THE MARKET DANCE BETWEEN THE RHYTHM OF BITCOIN PRICES AND THE S&P 500 INDEX

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Abstract. The financial markets experienced a thrilling saga between 2020 and 2023, characterised by a series of unprecedented events and captivating dynamics that set the stage for a compelling exploration of the interaction between bitcoin prices and the S&P 500 Index. This study systematically examines the correlation between bitcoin prices and the S&P 500 index using the Yahoo Finance dataset over a 48-month period. Using the extensive Yahoo Finance dataset and the analytical capabilities of R Statistics & R Studio, the present research covers a comprehensive period of 48 months (2020-2023). The study identifies a robust positive correlation, quantified by a correlation coefficient of 0.7726, indicating a significant alignment between bitcoin price movements and the S&P 500 index. Monthly price variables obtained from an open-source repository provide a comprehensive overview of the relative dynamics of these financial assets. This analysis provides valuable insights into the current behaviour of bitcoin and the S&P 500 index, as well as concise observations on the dynamics of their correlation.

Keywords: bitcoin, S&P 500, COVID-19, correlation, periodic returns.

JEL Classification: F40, F60, G30.

1. Introduction

At the dawn of the global financial crisis in 2008-2009, an intense desire for financial autonomy and resistance to centralized control resulted in the emergence of the so-called "digital gold", bitcoin [BTC] (Whirty, 2018), raising considerable enthusiasm among market participants, which has made it the most popular digital financial asset (Momtaz, 2021). To many, BTC and the other types of cryptocurrencies, such as Ethereum or Ripple, represented and still represent great promise of an anonymous, decentralized financial system without any interventions of banks and governments (Biais et al., 2023). It shall be noted that BTC represents one of the most successful applications of decentralised Blockchain technology (Nuttah et al., 2023). It functions as a peer-to-peer electronic payment system, enabling secure transactions without the need for a central authority (Karthika & Jaganathan,

2019). The strong influence of BTC could lead some institutions and countries to use it as a transactional tool. More specifically, digital gold has the potential to improve national payment systems and can be used as legal tender in some countries: Venezuela and Zimbabwe (Sorokina et al., 2021). Despite its potential, there are legal issues associated with its use, which may hinder its widespread adoption (Grinberg, 2011).

So far, it has been increasingly used for speculation rather than transaction. In fact, 73% of this cryptocurrency is held in dormant accounts (Böhme et al., 2015). BTC is mainly used for speculative investment (Baur et al., 2018). In support of this statement, (Nekhili, 2020) argues that traders in the BTC future market are motivated by speculation rather than hedging. This implies that the main function of the best-known cryptocurrency is its use as a speculative asset rather than a practical currency for transactions.

While the decentralized nature and finite supply of the major cryptocurrency contribute to its potential as a store of value, the inherent volatility of its price poses a challenge for investors and is a pertinent subject to be studied. Indeed, there is an increasing number of studies on its volatility dynamic (Catania et al., 2019; Katsiampa et al., 2019). To illustrate this fluctuation, in the early 2017, the price was one thousand dollars, reaching nearly twenty thousand dollars at the end of this year (Pichet, 2017). Moreover, in the past and also more recently, its price has been highly influenced by the statements and actions of institutions or influential figures.

The concept of volatility is not limited to the cryptocurrency market only, usually experiencing both considerable price increases and major corrections. At the same time, this concept also applies to various other markets where financial assets are bought and sold, especially conventional financial markets, exemplified by the Standard & Poor's 500 Index (S&P 500). Since 1957, the S&P 500 has showed excellent performed, outperforming leading asset classes such as bonds and commodities (Mustapa & Ismail, 2019). This index increment has been often interpreted as providing powerful evidence concerning the economic health and vitality of the US stock market performance (Goetzel et al., 2019). Indeed, as an influential benchmark, it measures the performance of 500 large companies listed on the US stock exchanges.

As mentioned, both BTC and the S&P 500 index prices can be positively or negatively affected by many factors. Due to its decentralized nature, BTC's volatility is higher than that of international currencies and stocks as investment tools (Deng, 2023). Yet, the S&P 500 index price is mostly affected by investor sentiment, which results in steep or moderate volatility (Han, 2005).

Therefore, the aim of this paper is to contribute to the emerging literature of BTC by examining the correlation between the price of "digital gold" and the S&P 500 Index. The implications drawn from this study provide valuable perspectives for investors, analysts and researchers navigating the complexities of today's financial markets.

The present study provides profound insights important for understanding the interactions between these two financial entities. As a matter of fact, considering two hypotheses: (H_0) = there is no significant relationship between BTC and the S&P 500 ($\rho = 0$) and (H_1) = there is a remarkable positive correlation between the two entities from 2020 to 2023 ($\rho > 0$); the finding shows that the positive correlation implies a compelling relationship between the BTC price movements and the S&P 500 Index, which supports the conclusion that these assets exhibited synchronised behaviour during the period considered.

The following part of the paper is divided into four specific sections with the following structure: Section 1 presents and describes the literature in the field. Section 2 introduces the methodology used for the purposes of the study. Next, Section 3 discusses the findings analysed with the help of specific statistical methods. In the final section, the main findings are summarized.

2. Literature review

2.1. BTC and S&P 500 in contemporary finance

As the most popular digital currency, BTC has the potential to significantly impact the financial environment (Chowdhury & Mendelson, 2013). Its open ledger system and distribution network make it a valuable system, with the potential to solve many of the current financial system's problems (Cascarilla, 2015). Notwithstanding, its role in the financial system is still evolving, and issues such as price dynamics, volatility, and regulation need to be further addressed (Kayal & Rohilla, 2021). Regardless of these challenges, the disruptive potential of BTC in the financial world is significant, with the potential to render banks and financial intermediaries obsolete (Salman & Razzaq, 2018).

The status of digital gold as an investment is a subject of debate. In fact, Baek & Elbeck (2014) and Baur et al. (2018) suggest that it is primarily a speculative instrument and investment. This is supported by Rudolf et al. (2021), who highlights the potential of BTC as an investment and hedging alternative. In conjunction with the previous idea, Wolla (2018) adds that although BTC can be serve as a currency, its current use is rather as a tool of a financial investment. Moreover, BTC has shown to have potential as an investment asset, particularly in terms of diversification and portfolio efficiency (Apolónia, 2021). It is an attractive option for diversification (Trautman, 2018).

The S&P 500 is a widely used benchmark in traditional financial markets, serving as a means of directing investor capital, evaluating investment portfolios and managers, and assessing corporate performance (Robertson, 2018). Despite its widespread use, the author adds that the index is not neutral and its structure changes over time, leading to its potential misuse. The index has consistently outperformed other asset classes, and its original companies have shown strong long-term returns (Siegel & Schwartz, 2006). In fact, this outperformance is attributed to the fact that original companies becoming more heavily weighted with high dividend payouts and low P/E stocks, particularly large oil producers (Fuller & Goldstein, 2003).

The S&P 500 is also a major indicator of the economy and a default tool for passive investors (Mustapa & Ismail, 2019). Despite this, it remains a key indicator of the U.S. economy and a popular choice for passive investors (Arshanapalli, 2004). However, the performance of the index is influenced by the addition and removal of companies, with the committee balancing representation and performance (Asem, 2012).

2.2. Volatility patterns in BTC and S&P 500 amidst macroeconomics influences

The volatility of BTC is significantly impacted by the S&P 500, particularly during periods of high uncertainty such as the COVID-19 pandemic (Nguyen, 2022).

E-commerce underwent a significant stress test during the onset of the global COVID-19 pandemic. Panic buying, partial closure of brick-and-mortar shops, and overall market uncertainty created unprecedented conditions for all market players (Pollák et al., 2022). Additionally, the realized volatility of the S&P 500 Index and volatility risk premium have been found to have significant effects on the long-term BTC volatility (Conrad et al., 2018). In other studies, Shi et al.(2020) further complicates the picture by identifying significant positive correlations between the volatility of BTC and other cryptocurrencies, such as Litecoin, Ethereum, Ripple, and Stellar. Therefore, the author suggests that while BTC certainly has a limited direct impact on traditional assets, it may have a more significant effect on the value of other cryptocurrencies.

A range of macroeconomic factors have been found to influence both BTC and the S&P 500. Entrop et al. (2020) and Havidz (2021) highlight the role of market quality, uncertainty, and trading volume in determining the BTC price; Havidz (2021) also points out the impact of the US dollar, interest rates, and gold. Yet, Corbet et al. (2020) further explores the impact of macroeconomic news on BTC returns, finding that positive news on unemployment and durable goods can reduce its returns, while negative news can increase them.

2.3. Correlation trends in financial research

The analysis of this study is inspired by various scholars that highlight the importance of correlation analysis in understanding the complex dynamics of financial markets. Livan & Rebecchi (2012) and Kenett et al. (2015) deal with the application of correlation analysis in financial markets where Livan & Rebecchi (2012) focuses on the spectral properties of correlation matrices, particularly in the context of time-lagged correlations, while Kenett et al. (2015) introduces the use of partial correlation to identify underlying relationships between stocks. Moreover, Zhukova & Kagirova (2018) extends this analysis by using adaptive correlation coefficients to characterize the dynamics of financial processes and proposes a hybrid model for predicting structural shifts. Ultimately, Kenett et al. (2012) quantifies meta-correlations in financial markets, finding a significant correlation between changes in index returns and changes in mean correlation.

Research has been conducted to determine the relationship between BTC and the S&P 500. According to Wang et al. (2020) and Nguyen (2022), the S&P 500 has a significant impact on BTC. Want (2020) describes a relatively strong effect, while Nguyen (2022) highlights the influence during periods of high uncertainty. Erdas & Çağlar (2018) further supports these findings by identifying a causal link between BTC and the S&P 500, suggesting that changes in BTC prices can influence investor decisions in the S&P 500. Finally, Hung (2022) adds that the S&P 500 is a net recipient of volatility from BTC, indicating a dynamic intercorrelation between the two.

The existing literature on the relationship between BTC and the S&P 500 index prices is still growing. Many related studies focus on the influence of macroeconomic factors impacting the value of both assets, thus impacting their valuation. The concept of volatility is also frequently mentioned and studied by researchers. Many studies in this field rely on analysing complex dynamics by observing the level of correlation between different assets or institutions. Nevertheless, only few of them have focused on the trajectories of BTC and the S&P 500 index.

3. Methods

This study attempts to systematically examine the correlation between BTC prices and the S&P 500 Index. The data for this analysis were obtained from the open source repository Yahoo Finance, which provides a comprehensive dataset of historical prices. The study focuses on monthly price variables covering the period from 2020 to 2023, a total of 48 months. The research sample was selected systematically to ensure a representative and meaningful analysis of the correlation between the price of BTC and the S&P 500 Index. The choice of this timeframe is intentional, as it coincides with the onset and spread of the COVID-19 pandemic and provides a contextual framework for understanding the dynamic relationship between these financial instruments during a period of significant global economic change.

The use of Pearson correlation coefficient serves as the primary statistical method to assess the strength and nature of the linear relationship between monthly BTC prices and the S&P 500 Index.

Pearson Correlation Coefficient

$$rXY = \frac{\mathrm{cov}(X,Y)}{\sigma X \cdot \sigma Y},$$

here: cov (X, Y) covariance between X and Y; σX, σY standard deviation of X and standard deviation of Y.

In our analysis, X represents the price of Bitcoin, while Y symbolizes the value of the S&P 500 Index. In the context of assessing the correlation coefficient, we routinely set a predetermined alpha level, as $\alpha = 0.05$, to assess whether the observed correlation is statistically significant.

The Pearson correlation coefficient is known for its effectiveness in assessing the degree of correlation between continuous variables and is used to identify patterns and trends within a data set. The dataset compiled by Yahoo Finance includes daily closing BTC and the S&P 500 prices. These data points are aggregated on a monthly basis to be consistent with the time frame of the analysis. By focusing on granular monthly frequency, the study attempts to capture the nuances in price movements and correlation between the two assets.

An analysis of variance (ANOVA) has also been conducted to compare the means of the two assets analyzed in this study: BTC price and S&P 500 Index. Indeed, this statistical method is used to analyze the differences between groups means in a sample. The F-value is a relevant indicator to define the statistical significance of the two assets and therefore observing the variation between groups.

One way ANOVA statistics

$$F = MS_{within} MS_{between},$$

here: F is the F-statistics; $MS_{between}$ represents the mean square between groups; MS_{within} is the mean square between groups.

In addition to correlation analysis and analysis of variance, the research also includes a comparative assessment of the periodic returns of BTC and the S&P 500 index.

The formula to calculate the rate of return (*RoR*)

$$Rate\ of\ return = \frac{Current\ value - Initial\ value}{Initial\ Value} x100.$$

This complementary approach to analysis aims to increase accuracy by examining the percentage change in price at specific time intervals. This provides a more complete understanding of the dynamics of the relationship beyond simple price correlation.

The present study provides profound insights important for understanding the interactions between these two financial entities. As a matter of fact, considering two hypotheses: (H_0) = there is no significant relationship between BTC and the S&P 500 ($\rho = 0$) and (H_1) = there is a remarkable positive correlation between the two entities from 2020 to 2023 ($\rho > 0$).

4. Results and discussion

The research problem at the core of the study examines the correlation between the price of BTC and the trends observed in the S&P500 Index over the period of 48 months. To identify the complexity of this relationship, specific research questions are formulated to address this problem.

Table 1. Regression Statistics

Regression Statistics	
Multiple R	0.7725677
R Square	0.59686085
Adjusted R Square	0.58809695
Standard Error	343.996552
Observations	48

Source: author's calculation

The correlation coefficient between the price of BTC and the S&P 500 is 0,7726, indicating a strong positive correlation between the two variables, see Table 1. A positive correlation coefficient of 0.7726 means that the price of BTC and the S&P 500 Index strongly tend to move in the same direction. With the rising S&P 500 index, the value of BTC is very likely to increase and vice versa. This positive correlation suggests a certain degree of common movement between the two financial assets over time.

Additionally, the R^2 value is 0.5969, suggesting that approximately 59,69% of the variability in the price of BTC can be explained by the movements in the S&P 500 during the monitored period of 2020 to 2023 (Figure 1).
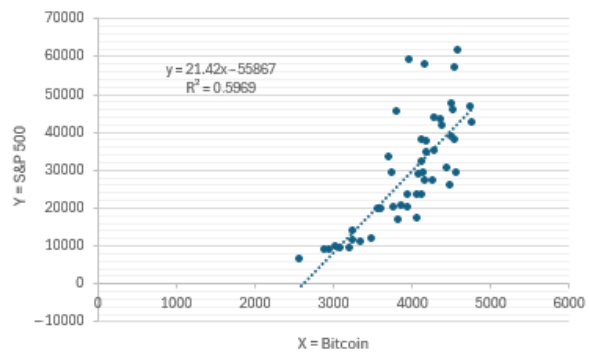

Figure 1. Scattered Plot *Source*: author's calculation

Moreover, this value highlights the goodness of fit of the observed data. Therefore, the R^2 value of 0.5969, beyond indicating the explanability in BTC and S&P 500 variation, also point out the accuracy of the model fitting the observed data. This indicates a moderate explanatory power of the S&P 500 Index in predicting or understanding the fluctuations in the price of BTC over the 48-month period under review.

Table 2. ANOVA statistics

ANOVA

	df	SS	MS	F	Significance F
Regression (between groups)	1	8059055	8059055	68,104521	1,258E-10
Residual (within groups)	46	5443346,9	118333,63		
Total	47	13502402			

Source: author's calculation

In addition to the correlation coefficient and R^2 value (see Table 2), it is notable that the significance level (F) of the analysis of variance (ANOVA) comparing the relationship between the BTC price and the S&P 500 index is remarkably low at 1,258 (0.0000000126%). This significance level was compared to the commonly used alpha value of 0.05% in statistical analyses. The remaining variability may be due to other factors not included in the analysis. The 48 months of observation, the analysis covers a significant time frame and provides a reliable dataset to assess the relationship between BTC and the S&P 500 Index. This period, which includes the impact of the COVID-19 pandemic, allows for a more comprehensive understanding of how the two assets react to different market conditions.

In summary, the positive correlation coefficient and relatively high R^2 value indicate a significant relationship between the price of BTC and the S&P 500 index over the period. For investors and analysts, particularly in the context of broader economic trends and events, these findings may be valuable when considering the interaction between the two assets. However, it shall be noted that correlation does not imply causation. BTC prices may be influenced by factors other than the S&P 500 Index (Figure 2).
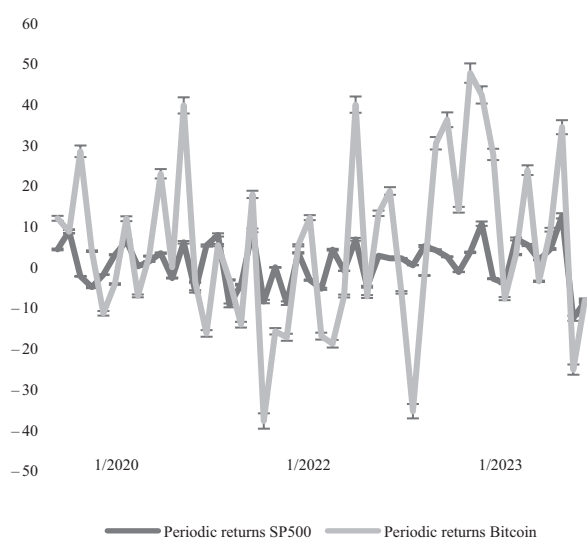
Figure 2. Periodic returns of S&P 500 Index and Bitcoin
Source: author's calculation

BTC prices reached their peak in December 2020, with a remarkable 47.7% increase compared to the previous month. Conversely, it bottomed out in June 2022, with a significant month-on-month decline of 37.5%. The volatility of BTC´s value is further accentuated by regular fluctuations that cross both positive and negative thresholds, with instances of sharp increases of more than 30% and decreases of up to – 15%. The high volatility of BTC over the period under review highlights its susceptibility to rapid and significant price changes. Although there have been instances of significant positive gains, the cryptocurrency has also experienced notable declines. This increased variability can be attributed to the interaction of several factors, including market sentiment, macroeconomic development, and regulatory considerations. Such insights based on close examination of historical price movements contribute to a deeper understanding of BTC's behaviour in the broader financial environment. The year 2020 began with BTC being traded at a relatively stable price, but the cryptocurrency quickly reacted to broader market dynamics. The outbreak of the COVID-19 pandemic in March 2020 triggered a sharp market sell-off that affected several asset classes, including BTC. However, BTC rebounded impressively in the second half of 2020, surpassing its previous all-time high. Throughout 2021, BTC continued to experience periods of increased volatility. The cryptocurrency market saw both significant price rises and significant corrections. In this period, BTC price dynamics were influenced by regulatory developments, market sentiment and macroeconomic factors; the price of BTC was strongly influenced by the statements and actions of influential figures such as Elon Musk. Musk's public comments on BTC, along with Tesla's decision to accept and then stop accepting BTC payments, contributed to short-term market volatility and changes in sentiment. Institutional acceptance of BTC gained momentum during this period, with major corporations and institutional investors publicly

disclosing their investments in BTC. This institutional outflow was seen as confirmation of BTC's position as a legitimate asset class.

In parallel, at its peak at the end of March 2020, the S&P 500 index saw a significant month-on-month increase of 12.8%. Conversely, the low was recorded at the beginning of March, with a decline of 12.5%. It shall be notedthat like BTC, the S&P 500 index shows a dynamic range of fluctuations, capturing both positive and negative movements during the period under review. The S&P 500 Index, along with global financial markets, experienced significant turbulence in early 2020 as a result of the COVID-19 pandemic outbreak. In March 2020, the index saw a sharp decline due to widespread uncertainty and economic disruption. In the second half of 2020, the S&P 500 Index showed a remarkable recovery. Supported by fiscal stimulus, central bank interventions and positive development associated with vaccination, the index rebounded to new all-time highs at the end of the year. Technology and growth stocks were the key drivers of the S&P 500's performance during this period. In particular, large-cap technology companies reported considerable gains, thus contributing significantly to the overall performance of the index. In 2021 and early 2022, concerns about rising inflation and potential cuts in central bank stimulus led to increased market volatility. Investors closely monitored economic indicators and central bank communications for signals on future monetary policy actions. Changes in interest rate expectations influenced investor behaviour and contributed to fluctuations in the S&P 500 Index. Changes in bond yields, particularly 10-year Treasury yields, were closely monitored to identify their potential impact on equity markets. Indeed, the S&P 500 Index reached record highs during this period, reflecting its resilience and adaptability to changing market conditions.

5. Conclusions

This research systematically examines the correlation between BTC prices and the S&P 500 Index, providing detailed findings to understand the interactions between these two financial entities. The analysis, which covered a robust 48-month period from 2020 to 2023, was based on a comprehensive dataset obtained from Yahoo Finance open-source repository, which provides an in-depth analysis of monthly price variables. The core of this study is a correlation coefficient of 0.7726, a statistically significant indicator that suggests a strong positive correlation between the price of BTC and the S&P 500 Index over the period under study. This finding means that fluctuations in the price of BTC were strongly correlated with movements in the S&P 500 Index, thus confirming the correlation of these two distinct but influential assets.

With regard to the research hypotheses, if H0 assumes that there is no significant correlation between the price of BTC and the S&P 500 index over the period 2020–2023, and H1 assumes that there is a significant

positive correlation over the same period, the obtained correlation coefficient of 0.7726 leads to the rejection of the null hypothesis in favour of the alternative hypothesis. The positive correlation found indicates a compelling link between the price movements of BTC and the S&P 500 index, supporting the view that these assets exhibited synchronised behaviour over the period under consideration. Moreover, the F-statistic of 68.104, accompanied by an extremely low correlation p-value (significance F) of 1.258, further supports the rejection of the null hypothesis. Since the p-value is lower than the significance level (usually $\alpha = 0.05$), we conclude that there is a significant relationship between the predictor variable (X – Bitcoin) and the response variable (Y – S&P 500 Index). This reinforces the robustness of the observed correlation between BTC prices and the S&P 500 index over the period under study. As for the benefits of the study, this research contributes to a broader understanding of the financial environment and highlights the complex dynamics between an emerging cryptocurrency, represented by BTC, and the established stock exchange, represented by the S&P 500 Index. The findings of this study provide valuable perspectives for investors, analysts and researchers who operate in the complex environment of today's financial markets. A limitation can be seen in the fact that the research is focused on a specific period of 48 months, from 2020 to 2023. While the chosen timeframe allows for a detailed examination, it may not capture long-term trends or events that could affect correlation dynamics over a longer period. This study provides a promising direction for further research, especially given the technological underpinnings of BTC that are rooted in blockchain technology. The first direction of research could be a comparative analysis of BTC and the Nasdaq 100 index, which is primarily made up of technology-oriented companies.

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