DOI: https://doi.org/10.31410/ERAZ.2022.87

The Evolution of the Cryptocurrency Market Is Trending toward Efficiency?

Rui Dias[1]
Nicole Horta[2]
Catarina Revez[3]
Paula Heliodoro[4]
Paulo Alexandre[5]

Received: July 2, 2022
Revised: October 7, 2022
Accepted: October 7, 2022
Published: December 30, 2022

Keywords:
Cryptocurrency markets;
Efficient market hypothesis;
Market efficiency

Abstract: *When compared to traditional financial markets, cryptocurrencies were seen as assets with minimal correlations. However, because this continually expanding financial market is marked by substantial volatility and strong price movements over a short period, developing an accurate and reliable forecasting model is deemed crucial for portfolio management and optimization. Given the relevance of cryptocurrencies in the global economy, it is important to determine if Bitcoin (BTC) becomes more predictable as investors adopt more aggressive trading positions. We examine BTC over the period from May 15th, 2021, to April 14th, 2022 (8676-time data), using intraday (hourly) time scales. The results reveal that the random walk hypothesis is rejected at lags of 3 to 16 days, while we see that the BTC market tends toward efficiency (see the evolution between lags of 16 and 2). These findings reveal that, given the uncertainty in the global economy in 2022, namely the Russian invasion of Ukraine, the BTC market shows values of the variance ratios close to unity, implying that it is, apparently, not predictable and that the residuals are not autocorrelated in time. In addition, the results of the Detrended Fluctuation Analysis (DFA) exponent show that this market does not exhibit characteristics of (in) efficiency in its weak form. In other words, this market does not have persistent and mean-reverting properties, thus validating the results of Wright's Rankings and Signs variance test.*

1. INTRODUCTION

On February 24th, 2022, Russia launched a full-scale military invasion against Ukraine, one of its southwest neighbours, escalating a conflict that began in 2014. Several analysts called the invasion the largest military invasion in Europe since World War II (Bloomberg, 2022).

In recent years, we have observed a tendency in financial institutions to include digital assets in their portfolios, such as cryptocurrencies, in order to diversify their portfolios more efficiently. Although cryptocurrencies have some similarities with certain traditional assets, financial agents and investors have recognized that digital currencies have their own nature, and the market fluctuations are currently being studied for a deeper understanding (Fang et al., 2022).

Cryptocurrency is a new type of asset that emerged because of the evolution of financial technology and created a great opportunity for research work. Due to volatility and price dynamism, a cryptocurrency price forecast is challenging. However, hundreds of cryptocurrencies are in circulation throughout the world (Hamayel and Owda, 2021).

[1] School of Business and Administration, Polytechnic Institute of Setúbal, Portugal; CEFAGE-UE, IIFA, University of Évora, Portugal.
[2] School of Business and Administration, Polytechnic Institute of Setúbal, Portugal
[3] School of Business and Administration, Polytechnic Institute of Setúbal, Portugal
[4] School of Business and Administration, Polytechnic Institute of Setúbal, Portugal
[5] School of Business and Administration, Polytechnic Institute of Setúbal, Portugal

In this way, this research will test the persistence and efficiency, in its weak form, of the BTC from May 15th, 2021, to April 14th, 2022 (8676-time data), using intraday (hourly) time scales. The findings indicate that the BTC market does not show evidence of (in) efficiency in its weak form. In other words, this market does not exhibit the properties of persistence and mean-reversion, thus validating the results of Wright's (2000) Rankings and Signals variance test. These findings indicate that it will be difficult for investors to achieve above-market average returns without incurring additional risk.

This study contributes to the current body of knowledge. The first contribution relates to the study of efficiency, in its weak form, of the BTC market, using intraday data. The second contribution, on the other hand, is related to the time-lapse, being marked by the global pandemic of 2020 and the Russian invasion of Ukraine in 2022. As far as we know, this is the first study that analyses this theme.

The article is structured into five sections. The introduction to the investigation issue and the research question may be found in Section 1. Section 2 is dedicated to a literature review of market efficiency. Section 3 presents the data as well as the methodology to answer the research question. In Section 4, we can see the study results, and in Section 5, we can see the key findings.

2. LITERATURE REVIEW

In recent years, institutional and individual investors have expressed an interest in the growth of digital currencies, with an emphasis on Bitcoin and Ripple. The trading of these cryptocurrencies has led to fluctuations in the formation of speculative prices, and the literature has shown that this trading strategy has caused "bubbles" in international financial markets, resulting in sharp structural breakdowns (e.g., the Dot.com crisis, the 2007-2008 crisis, the 2015-2016 stock market crash in China, among others). Because precious metals markets such as gold are less correlated with global stock indexes and cryptocurrencies have the same trading characteristics as stocks, precious metals can operate as safe-haven assets (Kakinaka and Umeno, 2021).

Kristoufek (2018) investigated the efficiency, in its weak form, of the digital currency BTC and compared it with the U.S. dollar and Chinese yuan. The author demonstrates that BTC was inefficient in the years from 2010 to 2017 and contends that this inefficiency was caused by digital market disinvestment. The authors, Dimitrova et al. (2019), investigate if BTC-USD had long memories between 2010 and 2019. The authors show that the exponents of the BTC-USD series are more than 0.5, but they also show that this result does not demonstrate long memories and that its likely reason is connected to a distribution with sharp tails.

In 2020, Chibane and Janson (2020) examined the presence of long memories in digital currencies, namely Bitcoin and Ethereum. In their research, they estimated the multifractal trend of time series and demonstrated that the inefficiency is related to digital market disinvestment. Krückeberg and Scholz (2020) examined time data from BTC, at the tick level, in the period from February 2013, to April, 2018, demonstrating that spreads increase during the first hours of the day (according to universal time) when new exchanges occur in the markets.

The authors show that during the 2017 year and the first quarter of 2018, they had $38 million in arbitrage net profit opportunities, implying and relying on long-term analysis and demonstrating the inefficiencies of the BTC market over time.

Shrestha (2021) measured BTC in order to determine if BTC has persistence in its returns. For this purpose, the author employed the econophysical model Multifractal Detrended Fluctuation Analysis (MF-DFA). According to the author, BTC has long memories and the formation of its market price may be predictable with a more aggressive trading strategy and with the required lags.

In more recent studies, Fang et al. (2022) used the generalized Hurst exponent, to analyse the efficiency of BTC with intraday (1 minute), daily, and weekly data. The authors show that efficiency is related to time scales; that is, in the long run, BTC is efficient regardless of frequency, whereas evaluating data for 1 minute and weekly BTC shows predictability.

Wu et al. (2022) compared BTC to the Ethereum, Binance Coin, S&P 500, and Spot Gold markets during the Covid-19 pandemic. According to the findings, BTC remains efficient after the beginning of the pandemic and is more efficient than Ethereum, Binance Coin, and S&P 500 during the pandemic.

This research work aims to make a significant contribution to the current literature by demonstrating whether BTC is efficient in periods of uncertainty, particularly during the global pandemic of 2020 and the Russian invasion of Ukraine in 2022.

3. METHODOLOGY

3.1. Data

Data regarding the closing prices of the BTC cryptocurrency was obtained from the Thomson Reuters Eikon platform. The price indexes are intraday, and comprise hourly time scales, over the period from May 15th, 2021, to April 14th, 2022 (8676-time data).

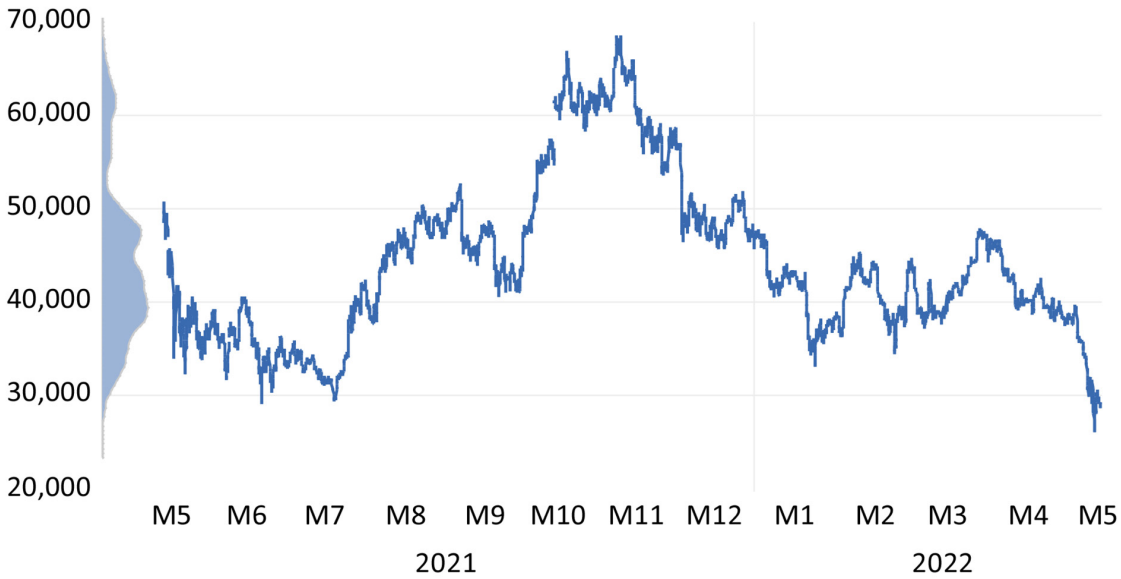
3.2. Methodology

We described and summarized collected research data using particular methodologies such as descriptive statistics (mean, standard deviation, skewness, and kurtosis). The understanding of the shape of data is a critical step to check the normality of the distribution of observations, required by many parametric tests. Thus, skewness and kurtosis are two key statistical techniques to study the normal distribution of the time series. The skewness essentially measures the symmetry of the distribution, and the kurtosis determines the heaviness of the distribution tails. To validate the results, we applied the Jarque and Bera (1980) goodness-of-fit test and, additionally, through graphic representations, we analysed the stability of the residuals.

To answer the research question and with the purpose of testing market efficiency, in its weak form, we employed a non-parametric test developed by Wright (2000), to conclude the random walk and martingale hypotheses. This approach includes two tests, namely the Rankings test for homoscedastic series and the Signs test for heteroscedastic series. To validate the results, we used the Detrended Fluctuation Analysis (DFA). DFA is an analysis method that examines temporal dependence on several time scales, thus avoiding spurious results. Its interpretation should be understood as follows: $\alpha_{DFA} < 0.5$ (long-range, anti-persistent); $\alpha_{DFA} \simeq 0.5$ (uncorrelated, white noise); $\alpha_{DFA} > 0.5$ (long-range persistent). For a better understanding of the econophysical model, see the articles by the authors Dias et al. (2021), Zebende et al. (2022), Dias et al. (2022), Guedes et al. (2022).

4. RESULTS

Figure 1 shows the evolution of BTC over the period from May 15th, 2021, to April 14th, 2022, with hourly time scales. Based on the graphical analysis we can see structure crashes in July 2021 and in January 2022, with the most significant crash in May 2022. These crashes are related to the instability experienced in international financial markets, due to the situation arising from the Russian invasion of Ukraine.



Note: Thomson Reuters Eikon: 8676 data, time scale in hours.

Figure 1. Evolution (in levels) of the BTC
for the period from May 15th, 2021, to April 14th, 2022

Source: Own elaboration

Figure 2 shows the main descriptive statistics regarding BTC, for the period May 15th, 2021, to April 14th, 2022, with intraday (hourly) data, and we can contract that the average market return is negative, the standard deviation presents a value of 0.008, and the asymmetry presents negative values (-0.26), and the kurtosis sharp values (21.89). Additionally, the asymmetry and kurtosis coefficients are statistically different from those of a normal distribution, being leptokurtic and asymmetric. The results suggest a deviation from normality and these findings are validated by the Jarque and Bera (1980), goodness-of-fit test (H_0 is rejected for a significance level of 1%).

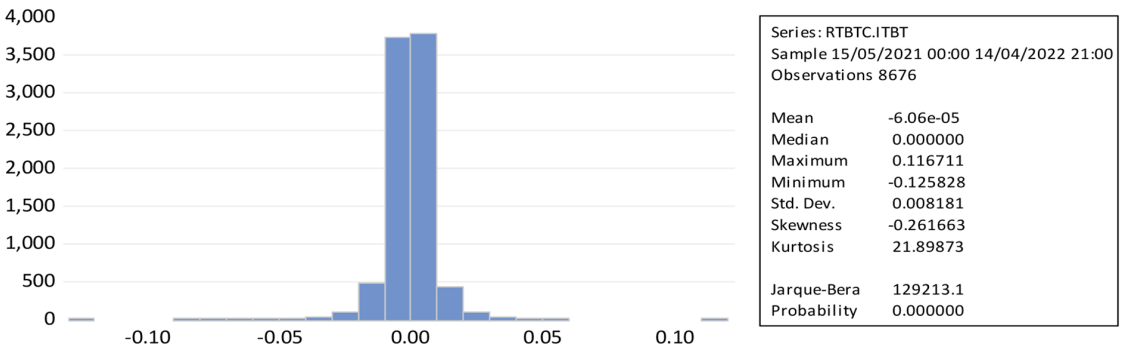


Figure 2. Descriptive statistics, return, of BTC
for the period from May 15th, 2021, to April 14th, 2022

Source: Own elaboration

Since we are estimating time series, we must examine the stationary nature of the BTC time series, with intraday (hourly) scales. The Dickey and Fuller (1981), Perron and Phillips (1988) tests postulate that the null hypothesis has unit roots, showing the stationarity of time series, in first differences. The Kwiatkowski et al. (1992) test, on the other hand, postulates stationarity in the null hypothesis and, as we can see, there is no rejection of H_0, but it should be noted that we had to transform the original time series (prices) into returns to achieve stationarity (see tables 1, 2 and 3).

Table 1. Dickey and Fuller (1981) stationarity test applied to BTC for the period from May 15th, 2021, to April 14th, 2022

Null Hypothesis: D(BTC.ITBT) has a unit root		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-91.40209	0.0001
Test critical values:	1% level	-3.430928	
	5% level	-2.861680	

Note: *MacKinnon (1996) one-sided p-values.

Source: Own elaboration

Table 2. Perron and Phillips (1988) stationarity test applied to BTC for the period from May 15th, 2021, to April 14th, 2022

Null Hypothesis: D(BTC.ITBT) has a unit root		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-91.38723	0.0001
Test critical values:	1% level	-3.430928	
	5% level	-2.861680	

Note: *MacKinnon (1996) one-sided p-values.

Source: Own elaboration

Table 3. Kwiatkowski et al. (1992) stationarity test applied to BTC for the period from May 15th, 2021, to April 14th, 2022

Null Hypothesis: D(BTC.ITBT) is stationary		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.127761
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000

Note: *Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Source: Own elaboration

Figure 3 illustrates the stability test performed on the residuals of the BTC time series and we found a non-stable variance with the violation of the probability bounds at 95%, indicating significant volatility due to the global economy uncertainty.

The statistics of Wright's (2000) Rankings and Signals variance test can be observed in table 4. The statistics were calculated for lags of 2 to 16 days and considering the p-values, the random walk hypothesis is rejected at lags 3 to 16 days, but we found that the BTC market tends toward efficiency (see evolution from lag 16 to 2).

Given the uncertainty in the global economy in 2022 as a result of Russia invasion of Ukraine, these findings reveal that this market shows values of the variance ratios close to unity, which implies that this market is apparently not predictable and that the residuals are not autocorrelated in time.

The authors Dias et al. (2020), Dias et al. (2021), Zebende et al. (2022), Dias et al. (2022), do not validate the findings, because authors show evidence in their works that international financial markets may be predictable and that investors who use aggressive trading strategies with market-adjusted lags can eventually achieve above-average returns without incurring additional risk.

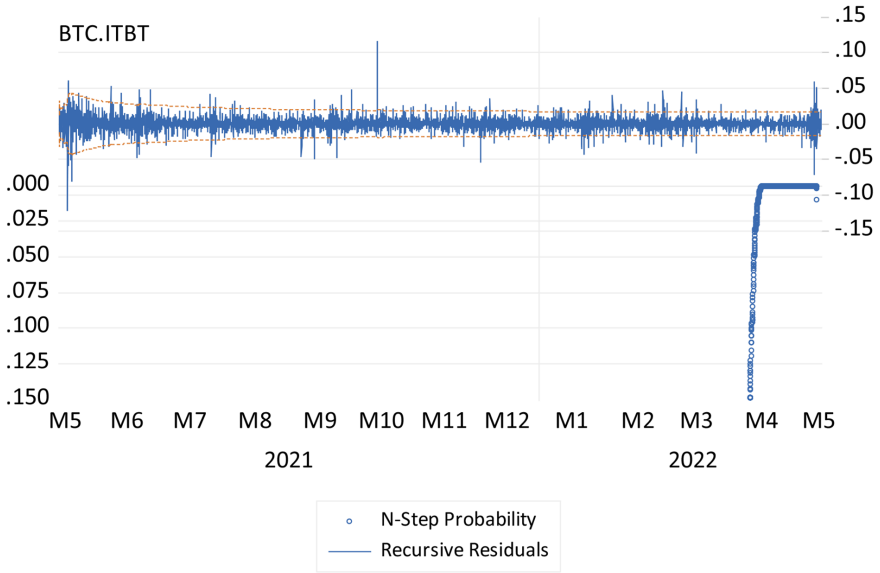


Figure 3. Stability test carried out on BTC waste for the period from May 15th, 2021 to April 14th, 2022

Source: Own elaboration

Table 4. Tests of Wright's (2000) Variance Ratios of Rankings and Signals, in yields, referring to BTC for the period May 15th, 2021 to April 14th, 2022.

Null Hypothesis: BTC. ITBT is a random walk (Rank Score Variance Ratio)

Joint Tests	Value	df	Probability
Max |z| (at period 6)	2.906991	8675	0.0130
Wald (Chi-Square)	20.15325	15	0.1860
Individual Tests			
Period	Var. Ratio	Std. Error	z-Statistic	Probability
2	0.994963	0.010737	-0.469103	0.6190
3	0.969129	0.016005	-1.928793	0.0510
4	0.947845	0.020086	-2.596540	0.0060
5	0.932760	0.023523	-2.858518	0.0020
6	0.922844	0.026541	-2.906991	0.0020
7	0.918999	0.029263	-2.768034	0.0030
8	0.914941	0.031759	-2.678235	0.0050
9	0.911127	0.034078	-2.607963	0.0120
10	0.910388	0.036251	-2.472005	0.0110
11	0.908273	0.038303	-2.394761	0.0150
12	0.904925	0.040252	-2.361977	0.0180
13	0.900162	0.042112	-2.370748	0.0180
14	0.896416	0.043894	-2.359841	0.0200
15	0.893537	0.045608	-2.334319	0.0230
16	0.891887	0.047259	-2.287652	0.0250

Note: Test probabilities computed using permutation bootstrap: reps=1000

Source: Own elaboration

Table 5 shows the results of the Detrended Fluctuation Analysis (DFA) exponent for the BTC market, applied with intraday (hourly) scales, and we find that this market has no evidence of (in)efficiency, in its weak form, in other words, this market does not have the persistent and mean-reverting properties, thus validating the results of Wright's (2000) Rankings and Signals variance test.

Table 5. DFA exponent, in return, with adjustment $R^2 > 0.99$

Index	DFA exponent
BTC	$0.47 \cong 0.00068$

Note: The hypotheses are H_0: $\alpha = 0.5$ and H_1: $\alpha \neq 0.5$.

Source: Own elaboration

5. CONCLUSION

The purpose of this research was to see if BTC becomes more predictable as investors take more aggressive trading positions. We examined BTC over the period from May 15th, 2021, to April 14th, 2022 (8676-time data), using intraday (hourly) time scales. We performed two tests, one econometric and one econophysical, to examine the study subject. We investigated the efficiency of the BTC market in its weak form using Wright's Rankings and Signs variance test. We used the Detrended Fluctuation Analysis (DFA) approach to analyse time dependency in non-stationary data series.

The results show that the random walk hypothesis is rejected at lags of 3 to 16 days, but we see that the BTC market tends toward efficiency (see evolution between lags of 16 and 2). Given the uncertainty in the global economy in 2022, the results indicate that this market has variance ratios close to unity, implying that this market is apparently not predictable, and that the residuals are not autocorrelated in time. In addition, the findings of the Detrended Fluctuation Analysis (DFA) exponent show that this market does not exhibit characteristics of (in) efficiency, in its weak form. In other words, this market does not have persistent and mean-reverting properties, thus validating the results of Wright's Rankings and Signs variance test.

In conclusion, we can demonstrate that the worldwide pandemic of 2020 and the Russian invasion of Ukraine in 2022 caused structural breakdowns in the cryptocurrency market, but the answer is negative when we examine if these events induced memory in BTC quotation prices. The findings indicate that the BTC market has no memory during the time period under consideration, and the residues are independent and identically distributed, indicating that yesterday's price does not explain today's price.

REFERENCES

Chibane, M., & Janson, N. (2020). Do Bitcoin Stylized Facts Depend on Geopolitical Risk? *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3530020

Dias, R., Heliodoro, P., & Alexandre, P. (2020). Efficiency of Asean-5 Markets: An Detrended Fluctuation Analysis. *Mednarodno Inovativno Poslovanje = Journal of Innovative Business and Management*, *12*(2), 13–19. https://doi.org/10.32015/jibm.2020.12.2.13-19

Dias, R., Heliodoro, P., Alexandre, P., Santos, H., & Farinha, A. (2021). Long memory in stock returns: Evidence from the Eastern European markets. *SHS Web of Conferences*, *91*. https://doi.org/10.1051/shsconf/20219101029

Dias, R., Pereira, J. M., & Carvalho, L. C. (2022). Are African Stock Markets Efficient? A Comparative Analysis Between Six African Markets, the UK, Japan and the USA in the Period of the Pandemic. *Naše Gospodarstvo/Our Economy*, *68*(1), 35–51. https://doi.org/10.2478/ngoe-2022-0004

Dias, R. T., Pardal, P., Santos, H., & Vasco, C. (2021). *Testing the Random Walk Hypothesis for Real Exchange Rates*. *June*, 304–322. https://doi.org/10.4018/978-1-7998-6926-9.ch017

Dickey, D., & Fuller, W. (1981). Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica*, *49*(4), 1057–1072. https://doi.org/10.2307/1912517

Dimitrova, V., Fernández-Martínez, M., Sánchez-Granero, M. A., & Segovia, J. E. T. (2019). Some comments on Bitcoin market (in)efficiency. *PLoS ONE*, *14*(7). https://doi.org/10.1371/journal.pone.0219243

Fang, F., Ventre, C., Basios, M., Kanthan, L., Martinez-Rego, D., Wu, F., & Li, L. (2022). Cryptocurrency trading: a comprehensive survey. In *Financial Innovation* (Vol. 8, Issue 1). https://doi.org/10.1186/s40854-021-00321-6

Guedes, E. F., Santos, R. P. C., Figueredo, L. H. R., Da Silva, P. A., Dias, R. M. T. S., & Zebende, G. F. (2022). Efficiency and Long-Range Correlation in G-20 Stock Indexes: A Sliding Windows Approach. *Fluctuation and Noise Letters*. https://doi.org/10.1142/S021947752250033X

Hamayel, M. J., & Owda, A. Y. (2021). A Novel Cryptocurrency Price Prediction Model Using GRU, LSTM and bi-LSTM Machine Learning Algorithms. *AI*, *2*(4). https://doi.org/10.3390/ai2040030

Jarque, C. M., & Bera, A. K. (1980). Efficient tests for normality, homoscedasticity and serial independence of regression residuals. *Economics Letters*, *6*(3), 255–259. https://doi.org/10.1016/0165-1765(80)90024-5

Kakinaka, S., & Umeno, K. (2021). Exploring asymmetric multifractal cross-correlations of price–volatility and asymmetric volatility dynamics in cryptocurrency markets. *Physica A: Statistical Mechanics and Its Applications*, *581*. https://doi.org/10.1016/j.physa.2021.126237

Kristoufek, L. (2018). On Bitcoin markets (in)efficiency and its evolution. *Physica A: Statistical Mechanics and Its Applications*, *503*, 257–262. https://doi.org/10.1016/j.physa.2018.02.161

Krückeberg, S., & Scholz, P. (2020). Decentralized Efficiency? Arbitrage in Bitcoin Markets. *Financial Analysts Journal*, *76*(3), 135–152. https://doi.org/10.1080/0015198X.2020.1733902

Kwiatkowski, D., Phillips, P. C. B., Schmidt, P., & Shinb, Y. (1992). Testing the null hypothesis of stationary against the alternative of a unit root. *Journal of Econometrics*, *54*(1), 159–178. https://doi.org/http://dx.doi.org/10.1016/0304-4076(92)90104-Y

Perron, P., & Phillips, P. C. B. (1988). Testing for a Unit Root in a Time Series Regression. *Biometrika*, *2*(75), 335–346. https://doi.org/10.1080/07350015.1992.10509923

Shrestha, K. (2021). Multifractal Detrended Fluctuation Analysis of Return on Bitcoin*. In *International Review of Finance* (Vol. 21, Issue 1). https://doi.org/10.1111/irfi.12256

Wright, J. H. (2000). Alternative variance-ratio tests using ranks and signs. *Journal of Business and Economic Statistics*. https://doi.org/10.1080/07350015.2000.10524842

Wu, X., Wu, L., & Chen, S. (2022). Long memory and efficiency of Bitcoin during COVID-19. *Applied Economics*, *54*(4). https://doi.org/10.1080/00036846.2021.1962513

Zebende, G. F., Santos Dias, R. M. T., & de Aguiar, L. C. (2022). Stock market efficiency: An intraday case of study about the G-20 group. *Heliyon*, *8*(1), e08808. https://doi.org/10.1016/j.heliyon.2022.e08808