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Is Bitcoin an emerging market? A market efficiency perspective

Abstract

Despite recent studies focused on comparing the dynamics of market efficiency between Bitcoin and other traditional assets, there is a lack of knowledge about whether Bitcoin and emerging markets efficiency behave similarly. This paper aims to compare the market efficiency dynamics between Bitcoin and the emerging stock markets. In particular, this study indicates whether the dynamics of Bitcoin market efficiency mimic those of emerging stock markets. Thus, the paper's contribution emerges from the combination of Bitcoin and emerging markets in the field of dynamics of market efficiency. The dynamics of market efficiency are measured using the Hurst exponent in the rolling window. The study uses daily data for the MSCI Emerging Markets Index and the Bitcoin market over the period 2011–2022. Our results show that there is at most a moderate correlation between the dynamics of Bitcoin and emerging stock markets' efficiency over the entire study period. The strongest correlations occur mainly in periods of high economic policy uncertainty in the largest Bitcoin mining countries. Therefore, the association between Bitcoin market efficiency and emerging stock markets' efficiency may strengthen with an increase in economic policy uncertainty. These findings may be useful for investors and portfolio managers in constructing better investment strategies.

Keywords

bitcoin | market efficiency | emerging stock markets | long-range dependence | Hurst exponent

JEL Codes

G11, G14, G15

1. Introduction

Bitcoin is the largest (when it comes to capitalisation) and the most researched cryptocurrency in the context of informational efficiency (Urquhart, 2016; Bariviera, 2017; Kristoufek, 2018; Kumar & Zargar, 2019; Tran & Leirvik, 2020; Noda, 2021). The majority of these studies have confirmed that the Bitcoin market is the least inefficient among cryptocurrencies. Thus, Bitcoin seems to be the most mature market and representative cryptocurrency (in terms of researchers' and investors' attention). However, similarly to other cryptocurrency markets, many previous studies also indicate that the Bitcoin market is still inefficient (e.g. Kosc, Sakowski & Ślepaczuk, 2019).

The market is efficient when investors are not able to earn abnormal returns based on their past values (Fama, 1970). In other words, the market prices include all information. However, changes in market conditions and behavioural biases may make that market efficiency dynamic. For example, loss aversion may affect investor decision-making under business uncertainty (Kahneman & Tversky, 1979). The Adaptive Markets Hypothesis combines these components and assumes that investors learn from their mistakes. After some time (change in market conditions), investors adapt to this new environment and then the market may be very close to efficiency. But market conditions vary over time, leading to behavioural biases of investors (e.g. overconfidence, overreaction) and, in effect, the dynamics of market efficiency can be observed (Lo, 2004). For example, Lim, Brooks and Kim (2008) find the dynamics of stock market efficiency during different market conditions. So it seems that changes in economic uncertainty related to different market conditions affect market efficiency.

So far, there is no comprehensive answer to the question of whether the Bitcoin market efficiency is developing better than that of emerging markets. This paper aims to fill this gap by comparing the dynamics of market efficiency in the Bitcoin market with that of the emerging stock markets. This may help investors to allocate capital more efficiently. In particular, the survey of the relationship between emerging markets

and Bitcoin over time could indicate whether a portfolio's chance of obtaining a given return is greater by including both markets. On the other hand, this analysis from a market efficiency perspective may show in which sub-periods there is a delay in the price's reaction to information and what the size of the price's deviation from the random walk process is. Thus, it could be used by investors in constructing better investment strategies.

The latest research on cryptocurrency market efficiency has focused on the resilience of this Bitcoin market efficiency to global shocks such as the Covid-19 pandemic. Phiri (2022) shows that the pandemic has affected the dynamics of Bitcoin market efficiency. A similar view is developed by Fernandes et al. (2022), who conclude that the response of Bitcoin market efficiency to Covid-19 is different from other markets. This evidence is supported by others (Wang et al., 2021; Diniz-Maganini, Diniz & Rasheed, 2021; Mensi et al. 2022) who also compare the dynamics of market efficiency in Bitcoin with developed markets and traditional investments. The above-mentioned studies do not include emerging stocks in this context. However, Lim et al. (2008) confirm that some emerging markets exhibit higher market inefficiency in times of financial crisis. Baur and McDermott (2010) note that large emerging markets react differently to economic shock (compared to developed stock markets). Thus, the dynamics of market efficiency of both the emerging and Bitcoin markets seem to be affected by unexpected events in different ways than developed stock markets. Because of this, a study on the resilience of Bitcoin and emerging markets' efficiency to economic shocks is needed. Therefore, this paper joins a discussion on the comparison of the dynamics of Bitcoin market efficiency with the dynamics of market efficiency in other traditional markets.

Existing studies cover the relationship between Bitcoin and emerging markets in other aspects than dynamics of market efficiency (Carrick, 2016; Bouri et al., 2017; Shahzad et al., 2019; Mizerka, Stróżyńska-Szajek & Mizerka, 2020; Bouri et al., 2020). Specifically, the studied areas include the dependence between Bitcoin and emerging markets returns, the co-movement of markets at different time horizons, the predictability of asset returns from stock market returns. The majority of these studies suggest that this association is weak and may be time-varying. The reaction of the correlation between the markets and economic shocks may affect the losses of their investors during these events (Baur & McDermott, 2010). In particular, they notice the reactions of emerging markets, their difference from developed markets, during extreme events. However, there is a lack of empirical analysis of the relationship between the dynamics of Bitcoin market efficiency and the dynamics of emerging markets' efficiency over time. Therefore, the studies of the association between markets during economic shocks should be deepened.

Several studies indicate some similarities between Bitcoin and emerging markets from a market efficiency perspective. Urquhart (2016), Bariviera (2017), and Takaishi and Adachi (2020) find that the Bitcoin market has become more efficient over time. This trend in market efficiency is also documented in the case of some emerging stock markets by Cajueiro and Tabak (2004), Sukpitak and Hengpunya (2016), and Hkiri et al. (2021). In this context, it can be concluded that some emerging markets and Bitcoin become more efficient in the years 2015–2016. However, in the Chinese and Bitcoin markets during the years 2014–2015, bubble-like price dynamics could be observed. According to Kristoufek (2018), the Bitcoin market is efficient only after price bubbles, that is, during low Bitcoin price dynamics. Some studies (e.g. Lim et al., 2008; Hull & McGroarty, 2014) also report that emerging markets exhibit higher inefficiency in certain periods. Motivated by various results, this paper verifies whether both emerging and Bitcoin markets will become more efficient over time.

The research gap consists of several strands. Firstly, it concerns the comparison of Bitcoin with emerging stock markets' efficiency. In particular, the relative dynamics of market efficiency in both markets have not been analysed in times of different turmoils. Furthermore, so far, the relationship between Bitcoin and emerging markets' efficiency have not been linked to the high economic policy uncertainty events in its largest mining countries during this period. Besides, to the best of the author's knowledge, the rolling correlation between the dynamics of market efficiency of Bitcoin and emerging markets has not been measured. It may help to compare the relative chance of profitable investment strategies in different markets at some time horizon. Thus the following research question was asked: What is the relationship between Bitcoin and emerging stock markets from the market efficiency perspective?

The main purpose of this article is to compare the dynamics of market efficiency between Bitcoin and the emerging stock markets. For this aim, the weak form of market efficiency is analysed over time by applying the Hurst exponent in the rolling window.

Specifically, the dataset consists of daily closing prices of the MSCI Emerging Markets Index and the Bitcoin market from the period 2011 to 2022. Finally, the correlation coefficient is measured between two-time series of Hurst exponents on a rolling window. In effect, the dynamic relationship between the Bitcoin market efficiency and the emerging stock markets' efficiency is shown. Thus, it is indicated whether Bitcoin and emerging stock markets show some similarities in their efficiency.

Findings show that there is a moderate correlation between the market efficiency of Bitcoin and emerging stock markets at some periods (the strong value of the correlation is not confirmed in the additional tests). This is in contrast to previous research on the association between Bitcoin and emerging market returns. Bitcoin market efficiency and emerging markets' efficiency report the most common fluctuations in periods of large economic policy uncertainty. Specifically, the jumps in correlation values occurred in the periods: the threat of a spillover of the euro area crisis in 2012, the threat of the US debt crisis at the end of 2013, Russia's aggression against Ukraine on February 2014, China's economic downturn in 2015, the USA – China trade tensions in the years 2018–2019, Covid-19 in 2020 and the Russia – Ukraine war in 2022.

Thus, the results can be assigned to the events related to the high economic policy uncertainty of the largest Bitcoin mining countries (e.g. China, the USA). For example, the uncertainty related to the US presidential election results in 2016 (Trump's election), the USA – China trade policy tensions in the years 2018–2019 and the threat of Covid-19 may be associated with the jumps in the values of correlation. The identified economic shocks extend the conclusions of the existing research on the dynamics of Bitcoin market efficiency because recent studies mainly verify the importance of Covid-19 for the dynamics of market efficiency as a global crisis. It can be supposed that the economic shocks of the largest Bitcoin mining countries also would have an impact on the dynamics of Bitcoin market efficiency and its relationship with the dynamics of emerging markets' efficiency. Therefore, investors should pay attention to the role of high economic policy uncertainty of these countries in the profitability of their portfolio diversification, which includes Bitcoin and emerging markets.

The contribution of this study is at least threefold. Firstly, this paper adds to the previous literature by comparing the dynamics of market efficiency in Bitcoin and emerging stock markets. In the existing research, there is no clear evidence of the 'emerging' nature of the cryptocurrency market efficiency. However, researchers refer to cryptocurrencies as an emerging market (Alvarez-Ramirez, Rodriguez & Ibarra-Valdez, 2018; Khuntia & Pattanayak, 2018; Kumar & Zargar, 2019). Inappropriate classification of the Bitcoin market may cause investors to treat it as less risky than it is. Therefore, this study contributes to the possibility of a better allocation, as it shows the actual and relative level of both Bitcoin market maturity and the degree of predictability of the returns time series of the studied markets. Thus, it is important to verify that the emerging market is the proper category, in the case of Bitcoin.

Secondly, the study extends a discussion on the resilience of market efficiency to economic shocks. The more resilience of market efficiency of one asset from another could be a potential attribute of the safe haven (Wang et al., 2021). In other words, the safe haven could be identified by the observation of negative predictability from the stock market to the (safe haven) asset or by the fact that losses from one investment are compensated by gains from another (Shahzad et al., 2019). This is the first study to compare the market efficiency dynamics of emerging stock markets and Bitcoin in different periods of economic shocks. Recent studies focus on the relationship between Bitcoin and emerging economies in the context of portfolio diversification opportunities (Bouri et al., 2017; Shahzad et al., 2019; Mizerka et al., 2020; Bouri et al., 2020). The low (or negative) correlation between Bitcoin and other assets may indicate benefits from portfolio diversification, especially during periods of market stress that may be characterised by a different herd behaviour of investors (because of different perceptions of the impact of a given shock on markets). However, there is still a research gap in this phenomenon from a market efficiency perspective. The findings show whether the chance to obtain profitable strategies based on historical quotations in one market may be higher than in another. If both markets are included in one portfolio, the low (or negative) correlation between the degree of the predictability of returns in these markets may indicate potential benefits of a safe haven from the investment strategies based on the market performance; that is, economic shock effects on both markets differ in terms of degree and/or nature of dependence (momentum/mean-reversion) in return time series in a given time. Thus, in terms of practical contribution, this study may help investors in developing better diversification

investment strategies. For example, the largest positive correlations between Bitcoin and emerging markets' efficiency in a period of market stress confirm that investment strategies based on the historical returns obtained in these markets should rather assume a reduction of the share of these investment assets in the portfolio during some unexpected events.

Thirdly, this paper contributes to the literature on the dynamics of Bitcoin market efficiency and its potential factors. Despite many recent studies on the dynamics of Bitcoin market efficiency, there is no comprehensive evidence on whether the dynamics of Bitcoin market efficiency are related to uncertainty (Wang et al., 2021; Diniz-Maganini et al., 2021; Mensi et al. 2022; Phiri, 2022; Fernandes et al., 2022; Mnif, Mouakhar & Jarboui, 2023). In addition, so far it has not been verified in the context of emerging stock markets. This research shows that high economic uncertainty potentially affects the changes in both Bitcoin and emerging stock markets' efficiency. In effect, investors should take the economic policy uncertainty of the largest emerging countries in Bitcoin mining into consideration. Thus, the novelty of this paper arises from the combination of the dynamics of Bitcoin and emerging markets' efficiency and uncertainty. This research makes a theoretical contribution by explaining the co-movements in the markets' efficiency dynamics of different investment assets by the sub-optimal investor reaction to the high economic policy uncertainty events concerning the largest countries in terms of the capital flows between these markets. In other words, the reason for the increase in the correlation between markets' efficiency may be that investors are more subject to the representativeness heuristic in times of high economic uncertainty events. Thus, this study deepens understanding of the Adaptive Markets Hypothesis.

The structure of the article is as follows: The first section is the introduction. The second part presents the literature background. Next, the data and methodology applied in this paper are described. The third section reports the results. The fourth part of the article consists of additional analyses. The last sections are the discussion and the conclusion.

2. Literature review

Bitcoin is the most popular cryptocurrency and the largest in terms of market capitalisation, which accounts for about 43% of the cryptocurrency market share (January 4, 2023). The purpose of the creation of Bitcoin is to be used as a payment system. In fact, some users treat Bitcoin as an alternative currency or even a store of value (Polasik et al., 2015). However, most participants in the cryptocurrency market perceive it as a speculative investment (Hileman & Rauchs, 2017, p. 24).

One of the most discussed issues in the context of Bitcoin is its market efficiency. This popular topic has been studied for many years in the stock markets since Fama (1970) formulated the efficient market hypothesis. According to Fama (1970), the efficient market hypothesis (EMH) means it is impossible to use past prices to predict future prices (weak form). Thus, it refers to informational efficiency (Czekaj, Woś & Żarnowski, 2001, 30) which is an important global problem, because the growth in market efficiency may lead to a better allocation of capital (both from the global and individual investors' perspectives).

The majority of early studies on Bitcoin market efficiency report that its price behaviour is non-random and characterised by dynamics. Urquhart (2016) and Bariviera (2017) applying the Hurst exponent showed that the Bitcoin market was inefficient in the years 2010–2016/2017 and that lately, there was a trend toward an efficient market. Other researchers (Aggarwal, 2019; Bouri et al., 2019; Jiang, Nie & Ruan, 2018; Kumar & Zargar, 2019; Takaishi & Adachi, 2020) also confirmed that the inefficiency of the Bitcoin market varies over time. Several of them found a long memory of Bitcoin returns, which signals a positive autocorrelation (e.g. Alvarez-Ramirez et al., 2018). Thus, the above-mentioned evidence suggested that Bitcoin may become more efficient over time. However, it seems to be still an inefficient market with the presence of long memory.

Similar results can be found in the context of emerging markets (Cajueiro & Tabak, 2004; Sukpitak & Hengpunya, 2016; Hkiri et al., 2021). These studies confirmed that emerging markets have become more efficient over time. Hull and McGroarty (2014), however, noticed that the emerging markets' efficiency was time-varying and characterised by a long-memory process most of the time. Therefore, the following research question was addressed: What is the relationship between Bitcoin and emerging stock markets from the market efficiency perspective?

Despite recent papers mainly contradicting Bitcoin market efficiency, many of them also focus on the factors of market efficiency (e.g. Brauneis & Mestel, 2018; Wei, 2018; Köchling, Müller & Posch,

2019; Khuntia & Pattanayak, 2020; Takaishi & Adachi, 2020; Noda, 2021; Phiri, 2022) or the relationship between the dynamics of market efficiency of Bitcoin and traditional financial assets (e.g. Al-Yahyaee, Mensi & Yoon, 2018; Plastun et al., 2019; Diniz-Maganini et al., 2021; Wang et al., 2021; Mensi et al., 2022) or other cryptocurrencies (e.g. Caporale, Gil-Alana & Plastun, 2018; Wei, 2018; Borowski & Matusewicz, 2019; Aslan & Sensoy, 2020; Noda, 2021; Assaf et al., 2022). In this context, several researchers (Brauneis & Mestel, 2018; Wei, 2018; Noda, 2021) found that Bitcoin was the least inefficient compared to other cryptocurrencies. Therefore, taking that this is the most studied, least inefficient, and largest cryptocurrency into consideration, it seems to be the most suitable representative of the cryptocurrency market with which to examine the dynamics of market efficiency.

Recent studies compare Bitcoin market efficiency to the efficiency of traditional assets such as gold, currencies, bonds, stock markets, and commodities (Al-Yahyaee et al., 2018; Plastun et al., 2019; Wang et al., 2021; Diniz-Maganini et al., 2021; Mensi et al., 2022; Chowdhury et al., 2023). Most of them indicate that the size of the Bitcoin market inefficiency is different from other markets. However, several studies confirm that these markets exhibit some similarities when it comes to market price reactions to economic shocks such as Covid-19. Mensi et al. (2022) and Wang et al. (2021) documented that the inefficiency of Bitcoin and other studied markets of traditional financial assets increased during the time of Covid-19. Lim et al. (2008) also support these findings in the case of the reaction of emerging market efficiency to a financial shock. Thus, it can be expected that in times of market turmoil, the correlation between the market efficiency of traditional emerging markets and Bitcoin strengthens and the market efficiency deteriorates in both cases.

Another interesting conclusion can be drawn in the context of the market efficiency resistance to high economic policy uncertainty. For example, Wang et al. (2021), Diniz-Maganini et al. (2021), and Mensi et al. (2022) observed that during Covid-19 the increase in the Bitcoin market inefficiency was smaller than for the other studied markets, which could be an attribute of a safe haven (Wang et al., 2021). A similar conclusion was developed by Fernandes et al. (2022), who stated that the dynamics of cryptocurrency market efficiency is robust to unpredictable shocks such as Covid-19. In contrast to them, Phiri (2022) obtained findings that contradict the resistance of the dynamics of Bitcoin market efficiency to shocks. Recently, Rufino (2023) confirmed that Bitcoin market efficiency deteriorated during the pandemic period. This is supported by Mnif et al. (2023), who also reported that during unexpected events such as the Russia-Ukraine war, the Bitcoin market inefficiency increases. However, Chowdhury et al. (2023) noticed that during the Covid-19 period, the market efficiency of the S&P 500 changed more than did that of Bitcoin. Thus, the majority of results provide evidence that supports the greater resilience of Bitcoin market efficiency to economic shocks compared to the markets of traditional investment assets. There is still no consistency, however, concerning whether Bitcoin market efficiency is robust to unexpected events.

So far, the studied factors of cryptocurrency market efficiency include liquidity (Brauneis & Mestel, 2018; Wei, 2018; Köchling et al. 2019; Takaishi & Adachi, 2020; Noda, 2021), halving (Phiri, 2022), market capitalisation (Brauneis & Mestel, 2018), or trading volume (Khuntia & Pattanayak, 2020). Although the latest research indicates that in the case of a speculative bubble or global crisis, there is an increased comovement of Bitcoin and most cryptocurrencies (Assaf et al., 2022) or traditional investments efficiency (Wang et al., 2021; Mensi et al., 2022). This has not been verified yet for the market efficiency of Bitcoin and emerging markets. Moreover, some researchers (Czarnecki, Grech & Pamuła, 2008; Hkiri et al., 2021) have noticed that the behaviour of the Hurst exponent of the developing stock markets may be related to the financial or political crisis. Therefore, it can be assumed that, similar to other traditional markets, the dynamics of emerging markets' efficiency may be more related to the dynamics of Bitcoin market efficiency during times of high economic policy uncertainty events. This is supported by large capital flows between emerging markets and Bitcoin in the context of cryptocurrency mining (Statista, 2022).

Only Plastun et al. (2019) examined emerging markets' efficiency and Bitcoin market efficiency. Specifically, they compared the market efficiency of two emerging markets (Russia and Ukraine) to Bitcoin market efficiency. Thus, they did not take China into account, which is the largest emerging market (the share of China in the MSCI Emerging Markets index was about 30% in late 2022) and one of the most important countries in the case of Bitcoin mining. Therefore, further studies which will include the largest emerging markets in this field are needed.

Plastun et al. (2019) also concluded that these markets exhibited different degrees of persistence in

returns for days of the week in the years 2014–2018, which is contrary to the efficient market hypothesis. Moreover, the majority of other studies suggested that the association between emerging markets and Bitcoin is weak and may be time-varying (Carrick, 2016; Shahzad et al., 2019; Bouri et al., 2020). Along these lines, it can be expected that the relationship between emerging markets and Bitcoin from a perspective of dynamics of market efficiency is weak for the whole period. On the other hand, Plastun et al. (2019) used the Hurst exponent for emerging markets in cross-section on different days of the week. This static approach does not include the dynamics of correlation and volatility clustering, changes in the underlying process which drives Bitcoin prices (Aggarwal, 2019). Thus, the results obtained by Plastun et al. (2019) should be verified by applying a different approach, such as dynamic correlation (e.g. sliding window). Besides, this evidence suggests that the relationship between emerging markets and Bitcoin efficiency may be time-varying.

To sum up, most studies of cryptocurrencies' market efficiency have been conducted on the Bitcoin market. This cryptocurrency has the largest share of the market and is the least inefficient. Furthermore, previous research looking at Bitcoin from a market efficiency perspective have focused on its relationship with other cryptocurrencies, uncertainty, or traditional assets such as gold, currencies, commodities, and developed countries' stocks. These studies don't take the large capital flows between emerging countries and Bitcoin into account. As an effect, no evidence includes the largest emerging stock markets from this perspective. However, the majority of them suggest that the association between emerging markets and Bitcoin is weak and may be time-varying (Carrick, 2016; Shahzad et al., 2019; Bouri et al., 2020). In particular, some studies conducted from a market efficiency perspective find separately that both Bitcoin (Urquhart, 2016; Bariviera, 2017; Takaishi & Adachi, 2020) and the emerging markets (Cajueiro & Tabak, 2004; Sukpitak & Hengpunya, 2016; Hkiri et al., 2021) have become more efficient over time. Thus, the research question concerns the relationship between Bitcoin and emerging stock markets' efficiency.

3. Data and methodology

In line with Urquhart (2016), Bariviera (2017), Kristoufek (2018), and Jiang et al. (2018), logarithmic returns are calculated to provide time series for analysis of market efficiency. To verify the market efficiency, the Hurst exponent is adopted. It is a measure of long-range dependence. Following Urquhart (2016) and Bariviera (2017), the Hurst exponent is calculated using the rescaled range analysis (R/S). According to Kristoufek (2010), this method can be represented as an analysis of the rescaled range of a time series for different scales of a given length. In effect, there is a dependence on a distraction (range - *R*) from different lengths of scale (*i*). Briefly, this relation is presented below:

$$R/S = a \cdot i^H \tag{1}$$

where H is the Hurst exponent, S is the standard deviation of the sums of departures of returns from the average in a given period, R (range) is a difference between the maximum and minimum of the sums of deviations from the average in each subinterval of 'i' length, 'a' is a constant.

When the above relationship imitates a linear trend in a double-logarithmic scale, there is a random walk of the time series. So, if the Hurst exponent equals 0.5, the market is efficient. The value of the Hurst exponent of more than 0.5 means that the time series is long memory persistent. On the other hand, when the value of the Hurst exponent is less than 0.5 it can be interpreted as a mean-reversion property of a time series.

As pointed out by Kristoufek (2010), the standard deviations for the rescaled range analysis are smaller compared to the detrended fluctuation analysis (DFA) which is a very popular alternative in this case. However, he states that in general, the results of both methods are quite similar. Furthermore, Kristoufek (2010) recommends applying a minimum scale of 16 observations and a minimum length of time series equal to 512 data points in the case of R/S. He argues that too-small scales can lead to an incorrect value of the standard deviation (bias), which is used to rescale the ranges during the estimation of the Hurst exponent. However, too-large scales may cause the impact of extreme values to be underestimated. Thus, the minimum scale of 16 and the length of 512 for the time series are used. In effect, to show the dynamics of market efficiency, we calculate the Hurst exponent over a rolling window of 512 data points (a fixed size) with one-day step. This is comparable to the two-year window exploited by Bariviera (2017).

Similar to Polanco-Martínez (2019), to present a dynamic relationship between two variables –

the Hurst exponents of the Bitcoin and the MSCI Emerging Markets Index – the rolling window correlation coefficients are estimated. Specifically, the Spearman rank correlation with p-values is exploited, because this is more robust to non-linear relationships of the analysed data series. The reasons for applying the rolling window correlation are the presence of volatility clustering (Bariviera, 2017) and structural breaks (Jiang et al., 2018) in financial time series which could signal nonlinear patterns in the dynamics of market efficiency. The correlations are based on the series of Hurst exponents. For example, it means that the dynamic correlation coefficient for the first of January 2021, refers to the behaviour of market returns in the previous period of two years plus the window size for the rolling correlation (251 or 126 data points).

Finally, the robustness of the results is verified in several ways. As proposed by Polanco-Martínez (2019), the dynamic correlation is applied for different window sizes. On the one hand, the small length of the time series which is used to compute the correlation could influence the significance of results. On the other hand, the use of larger window sizes may mean that the one correlation value includes the impact of several 'unpredictable' events (which are rare), so it will be difficult to isolate the importance of one event for the studied association. Therefore, only two window sizes are used: 126 and 251 data points. Besides, Kendall's correlation is applied to verify whether the results are robust.

Similar to Borowski and Matusewicz (2020), detrended fluctuation analysis (DFA) is also adopted to provide additional estimates for market efficiency. In contrast to the rescaled range analysis, DFA exploits the squared fluctuations function that is a measure of variability (instead of the range). Additionally, the overlapping rolling window of 512 observations with a minimum scale of 16 data points is used. As an effect, the dynamic Spearman correlation is applied to the Hurst exponents based on the DFA method.

The dataset consists of daily closing prices of Bitcoin and the MSCI Emerging Markets Index in the period September 13, 2011, through August 11, 2022. This period is limited by the availability of quotations from the Bitstamp exchange. Another reason for the length of this period is that it includes the largest changes in economic policy uncertainty, which allow us to study the price's reaction to different levels of information uncertainty. Similar to Bariviera et al. (2017) and Takaishi and Adachi (2020), the Bitcoin data from Bitstamp (the world's longest-standing cryptocurrency exchange) are used and collected through the website: http://api.bitcoincharts.com/v1/csv/. In this case, for each common business day, the day's closing price is exploited (according to Aslan and Sensoy (2020)). The MSCI Emerging Markets Index prices are sourced from the *Wall Street Journal* (https://www.wsj.com/market-data/quotes/index/XX/891800/historical-prices). Information about economic policy uncertainty events for China, Russia, and USA is downloaded from www.policyuncertainty.com (except for China's downturn in 2015).

Table 1 presents estimates of basic descriptive statistics for Bitcoin and the MSCI Emerging Markets Index. It can be noticed that Bitcoin reports a higher maximum daily return of 48% and the largest decrease of 66%, compared to the MSCI Emerging Markets Index. Besides, both return series are left skewed and leptokurtic. However, the left tail of the distribution in Bitcoin returns is much longer (-1.0666) than for the MSCI Emerging index (–0.5098). Results of the ADF test imply that returns for Bitcoin and the MSCI Emerging index are stationary. These findings suggest that Bitcoin returns are more volatile, and their distribution is more non-normal than in the case of the emerging stock markets.

Table 1. Descriptive statistics for the logarithmic return series of Bitcoin (BTC) and the MSCI Emerging Markets Index from 13 September 2011 to 11 August 2022

	BTC	MSCI Emerging Markets
Mean	0.0029	1.78E-05
Median	0.0026	4.55E-04
Maximum	0.4848	5.58E-02
Minimum	-0.6639	-6.94E-02
Std. Dev.	0.0558	0.0101
Skewness	-1.0666	-0.5098
Kurtosis	23.3798	8.0321
ADF	-11.764***	-14.166***
Observations	2835	2835

Note: *** means a 1% significance level. Source: Own calculations

4. Results

Figure 1 shows the time series of the Hurst exponents for both studied markets over time. The red and blue lines denote the Hurst exponents for Bitcoin and MSCI Emerging Markets Index, respectively. As seen in Figure 1, at most times there is a time-varying long memory of Bitcoin and the MSCI Emerging Markets Index, because both markets obtained the most values of the Hurst exponent more than 0.5. In particular, most of the largest deviations of the Hurst exponent from 0.5 are reached for Bitcoin. Thus, generally, the Bitcoin market seems to be more inefficient compared to the emerging stock markets. A similar conclusion can be drawn based on the results of another study (Plastun et al., 2019) in the context of a comparison of the market efficiency between two emerging markets.

Secondly, in the first half of the study period, the time series of the Hurst exponents shows a decreasing trend towards the value of 0.5 (an efficient market) for both the MSCI Emerging Markets Index and Bitcoin. This trend can be assigned to the announcements of Bitcoin regulations, and recommendations of supervisory authorities, which frequently occurred in the years 2013–2018. In particular, it concerns mainly the largest Bitcoin mining countries, which are China and the USA (Statista, 2022). These 'regulatory' events might ensure better access (for investors) to information that had been undefined (uncertain) before it appeared. In effect, a decrease in the Bitcoin market inefficiency can be observed, which is consistent with Urquhart (2016), Bariviera (2017), and Takaishi and Adachi (2020). During this period, there is also an improvement in market efficiency for the MSCI Emerging Markets Index. It confirms the findings of studies on market efficiency for some emerging stock markets (Cajueiro & Tabak, 2004; Sukpitak & Hengpunya, 2016; Hkiri et al., 2021).

In Figure 1, one can see that the behaviour of the Hurst exponent at some subperiods seems to be very close for the emerging markets and Bitcoin, especially during the pandemic era from 2020–2022. To be more precise, at the beginning of the pandemic period, a meaningful increase in market inefficiency can be observed for both studied markets. However, the initial reaction of the Hurst exponent to the economic shock (pandemic) is less for Bitcoin compared to the traditional assets, which are emerging stock markets. These above findings for the Bitcoin market are in line with Wang et al. (2021), Assaf et al. (2022), Mensi et al. (2022), and Chowdhury et al. (2023). In effect, it can be expected

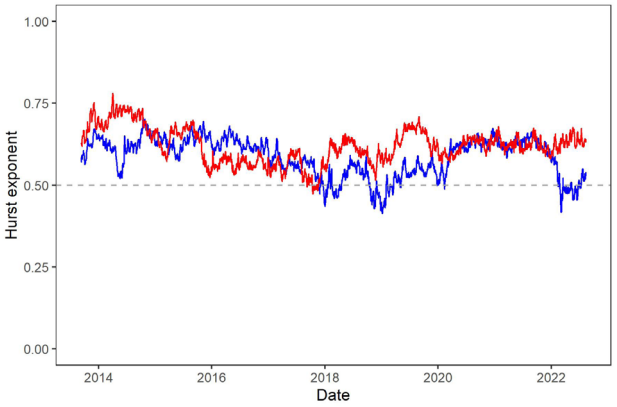

Figure 1. Hurst exponents of daily returns for Bitcoin and the MSCI Emerging Markets Index
Note: The date denotes the endpoints of the sliding windows. The red and blue lines mean Hurst exponents for Bitcoin and MSCI Emerging Markets Index, respectively. The dashed line denotes an efficient market – the value of the Hurst exponent is 0.5. Source: Own work

that the strength of the relationship between Bitcoin and emerging stock markets may be time-varying and related to some global economic shocks. Therefore, a dynamic correlation between the dynamics of the market efficiency of Bitcoin and the MSCI Emerging Markets Index is presented in Figure 2.

Time-varying correlation (Figure 2) shows that in the context of the dynamics of market efficiency, the relationship between Bitcoin and MSCI Emerging Markets is quite strong in some periods. The maximum Spearman coefficients are 0.83 (Panel A) and 0.81 (Panel B), which indicate a strong correlation. In particular, it can be observed that the significant (p-values less than 10%) and the largest correlations occur mainly in several periods, e.g. mid-2014, at the end of 2014, 2015, at the end of 2016, in early 2017, from 2018– 2019, 2020, in early 2021, at the end of 2021, and in early 2022.

The above periods can be assigned to the events of high economic policy uncertainty in the largest Bitcoin mining countries. Specifically, China and the USA were the largest Bitcoin mining countries in the last few years (Statista, 2022). However, until 2015 most Bitcoin mining industries were located in Europe and the USA (Tovanich, Soulié & Isenberg, 2021). Apart from that, China accounts for almost a third of the MSCI Emerging Markets Index. Another large emerging economy is Russia. In the study period, there are several economic shocks concerning these countries: the threat of a spillover of the euro area crisis in 2012, at the end of 2013 the threat of the US

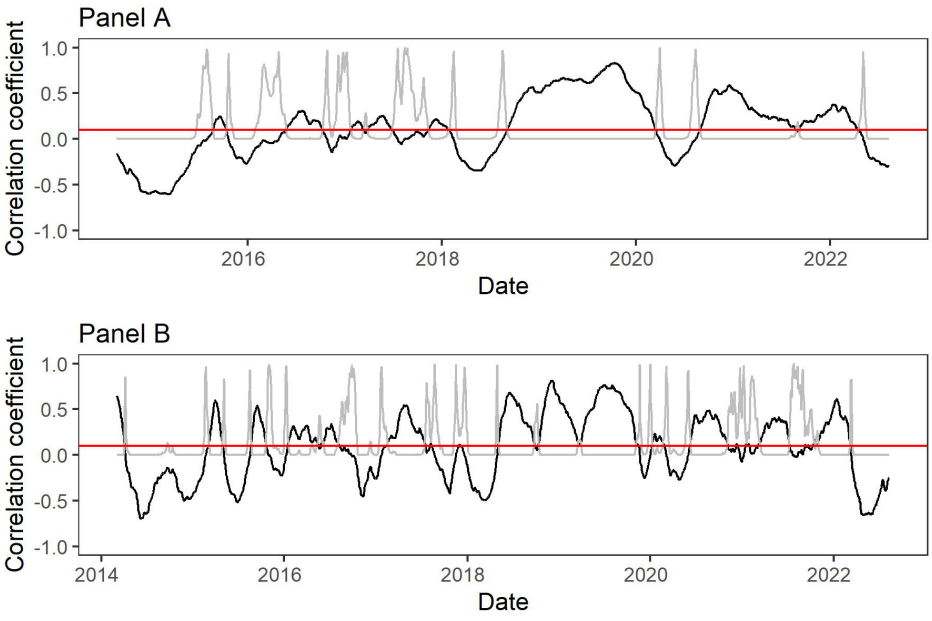

Figure 2. Dynamic correlation between Bitcoin and MSCI Emerging Markets Index using R/S at different lengths of the rolling window: 251 (Panel A), 126 (Panel B)
Note: Black and grey lines indicate correlation coefficients and p-values, respectively. The horizontal red line means p-values at 10%. Rolling window sizes are 251 (Panel A) and 126 Hurst exponents (Panel B). The date corresponds to the endpoints of the sliding windows for the correlation coefficient. Source: Own calculations

debt crisis, Russia's aggression against Ukraine on February 2014, China's economic downturn in 2015, the USA – China trade tensions in the years 2018–2019 (also related to the election of Donald Trump at the end of 2016), Covid-19 in 2020 and the Russia – Ukraine war in 2022.

In particular, the turbulence in the eurozone may cause investors to reduce the share of emerging economies in their investment portfolios. At the end of 2013, there was the threat of a debt crisis in the USA and China. China was America's largest foreign creditor in 2013. At that time, the US and Europe also had the largest share of Bitcoin mining. If Congress had not passed an increase in the national debt limit by October 17, foreign payments could be stopped. As a result, there was a partial shutdown of the US government for 16 days, because Congress could not agree on a budget. Next, there was Russia's aggression against Ukraine on February 2014. Another shock was related to uncertainty about the fact that Donald Trump won the election in late 2016. During the presidential campaign, he spoke about his future policy against the existing trade agreements with China. As a result, in January 2018, the USA set tariffs on China. This trade conflict intensified through 2019. The increase in the correlation value in the years 2020/2021 could be linked to the appearance of uncertainty related to the Covid-19 pandemic. In 2022, the threat of the Russia-Ukraine war could have affected investors in terms of increasing fear and herd behaviour.

The common feature of the above-mentioned economic shocks is their unpredictability. Because of a lack of certain information about these events (e.g. the threat of a debt crisis, the Covid-19 vaccine, trade policy between the USA and China, and war), they could not be included in market prices by the rational expectations of investors. Furthermore, investors could over- or underestimate the importance of these shocks for the economy due to the presence of a high level of fear. Thus, the irrationality of Bitcoin investors could arise from an increase in economic policy uncertainty. Besides, the specific features of cryptocurrencies also may affect investors' behaviour. The computing power which concentrates on this 'cryptocurrency system' is not related to one geographic territory. So, to estimate the distributed policy uncertainty of Bitcoin, investors may use heuristics based on the information from its largest mining countries.

Thus, it seems that events related to the high economic policy uncertainty in the largest emerging economies (e.g. China) have a meaningful impact on the comovement in dynamics of market efficiency of Bitcoin and the emerging stock markets. Specifically, in times of the highest economic policy uncertainty, the correlation value seems to strengthen. Despite

the association between Bitcoin and emerging stock markets efficiency is quite strong in some periods, a sign of the correlation changes. This may be because in the case of economic shock, in the short term, behavioural factors may be the main determinants of the efficiency of both markets. However, in the long run, the market efficiency of emerging stocks may be determined more by fundamentals, in contrast to the cryptocurrency market efficiency which may still be mainly the effect of behavioural factors. Furthermore, the negative values of the correlation could signal the feature of the safe haven in some periods for Bitcoin. This is in line with Wang et al. (2021), Maganini, Diniz and Rasheed (2021), and Mensi et al. (2022). The results are robust in the context of adopting different sizes of the rolling window. Generally, using 251 (Panel A) and 126 (Panel B) observations as a length of the sliding window, the significant and largest correlations are obtained mainly in similar periods. However, the values of the correlation based on the '126' data points are more volatile due to the shorter time series used for its calculation.

5. Additional analyses

To analyse the relationship between Bitcoin and emerging stock market efficiency more deeply, additional tests were carried out. One of them is the calculation of the correlations on the first differences of the Hurst exponents. In this case, the Hurst exponents are also based on the rescaled range analysis (R/S). The results are presented in Figure 3.

Time-varying correlation (Figure 3) shows that in the context of the dynamics of market efficiency, the relationship between Bitcoin and MSCI Emerging Markets in the pandemic period is one of the strongest compared to the whole period. However, the values of the association between Bitcoin and emerging markets suggest a weak or lack of statistical correlation in the analysed period. The strength of this association is different from the correlation based on the values (Figure 2). However, it could be expected, because the transformation of values to the first differences may result in the loss of some information.

In Figure 3, it can be observed that there are four local maxima of the correlation. Therefore, three main subperiods with different trends in the study association can be distinguished: the years 2014–2017,

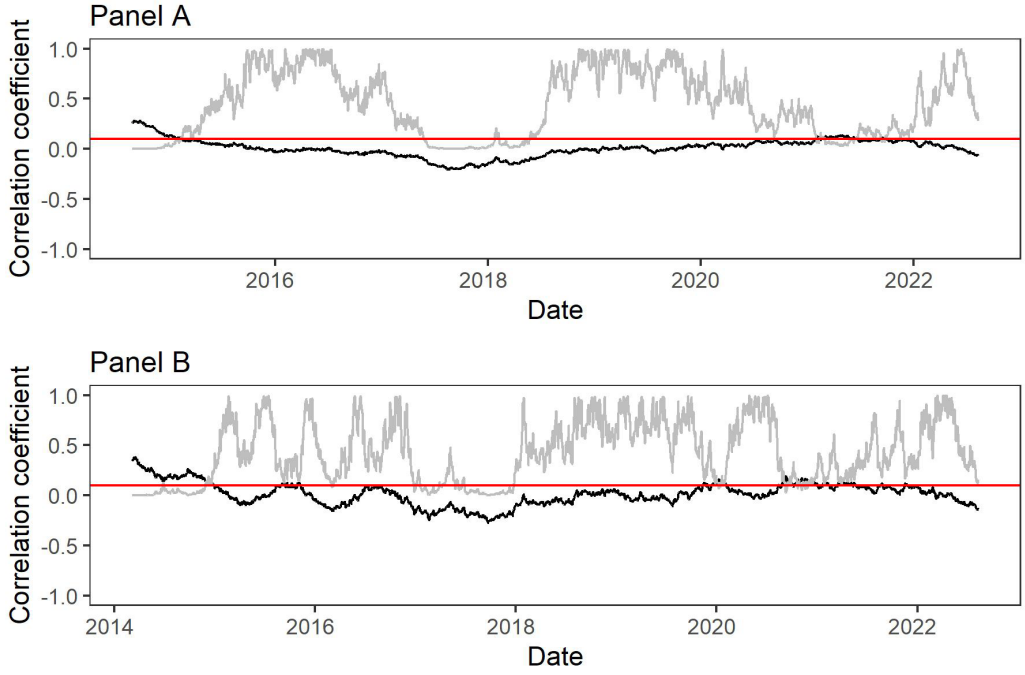

Figure 3. Dynamic correlation on the first differences of Hurst exponents between Bitcoin and MSCI Emerging Markets Index

Note: Black and grey lines indicate correlation coefficients and p-values respectively. The horizontal red line means p-values at 10%. Rolling window sizes are 251 (Panel A) and 126 Hurst exponents (Panel B). The date corresponds to the endpoints of the sliding windows for the correlation coefficient. Source: Own calculation

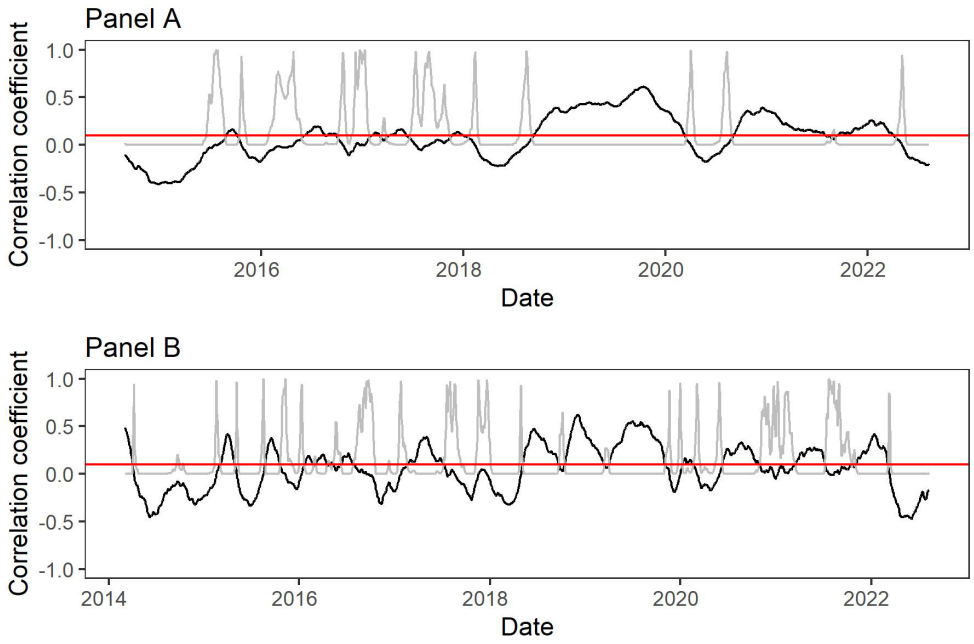

Figure 4. Dynamic Kendall correlation between Bitcoin and MSCI Emerging Markets Index using R/S at different lengths of the rolling window: 251 (Panel A), 126 (Panel B)
Note: Black and grey lines indicate correlation coefficients and p-values, respectively. The horizontal red line means p-values at 10%. Rolling window sizes are 251 (Panel A) and 126 Hurst exponents (Panel B). The date corresponds to the endpoints of the sliding windows for the correlation coefficient. Source: Own work

late 2017–2020, and from the end of 2020. The significant (p-values less than 10%) and the largest correlations occur mainly in three smaller periods – 2014–early 2015, in the years 2017–early 2018, and 2020–early 2021. These periods are covered by previous findings (Figure 2).

Figure 4 presents the dynamic correlation using Kendall's τ instead of the Spearman correlation. Notice that the results are identical to those reached by the Spearman correlation. In particular, the dynamics of the correlation coefficient are similar to that observed in the case of the Spearman correlation. The subperiods with the largest values of the study association are the same as before (Figure 2). However, the maximum value of the correlation coefficient (0.61) is smaller compared to that of 0.83, noted for the Spearman method using 251 data points as a length of the rolling window. This is also supported by the results obtained using the sliding window of 126 observations.

Figure 5 reflects estimates of the Hurst exponent using DFA (detrended fluctuation analysis). In Figure 5, some similarities can be seen in the dynamics of market efficiency using both methods – rescaled range analysis and detrended fluctuation analysis. Specifically, the significant (p-values less than 10%) and the largest correlations between Bitcoin and MSCI Emerging Markets from a market efficiency perspective can be observed mainly in similar subperiods – end of 2014/early 2015, at the end of 2015, at the end of 2016/early 2017, 2018, at the end of 2018 and 2019, at the beginning of 2020, and the end of 2020/the beginning of 2021, at the end of 2021, and in early 2022. Except for the very rare cases (periods: 2016/2017 and 2018/2019), the signs or values of the correlation are very similar for both methods. However, DFA reached on average lower maximum correlation coefficients compared to R/S while the studied relationship may be considered moderate in most periods of market stress for both methods. The reason for this can be that only DFA (contrary to R/S) uses a polynomial fit detrending in subperiods. It may be more resistant to the non-stationarity of time series compared to R/S (Kristoufek, 2010).

To show more precisely the periods in which the correlations are the strongest, the Spearman correlations based on Hurst exponents by both DFA and R/S methods, and the First differences are presented together in Figure 6.

In some periods Figure 6 presents similar dynamics of the Spearman correlation coefficients based on the Hurst exponents of both methods (DFA and R/S). In

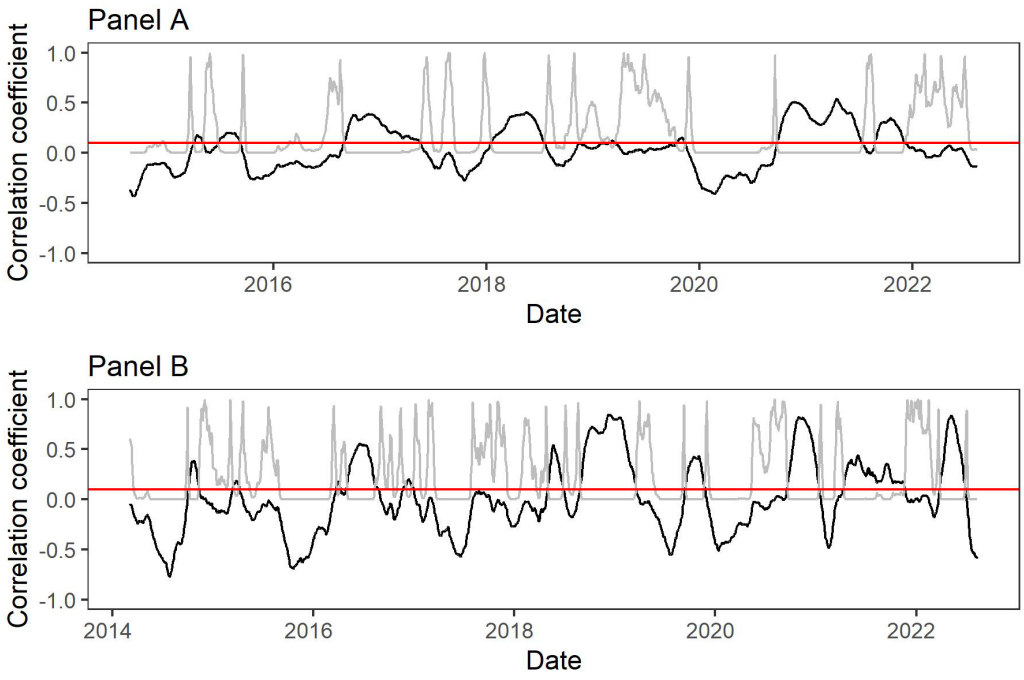

Figure 5. Dynamic correlation between Bitcoin and MSCI Emerging Markets Index using DFA at different lengths of the rolling window: 251 (Panel A), 126 (Panel B)
Note: Black and grey lines indicate correlation coefficients and p-values, respectively. The horizontal red line means p-values at 10%. Rolling window sizes are 251 (Panel A) and 126 Hurst exponents (Panel B). The date corresponds to the endpoints of the sliding windows for the correlation coefficient. Source: Own calculations

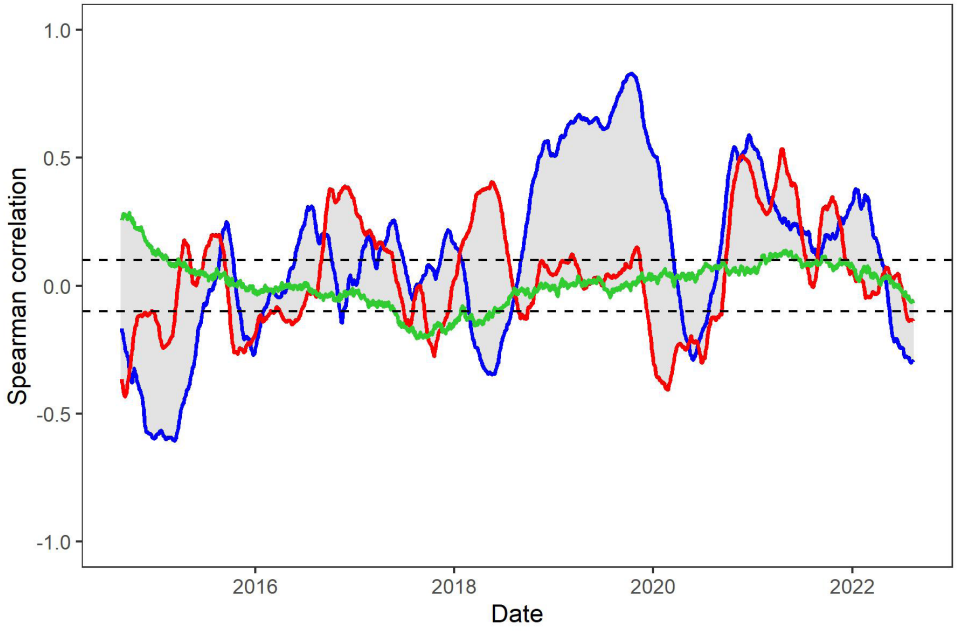

Figure 6. Dynamic Spearman correlation between Bitcoin and MSCI Emerging Markets Index based on Hurst exponents using R/S, DFA and First differences of Hurst exponents in the rolling window of 251 observations
Note: Blue and red lines indicate correlation coefficients based on Hurst exponents using R/S and DFA, respectively. The green line means correlation coefficients based on the first differences of Hurst exponents using R/S. The grey colour indicates the range of the correlation values (minimum, maximum) relative to the time point (x-axis). The correlation coefficients located in the area between two horizontal black dashed lines are statistically insignificant (p-values less than 10%). The date corresponds to the endpoints of the sliding windows for the correlation coefficient. Source: Own calculation

particular, the most similar dynamics and correlation values can be observed during the pandemic. Thus, the link between global economic shocks and the dynamics of correlation seems to be the most confirmed. On the other hand, the correlation values in some cases differ in the sign of the correlation or its value (especially in the years 2018–2019). However, dynamics of both correlations are very similar in the period of local economic shocks (e.g. from mid-2018 to 2019). Therefore, it cannot be unequivocally stated whether "local" economic shocks contribute to the largest correlation values between Bitcoin and the emerging stock markets' efficiency. But, in general, the results confirm that the dynamics of the correlation between the emerging stock and Bitcoin markets efficiency behave similarly during times of high uncertainty related to the economic turmoils in the countries with the largest Bitcoin mining or global economic shocks. This is also supported by the separate phases of the dynamic correlation trend for the first differences in market efficiency. The correlation of changes in the dynamics of market efficiency strengthens with the accumulation of uncertainty related to economic shocks.

6. Discussion

Generally, the results show that in times of unexpected events, the correlation between emerging stock and Bitcoin markets efficiency is the strongest, although the strength of this association can be considered moderate. However, only at some subperiods is there a negative sign of the correlation, which may indicate Bitcoin's potential to be a safe haven in the context of market efficiency. This is in line with the view presented by others (Wang et al., 2021; Maganini, Diniz, & Rasheed, 2021; Mensi et al., 2022). Besides, this paper confirms the findings of previous studies, uncovering in separate research that the market efficiency in the emerging markets and Bitcoin is time-varying and characterised by the long-memory process most of the time, for example as in Bariviera (2017) and Hull and McGroarty (2014).

Furthermore, our results indicate that the market efficiency dynamics of Bitcoin and emerging stock markets are different. In particular, the findings obtained by detrended fluctuation analysis show at most a moderate association between the dynamics of Bitcoin market efficiency and emerging markets efficiency. This confirms the results reached by Plastun et al. (2019) for Russia and Ukraine. Thus, future studies should treat Bitcoin rather as a specific investment instead of an emerging market from the perspective of the dynamics of market efficiency. This is contrary to the nomenclature presented by others (Alvarez-Ramirez et al., 2018; Kumar & Zargar, 2019).

The findings suggest that the main events related to economic policy uncertainty may affect the dynamics of market efficiency of Bitcoin and emerging stock markets. These economic shocks mainly concern the largest Bitcoin mining countries and their major trading partners, and global economic threats such as Covid-19. Thus, investors should track the economic policy uncertainty of the largest Bitcoin mining 'geographic territory'. Furthermore, different reactions of market efficiency in these markets to some economic shocks imply the potential to benefit from a diversification strategy using Bitcoin and the emerging markets in one investment portfolio during economic turmoil. Thus, the result may have an impact on the more efficient allocation of capital. Besides, our findings indicate that regulators of the Bitcoin market and the emerging markets should be cautious about the impact of their economic policy transparency on the reaction of these market investors.

The research has shed light on the dependence between the dynamics of market efficiency of Bitcoin and emerging markets in the context of high economic policy uncertainty in major Bitcoin mining countries. Future studies should deepen this issue. Furthermore, because Bitcoin is more inefficient than emerging markets most of the time, its dynamics may be more dependent on behavioural factors (these factors, such as investor emotions, make investment decisions more difficult). This could be verified by future studies. Our results suggest that the largest emerging countries with a meaningful share in Bitcoin mining could play an essential role in this market during economic shocks. Therefore, a study of the dynamic relationship between Bitcoin market efficiency and emerging stock markets efficiency across countries is needed. Finally, the results showing a negative correlation are only true for some identified economic shocks, so it is still uncertain whether Bitcoin can be treated as a safe haven from a market efficiency perspective.

7. Conclusion

This paper attempts to compare the dynamics of market efficiency between Bitcoin and the emerging stock markets in the years 2011–2022. It clarifies

whether Bitcoin can be treated as an emerging market or whether its market efficiency is more resistant to economic shocks than emerging markets' efficiency. To this end, the Hurst exponent is exploited as a measure of market efficiency. The Hurst exponent is calculated using the rescaled range analysis. Besides, the sliding window is applied to show the dynamics of market efficiency. Thirdly, the rolling window correlation is utilised to show how the association between studied variables varies over time.

The contribution of this article to the literature is at least threefold. Firstly, it concerns drivers of Bitcoin market efficiency. So far, there is a lack of knowledge of whether the dynamics of Bitcoin market efficiency are linked to economic policy uncertainty. Our results provide new insights into this issue, suggesting that future studies should focus on a dependence between the dynamics of Bitcoin market efficiency and economic policy uncertainty in the largest Bitcoin mining countries. Secondly, this paper adds to the literature by the verification of the 'emerging' nature of the cryptocurrency market efficiency. The findings report that the dynamics of Bitcoin and emerging stock markets' efficiency are different. Besides, this research presents different relative reactions of the Bitcoin and emerging stock markets' efficiency to economic shock (e.g. the pandemic).

This study has several limitations. Firstly, Bitcoin's weekend prices are excluded from our sample, because the stock market exchanges are closed at the weekend. Secondly, it is difficult to precisely identify concrete shocks in economic policy uncertainty as an interpretation of the values of correlation because the length of the 'overlapping' sliding windows (for the correlation and Hurst exponent calculation) covers from 2.5 to 3 years. Another limitation is the utilisation of the aggregate index of the largest emerging stock markets. In this case, the impact of economic policy uncertainty on a particular stock market may be different. Probably, the shocks will be more apparent in the smallest emerging markets, because of lower policy stability compared to the largest economies.

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