 2020, both in the case of BTC and ETH, which may be related to the period in which the country announced that it would consider higher regulation of blockchain technologies (Hamacher, 2019). With regard to France's EPU index, there was a red zone between the end of 2019 and mid-2020, which may be related to the country's initiative to test a digital currency (Lusa, 2019).



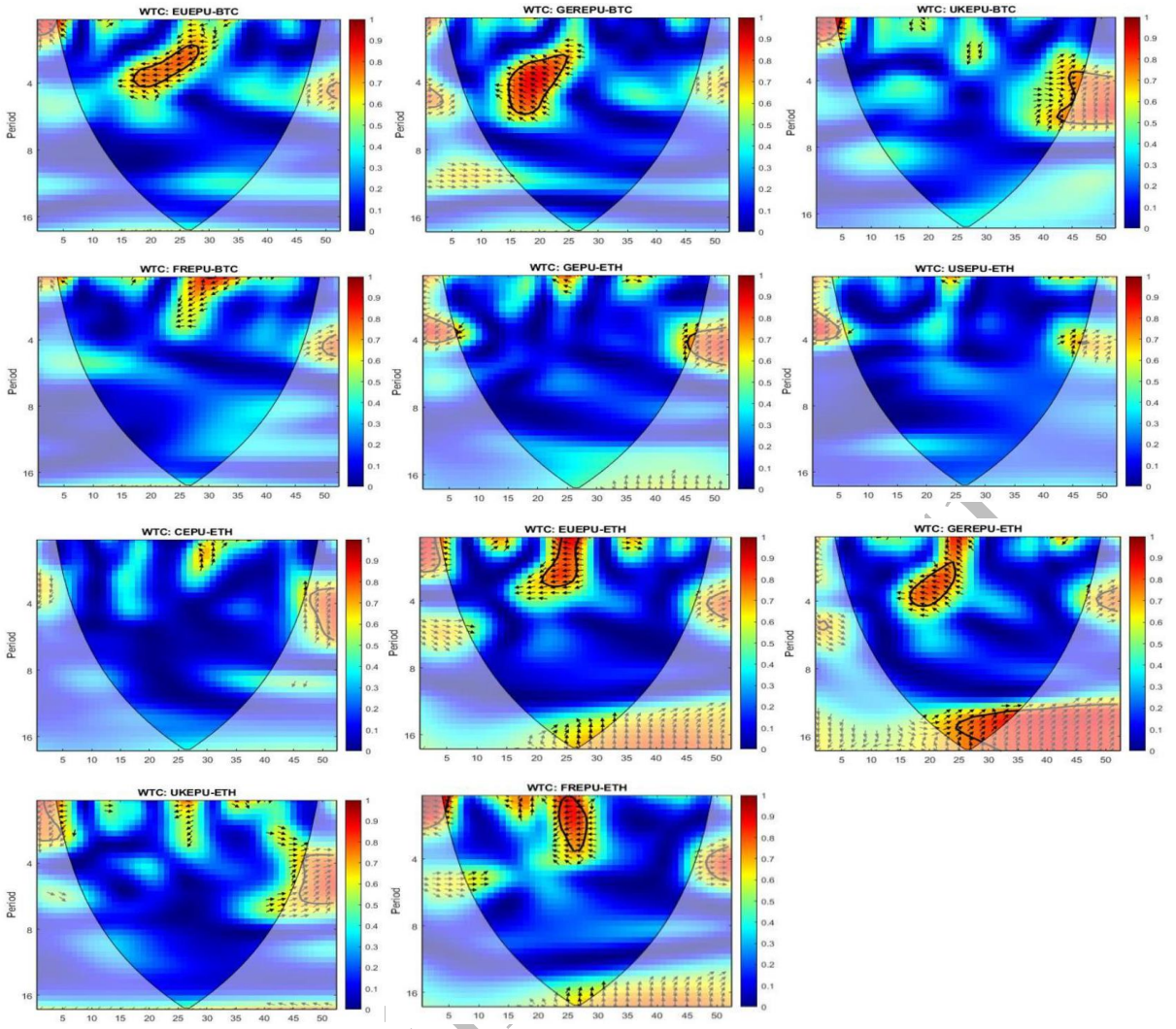


Figure 4 – Wavelet Coherence scalograms between different economic policy uncertainty indices (GEPU, USEPU, CEPU, EUEPU, GEREPU, UKEPU, FREPU) and the two cryptocurrencies (BTC and ETH).

Regarding BTC medium-term results, we found relationships with out-phase movements: between early 2019 and early 2020 (pre-COVID and COVID periods), BTC relationships with EUEPU and GEREPU show BTC leading. These results reveal that Bitcoin fails to act as a hedger or safe-haven against EUEPU and GEREPU indices during specified times over the pre-COVID and COVID periods.

Our results also reveal relationships with in-phase movements: from 2021 onwards (COVID and post-COVID periods), BTC relationships with GEPU, USEPU, CEPU and UKEPU show the indices leading. These results complement the findings by Shaikh (2020), Al-Yahyaee et al. (2019), Das et al. (2018) and Jiang et al. (2021), highlighting that Bitcoin may be considered as a good hedger or safe-haven against GEPU, USEPU, CEPU and UKEPU during specified times over the COVID and post-COVID periods.

Additionally, there is also evidence of no relationships in the medium-term between BTC and: GEPU, USEPU, CEPU, UKEPU and FREPU for the pre-COVID period; FREPU for the COVID period; EUEPU, GEREPU and FREPU for the post-COVID period. Thus, showing that Bitcoin can act as a diversifier against these indices over these periods.

Regarding ETH, results reveal medium-term relationships with out-phase movements in mid-2019 (pre-COVID period) for ETH relationships with GEREPU, where ETH is leading.

Hence, evidencing that Bitcoin may act as a hedger or safe-haven against GEREPU uncertainty index during the pre-COVID period.

The results also reveal evidence of relationships with in-phase movements: in end 2018 (pre-COVID period) ETH relationships with EUEPU show ETH leading, while relationships with FREPU show the index leading; from 2021 onwards (COVID and post-COVID periods) ETH relationships with USEPU, GEPU and UKEPU show the indices leading.

Consequentially, Ethereum may be seen as good hedger or safe-haven against: EUEPU and FREPU during the pre-COVID period; against UKEPU and FREPU during the COVID period; and against GEPU, USEPU and UKEPU during post-COVID period.

There is also evidence of no relationships in the medium-term between ETH and: GEPU, USEPU, CEPU and UKEPU for the pre-COVID period; GEPU, USEPU, CEPU and EUEPU for the COVID period; CEPU, EUEPU, GEREPU and FREPU for the post-COVID period. Hence revealing Ethereum's ability to act as a diversifier against these indices over these periods.

Regarding United Kingdom EPU, it is verified a significant red zone in its relationship with BTC from 2021 onwards, that might be related to PayPal's announcement allowing crypto-digital payments in the UK (Browne, 2021). Germany's EPU also reveal a significant red zone which might be justified similarly as it was in the short-term analysis.

In long-term analysis, our result reveal evidence of relationships with out-phase movements. From the end of 2019 until mid-2020 (COVID period), BTC relationships with GEPU and CEPU show the indices leading, while relationships with USEPU show BTC leading. These results complement the findings by Bouri et al. (2017), Al-Yahyaee et al. (2019), Wang et al. (2019) and Wang et al. (2022), however, contradict Cheng & Yen (2020) and Shaikh (2020) findings, by highlighting that Bitcoin fails to act as a hedger or safe-haven against GEPU, CEPU and USEPU during the specified times over the COVID period.

Additionally, there is also evidence of no relationships in the long-term between BTC and EUEPU, GEREPU, UKEPU and FREPU for the COVID period. Therefore, Bitcoin seems to act as a diversifier against these indices over COVID period.

Regarding ETH long-term analysis, our results reveal the existence of relationships with in-phase movements: from the end of 2019 until the end of 2020 (pre-COVID and COVID periods), ETH relationships with GEREPU show the index leading; and from the end of 2019 until the end of 2020 (COVID period), ETH relationships with EUEPU and FREPU show the indices leading. These results suggest that Ethereum may be considered as a hedge or safe-haven against the GEREPU during the specified times over the pre-COVID and COVID periods, and against the EUEPU and FREPU during the specified times over the COVID period.

Additionally, there is also evidence of no relationships in the long-term between ETH and GEPU, USEPU, CEPU and UKEPU for the COVID period. Consequently, Ethereum bears the ability to act as a diversifier against these indices over COVID period.

Specifically, in the case of Germany's EPU index relationship with ETH, there is a significant red area over the period between the end of 2019 and the end of 2020. This strong correlation may be justified based on the sharp growing legislation and regulation made by the German government in crypto-matters, specially focused on DeFi technologies (Baydakova, 2019).

5. CONCLUSION

In this study we address important literature gaps and evaluate how the economic policy uncertainties, particularly before, during, and after the COVID-19, impacts on the major cryptocurrencies. To this end, we defined a threefold objective: assess the relationships between the major cryptocurrencies (Bitcoin and Ethereum) and seven economic policy uncertainty indices (Global, USA, China, Europe, Germany, UK and France) in a monthly basis;

characterize cryptocurrencies as hedging, safe-haven or diversifier instruments of portfolio investment; and classify them over pre-COVID, COVID and post-COVID periods. The period of analysis is from January 2018 to April 2022, which encompasses monthly prices for Bitcoin and Ethereum, and EPU values.

Our results present some new insights on the relationships between EPU's and major cryptocurrencies with the distinction that our analysis is divided into pre-COVID, COVID and post-COVID periods.

The cross wavelet transform analysis reveals that both Bitcoin and Ethereum are predominantly characterized as a diversifier across all periods.

The wavelet coherence analysis reveals that both Bitcoin and Ethereum are in many cases also characterized as a diversifier across all periods. However, the wavelet coherence analysis also highlights that, in general over the post-COVID period there were mostly positive correlations, suggesting the ability of both Bitcoin and Ethereum to act as hedgers or safe-haven instruments against uncertainty. On the other hand, over the pre-COVID and COVID period, there were mostly negative correlations, suggesting the inability of both cryptocurrencies to act as hedgers or safe-haven instruments against uncertainty.

Our study adds to the current literature on cryptocurrencies relationship with uncertainty by presenting an earlier assessment regarding the pre, during, and post-COVID period analysis. Additionally, it also warrants new empirical evidence on the impact of major world economic powers' uncertainty over the most important cryptocurrencies.

A study with these macroeconomic implications, is of great interest to investors, managers, governors, market regulators, and academics (Das et al., 2018; L. Wang et al., 2022). Our findings present valuable insights for investors who consider cryptocurrencies into their portfolios and help them minimizing risks and maximizing returns against uncertainty. In addition, the EPU's effects provide insights for policymakers and regulators to adequately regulate these digital assets, regulations that are urgently needed.

As limitation of our study, we point out the frequency of the sample. As future venues of research we highlight the need to understand economic policy uncertainty's impact on other cryptocurrency classes such as Stablecoins and Memecoins, as well as assess the impact that Russia's war on Ukraine might have on the cryptomarket in general.

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