Correlation and causality between the S&P 500 and Bitcoin: A comparative study before and during the COVID-19 pandemic

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ABSTRACT

This undergraduate dissertation examines the correlation and causality between the S&P 500 and Bitcoin, both prior to and amidst the COVID-19 pandemic. The objective of this research is to offer novel perspectives on the interaction between these two financial instruments during the unprecedented economic instability triggered by the pandemic and to assess how their association has evolved throughout this time. By scrutinizing price fluctuations and the interconnections during distinct phases, this investigation seeks to enhance comprehension of how investors might optimally distribute their resources across these asset categories during periods of economic uncertainty.

The study is grounded in earlier investigations on the correlation and causation between the S&P 500 and Bitcoin, as well as their roles during economic downturns. Employing quantitative research techniques, this study explores the transformation in the correlation and causality between the two assets during the pandemic, utilizing data obtained from reputable sources and analyzed using statistical software. The Pearson correlation coefficient and Granger causality test serve as instruments for evaluating the correlation and causation between the S&P 500 and Bitcoin across the specified timeframes.

The findings of this research contribute to a more refined and all-encompassing comprehension of how the influence of the S&P 500 and Bitcoin exert on each other under varying economic circumstances and how their dynamics can shift during significant economic upheavals, such as the COVID-19 pandemic. This knowledge will aid investors in making well-informed choices and comprehending how to diversify their portfolios during similar occurrences in the future. Furthermore, the study offers recommendations for subsequent research in this domain and deliberates on its constraints.

Keywords: S&P 500, Bitcoin, Cryptocurrency, Pearson's correlation coefficient, Granger causality test, Covid-19, Stock market.

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1 INTRODUCTION

In this section, the background, purpose, and limitations of this thesis are presented. The research questions are also formed from the problem background and purpose and serve as a basis for the research conducted in this thesis. This section is finished with an overview of the layout of this thesis.

1.1 BACKGROUND

The COVID-19 pandemic, which surfaced in early 2020, has notably influenced the worldwide economy and financial sectors. The rapidly spreading virus prompted many countries to enforce strict measures to limit its transmission. These measures led to shifts in areas like consumer habits, the employment landscape, and firms financial standing (Baldwin & Weder di Mauro, 2020). As a result, both traditional financial assets, such as stocks symbolized by the S&P 500, and digital currencies like Bitcoin experienced changes in trading activity and price variation.

The S&P 500 is an index that represents the progress of the American stock market, encompassing the 500 largest companies on the New York Stock Exchange and Nasdaq. This US index serves as a crucial gauge of economic performance and is commonly utilized by investors to evaluate market conditions (Malkiel, 2015). While direct investment in the S&P 500 is not feasible as it is an index, many funds use it as a benchmark and follow its composition and performance (Kenton, 2023).

Bitcoin, a decentralized digital currency, has attracted substantial interest since its inception in 2009 (Nakamoto, 2008). It has become a favored investment choice for those seeking novel means to diversify their portfolios and safeguard their assets from fluctuations in traditional financial markets (Bouri et al., 2017). Bitcoin's popularity is due to its distinct characteristics, leading to increased utilization and acceptance. Browne referred to Bitcoin as a value reserve, a "digital gold" (Browne, 2022). This "digital gold" notion suggests that it should remain uncorrelated with financial markets and act as a safeguard against global economic instability and rapid price shifts (Baur & Lucey, 2010).

Earlier studies have scrutinized the correlation between conventional financial assets and digital currencies under diverse economic situations (Bouri et al., 2017; Baur & Lucey, 2010). Concerning the COVID-19 pandemic, investigations have observed that the linkage between the S&P 500 and Bitcoin has intensified, particularly during moments of heightened uncertainty. Additional examinations have also revealed that the pandemic has profoundly affected the stock market, encompassing cryptocurrencies, resulting in escalated uncertainty and a correlation between the two assets (Sansa, 2020).

Previous research has not employed causality tests to explore the causal relationship between the S&P 500 and Bitcoin before and throughout the pandemic. Nevertheless, Bouri et al. (2021) carried out a study examining the association between digital currencies, including Bitcoin, and the S&P 500 by utilizing Granger's causality test. Bouri et al.'s 2021 investigation centered solely on Granger's causality test between 2014 and 2019, preceding the COVID-19 pandemic, leaving research during the pandemic devoid of comparative causality between the S&P 500 and Bitcoin.

The objective of this paper was to investigate the impact of the COVID-19 pandemic on the correlation and causality between the S&P 500 and Bitcoin, aiming to deliver further insights into the interaction of these two asset classes under exceptional economic circumstances and address existing knowledge gaps. The paper will utilize a quantitative research approach by examining multiple time series of daily price data for the S&P 500 and Bitcoin, which will be separated into distinct periods: prior to the pandemic, throughout the pandemic, and an all-encompassing analysis of the entire duration that will contribute to the final conclusion.

The outcomes of this paper may potentially furnish a more profound comprehension of policy instruments concerning the relationship between the S&P 500 and Bitcoin to manage the prospective risks and impacts of forthcoming economic crises involving these two asset classes. We aspire for our research to augment the existing literature by delivering a thorough examination of the connection between the S&P 500 and Bitcoin during the widespread pandemic, thereby equipping both researchers and investors with valuable information for making well-informed decisions in the future.

1.2 Purpose

This study builds upon prior investigations that delved into the connection between the S&P 500 and Bitcoin in order to ascertain if our conclusions are consistent with existing observations and assessments. This study aspires to offer a unique perspective in comparison to previous works by examining the correlation and causality between the S&P 500 and Bitcoin, along with potential linkages. By contrasting our results with earlier research, this study strives to enhance the overall understanding of the ways in which these assets impact one another through a range of temporal and economic contexts.

1.3 Research questions

This research endeavors to examine and address the following central inquiries:

Has the correlation between the S&P 500 and Bitcoin undergone a significant transformation amid the COVID-19 upheaval, and if so, how can these alterations be characterized?

Is there causality present between the S&P 500 and Bitcoin, and if so, how can this cause-and-effect report be depicted and comprehended within the realm of financial markets?

1.4 Limitations

To maintain precision and coherence in the study, certain constraints have been set:

Time Span: This investigation examines the periods both before and amidst the COVID-19 crisis. Our primary analysis covers the dates from January 1, 2018, to December 31, 2021, although within the text, this timeframe is presented as spanning from 2018 to 2022. We've partitioned this time into two distinct phases: the pre-pandemic phase, technically spanning from January 1, 2018, to December 31, 2019, but labelled as 2018-2020 in the text, and the phase initiated by the onset of the pandemic, actually covering the dates from January 1, 2020, to December 31, 2021, but referred to as 2020-2022 in the report. This particular selection of

periods provides a window into the economic stability that characterized the pre-pandemic era of 2018-2020 and the economic volatility that marked the pandemic era of 2020-2022. The authors of the report believe that this temporal delineation provides an optimal framework for understanding the impacts of the COVID-19 pandemic.

Data origins: The investigation employs an official and reputable source for pricing data and market information on the S&P 500 and Bitcoin, Yahoo Finance, to ensure data reliability. This restricts the inquiry to the information accessible from this source.

Geographical range: The inquiry is confined to examining the association between the S&P 500, symbolizing the U.S. stock market, and Bitcoin, a decentralized digital cryptocurrency. This implies that the inquiry will not encompass other national stock markets, regional stock indices, or additional cryptocurrencies.

Methodological constraints: This study will utilize quantitative techniques to evaluate correlation and causality between the S&P 500 and Bitcoin. This study will therefore not emphasize qualitative aspects, such as business tactics, political choices, or individual investors' inclinations and actions, beyond the macroeconomic elements mentioned earlier.

1.5 LAYOUT

The paper's organization is as follows: Chapter 2 offers an extensive overview of pertinent theory, a literature review, and a closer inspection of relevant prior studies concerning the S&P 500 and Bitcoin, highlighting their importance to this paper. Chapter 3 delineates the research methods to be employed, encompassing data acquisition and analytical procedures. Chapter 4 unveils the study's results. Subsequently, in Chapter 5, the primary insights from the investigation, its constraints, and recommendations for possible future research are synthesized. Chapter 6 contains the concluding remarks of the paper.

2 LITERATURE REVIEW

In this chapter, theories that lay the foundation for the analysis are presented. A brief background on the S&P 500 and Bitcoin is provided to introduce readers who are unfamiliar with these asset classes. Lastly, knowledge gaps and research needs are addressed.

2.1 CORRELATION AND CAUSALITY AMONG FINANCIAL ASSETS

The correlation and causality between financial instruments are fundamental concepts in finance and portfolio theory (Markowitz, 1952). Correlation pertains to the statistical interdependence between two variables and their mutual interaction. The correlation coefficient is frequently employed to assess the extent of a linear association. Causality, or cause-and-consequence, delineates how alterations in one asset impact others (Pearl, 2009). It's crucial to recognize that correlation doesn't inherently indicate causality since other factors may influence the assets without a direct link.

Financial economics research on correlation and causality has predominantly emphasized comparative evaluations to optimize investor portfolios and possibly minimize risk (Elton & Gruber, 1997). By investigating the correlation and causality among different assets, investors have traditionally managed to establish diversified portfolios, dispersing their risks over multiple investments and potentially enhancing returns while lowering overall risk (Markowitz, 1952).

Previous studies have probed both correlation and causality between numerous financial instruments, such as equities, bonds, and commodities, using various techniques. For instance, research has compared Pearson's correlation coefficient and Granger's causality test, which will also be mentioned later in this paper (Engle & Granger, 1987; Granger, 1969). In this paper's context, it is vital to comprehend the association between digital assets, like Bitcoin, and their correlation and integration with more conventional financial instruments, as well as their impact on an investment portfolio.

2.2 BITCOIN AND CRYPTOCURRENCIES

The first digital currency created, Bitcoin (Nakamoto, S., 2008), has garnered significant attention from academics and investors alike since its inception. The groundbreaking concept was introduced in a 2008 white paper by an anonymous individual or group using the pseudonym Satoshi Nakamoto, with Bitcoin launching the following year. Bitcoin is a decentralized virtual currency that facilitates secure online transactions between parties without intermediaries. This allows users from any location to transfer bitcoins directly to each other, bypassing banks, governments, or other institutions.

All Bitcoin transactions are recorded and verified on the blockchain, rendering them completely transparent to those participating in the network. The blockchain serves as a digital, decentralized infrastructure for Bitcoin, ensuring that no single country, company, or entity can take control of the system. Participation in the blockchain is open to everyone. There is a fixed limit of 21 million bitcoins, expected to be reached around 2140 (Hayes, 2023). Distribution occurs at a predetermined inflation rate, initially set at 50% and now at 1.8%, with a planned halving at each "Bitcoin halving" event, which occurs approximately every four years.

Ultimately, the inflation rate will decrease to 0% upon reaching the cap. Miners, or computers that solve complex cryptographic challenges on the blockchain, earn bitcoins as rewards for solving these problems. Bitcoin's ability to operate as a payment method and value transfer system without intermediaries has made it an appealing topic for investigation and investment.

Past research has explored the relationship between Bitcoin and more traditional financial instruments such as stocks, bonds, and gold, yielding mixed results, as will be presented later in this chapter. Some studies discovered a weak correlation between Bitcoin and conventional assets (Bouri, E., Gupta, R., Tiwari, A. K., & Roubaud, D., 2017), while others observed a stronger correlation during specific periods. These findings could be attributed to factors like changes in investor risk preferences, market sentiment, and global economic events. The aim of these earlier studies was to enhance our understanding of how Bitcoin and other cryptocurrencies interact with and are affected by traditional financial markets. Researchers have also examined the causal relationship between Bitcoin and other cryptocurrencies. They found that cryptocurrencies are more tightly correlated with one another than with other traditional financial instruments, potentially due to their common technological underpinnings, market dynamics, and investor demographics (Sharma, R., 2022).

Prior research employed statistical techniques such as the Pearson correlation coefficient, Granger causality test, and time-varying regression to investigate correlations and causality. These approaches assist researchers in evaluating the relationship between Bitcoin and other assets and identifying potential causal connections (Wooldridge, J. M., 2015).

Overall, previous studies of the correlation between Bitcoin, cryptocurrencies, and traditional financial instruments have been essential for comprehending how these markets influence and interact with each other, aiding investors and decision-makers in making better-informed choices.

2.3 The S&P 500 and the Stock Market: A General perspective and its significance for investors

The S&P 500, a global equity index, functions as a barometer for gauging the advancement of the U.S. stock market and showcases the most prominent public enterprises listed on the New York Stock Exchange and Nasdaq. The index's weighting is dictated by the market value of the leading 500 public companies (Malkiel, 2015). At present, Apple Inc. holds the most substantial weight, followed by Microsoft Corporation, Amazon.com Inc., and other eminent firms from diverse sectors (Slickcharts, 2023).

This index frequently serves as a proxy for the overall well-being of the U.S. economy and investor sentiment, encompassing companies from vital economic domains like technology, healthcare, finance, manufacturing, and more (Reilly & Brown, 2011). When people discuss the market's ascent or descent, they typically allude to the U.S. market, with the S&P 500 being the standard frame of reference (Daks, 2022).

Investors often compare their portfolio's achievements with those of the broader stock market (Sharpe, 1966). The S&P 500 is utilized as a touchstone for this purpose, permitting investors to contrast their returns against the index's returns to appraise their portfolio's performance relative to the general market (Investopedia, 2023).

Investigations into the correlation between the S&P 500 and other financial assets suggest that this association can fluctuate over time and be influenced by numerous factors, such as economic cycles, political occurrences,

and market disturbances (Baur & Lucey, 2010). These elements may impact the S&P 500's effectiveness as an overall market yardstick and its representativeness for investors portfolios.

Comprehending the S&P 500's function is vital for investors to assess portfolio accomplishments and make well-considered investment choices. Despite specific constraints, like solely covering the U.S. market and excluding smaller enterprises, the S&P 500 is still deemed to provide a comprehensive and representative snapshot of the U.S. economy's state and investor conviction (Malkiel, 2015).

Moreover, the S&P 500 can be employed as a foundation for investment tactics such as passive management, wherein investors acquire and retain index funds that follow the S&P 500 to attain market returns with minimal expenses and risks (Fama & French, 1993). This approach has proven fruitful for numerous investors over time, particularly in the long run, as persistently outperforming the market through active management and stock selection has been arduous (Bogle, 2010).

2.4 Effects of COVID-19 on the financial market

The COVID-19 pandemic has significantly influenced financial markets, leading to heightened volatility and unpredictability (Baker et al., 2020). In March 2020, volatility reached its pinnacle when fear-driven investors started offloading their holdings, resulting in one of the most substantial downturns in American history (S&P Dow Jones Indices, 2020). Factors contributing to the decline encompassed heightened concerns about the coronavirus spread, plummeting oil prices, and the mounting probability of a recession (Acharya & Steffen, 2020).

Market uncertainty spurred investors to pursue secure investments and diversify their portfolios to safeguard against price fluctuations and unstable market conditions (Baur & Lucey, 2010). This led to a heightened interest in conventional safe havens like gold, recognized for its hedging and safe haven properties, particularly during periods of market stress, as well as government bonds, exemplified by Swiss government bonds, renowned for their high credit quality and safety. Moreover, stable currencies such as the Swiss franc and Japanese yen also saw increased demand as investors sought to mitigate risk and maintain portfolio value in the face of market instability (Christensen, J. H. E., & Mirkov, N. 2021).

Research has endeavored to comprehend how the COVID-19 pandemic has impacted the correlation between diverse financial assets and how investors have adjusted their strategies amid these turbulent times (Goodell & Goutte, 2020; Zhang, Hu, & Ji, 2020). These studies reveal that the pandemic has transformed the investment landscape and affected investors risk preferences, subsequently influencing the correlation between various assets and their returns. It is crucial to acknowledge that the COVID-19 pandemic is an unparalleled and unforeseeable event that has significantly affected financial markets. This implies that future research should devote more effort to examining the pandemic's influence on markets to better grasp the underlying mechanisms and their long-term consequences.

2.5 Knowledge gaps and research needs

As research on the relationship between Bitcoin and traditional financial assets like stocks, bonds, and gold continues to grow, uncertainties persist regarding the evolution of this correlation during events such as the COVID-19 pandemic and other financial crises (Bouri et al., 2017; IMF, 2022). Created in 2009 in response to

the 2008 financial crisis, Bitcoin has yet to experience a market downturn of a similar magnitude, as the stock market has consistently risen since its inception (Royal, J. 2023).

Nguyen, K. Q. (2022), investigated the link between Bitcoin and the S&P 500 during the COVID-19 pandemic using quantile-on-quantile (QQ) analysis. Their study unveiled a significant and positive association between Bitcoin and the S&P 500, particularly in times of high market volatility. This suggests that investors viewed Bitcoin as a riskier investment rather than a safe haven during the pandemic. Supporting this notion, the International Monetary Fund (IMF, 2022) reported that cryptocurrencies, including Bitcoin, displayed a stronger correlation with the stock market during the pandemic, indicating new considerations for investors and financial markets.

Despite the increasing number of studies exploring Bitcoin's relationship with traditional financial assets, research on the causality between Bitcoin and the S&P 500 during financial crises, such as the COVID-19 pandemic, remains limited. Gaining insights into causality can reveal how changes in one asset impact the other, enabling investors to better optimize their portfolios. A possible explanation for this knowledge gap is Bitcoin's status as a relatively young asset class that has not yet undergone a full economic cycle. It is important to recognize that the relationship between Bitcoin and the S&P 500 can fluctuate based on the timeframes examined and the analytical methods employed in the research.

Subsequent research efforts have been suggested to focus on identifying the causality between Bitcoin and the S&P 500 under varied economic circumstances and exploring how this causality evolves during times of instability compared to more stable periods (IMF, 2022). Delving into these questions can equip investors and decision-makers with vital information for adjusting their strategies to navigate risks and capitalize on diversification benefits in different market scenarios.

It is crucial to analyze how Bitcoin performs relative to an index like the S&P 500 in such situations and how the correlation between these assets shifts during these periods (Nguyen, K. Q. 2022). A deeper understanding of these dynamics can provide investors with insights into refining their strategies and evaluating the impact of events like the pandemic or other financial crises on diversification effects (Markowitz, 1952).

Future research endeavors can emphasize evaluating the fluctuations in the correlation between Bitcoin and traditional financial assets across diverse economic landscapes and assessing how these changes influence portfolio outcomes and diversification potential. This may entail examining the correlation between Bitcoin and the S&P 500 during economically uncertain periods, such as pandemics or financial crises, in contrast to periods of economic stability (Baur & Lucey, 2010; Akhtaruzzaman, M., Boubaker, S., Lucey, B. M., & Sensoy, A., 2021; IMF, 2022). Addressing these knowledge gaps can enhance our comprehension of Bitcoin's role in investments and its effects on conventional financial markets. Furthermore, forthcoming studies could investigate how governments and central banks can address emerging challenges associated with the increasing integration of digital currencies and equity markets (IMF, 2022). This may involve contemplating innovative regulatory strategies, strengthening supervision of the digital asset sector, and fostering international collaboration to ensure an effective response to potential risks.

Another potential research direction could explore the relationships between various types of digital currencies, such as altcoins and stablecoins, and traditional financial instruments under different economic conditions. This can furnish investors with valuable insights into utilizing these assets for diversification and risk mitigation purposes.

Additionally, academics should consider examining the impact of technological and regulatory developments on the connections between digital currencies and traditional financial assets. For instance, the rise of decentralized finance (DeFi) platforms and central bank digital currencies (CBDC) may alter the ways cryptocurrencies interact with established financial systems.

3 METHOD

In this chapter, statistical methods as well as data collection and research are covered. This is done for the purpose of providing the reader with an overview of how the chosen statistical models work and how the analysis of the study was conducted.

3.1 RESEARCH APPROACH

The methods used in this study will utilize a quantitative analytical approach to tackle the research questions detailed in Segment 1.3. A quantitative analytical approach entails amassing and scrutinizing digit-based details to evaluate theories, determine values, and investigate correlations among them methodically and impartially (USC Libraries, 2023). In this situation, the method aims to examine the link between the S&P 500 and Bitcoin.

Quantitative methodologies are identified by their capability to create results that can be extended to a larger population (Babbie, 2010). This makes it particularly fitting to address the query topics in this examination in an orderly and impartial way since the research needs to manage large quantities of data. This methodology contrasts with, for instance, a qualitative method, where the focus is on grasping and interpreting occurrences rather than quantifying them (Creswell, 2014).

This examination applies number-driven methodologies, extracting and scrutinizing numerical data from trustworthy sources. The aim is to identify and numerically express linkages and cause-and-effect relationships in the context of the S&P 500 and Bitcoin in the periods preceding and following the global health crisis of 2019–2020, which was centered around the COVID-19 pandemic. This strategy promises an unbiased and systematic breakdown of the information, enabling deductions about the connection between these two financial instruments. By employing a quantitative analytical approach and depending on details from reliable sources, such as fiscal records and public organizations, this examination enables an extensive and meticulous scrutiny of the relationship between the S&P 500 and Bitcoin. This approach bolsters the research's legitimacy and contributes to producing insights that might be valuable for financiers and decision-makers.

3.2 HYPOTHESES

Drawing from the literature assessment and the study's objectives, the subsequent hypotheses will be examined using the quantitative research method:

H_1: The correlation between the S&P 500 and Bitcoin has shifted considerably during the COVID-19 pandemic in comparison to the timeframe prior to the pandemic.

H_2: Causality exists between the S&P 500 and Bitcoin, and this causality has been impacted by the COVID-19 pandemic.

The formulated propositions are grounded in prior pertinent research and the literature assessment outlined in Section 2. The literature assessment underlines how market dynamics and the connections between various assets can potentially be influenced by economic instability and global occurrences, such as the COVID-19

pandemic. Based on these insights, the aforementioned propositions have been devised to explore how the S&P 500 and Bitcoin have been affected by the pandemic and how their association and causality may have evolved during this period.

3.3 DATA COLLECTION

Data on the S&P 500 and Bitcoin was gathered from a dependable source, Yahoo Finance, for the period spanning January 1, 2018, to January 1, 2022. Yahoo Finance was selected as the data source due to its quality and extensive compilation of financial information, making it an ideal source for amassing and examining data in a numerical study like this one.

The data acquisition process will be split into two segments: prior to the pandemic and following the pandemic's onset. This separation enables a more precise juxtaposition between the two timeframes and aids in assessing the influence of the COVID-19 pandemic on the association and causal connection between the S&P 500 and Bitcoin. By utilizing Yahoo Finance as a data source, the gathered information is assured to be both all-encompassing and precise. The platform offers historical pricing data and market details for both the S&P 500 and Bitcoin, which is crucial for performing a comprehensive and dependable evaluation of the link between these two assets throughout the specified time span.

3.4 STATISTICAL METHODS

To examine the data and evaluate the proposed hypotheses, a variety of statistical methods were employed. To gauge the association between the S&P 500 and Bitcoin, Pearson's correlation coefficient was utilized. This approach offers a quantitative appraisal of the intensity and course of the connection between the two variables.

To explore causality between the S&P 500 and Bitcoin, we have applied the Granger causality test, which aids in determining if fluctuations in one variable influence alterations in another variable over a period of time. By integrating these methods, a more profound comprehension of the fundamental relationship between the S&P 500 and Bitcoin and the manner in which this relationship has evolved during the timeframes under investigation can be acquired.

3.4.1 PEARSON CORRELATION COEFFICIENT

The statistical method known as Pearson's correlation coefficient (r), was first introduced by Karl Pearson in the early 1900s, is a mathematical technique for assessing the intensity and direction of the linear relationship between two continuous variables (Stewart, 2023). This method is applied to determine the existence of a linear connection between the S&P 500 and Bitcoin during specified time frames. The formula for calculating Pearson's correlation coefficient is as follows:

$$\rho = \frac{cov(X_1,\ X_2)}{sd(X_1)sd(X_2)} = \frac{cov(X_1,\ X_2)}{\sqrt{var(X_1)}\sqrt{var(X_2)}}$$

Where:

- Covariance (cov) is a measurement of the relationship between two random variables and how two variables change together, indicating whether they increase or decrease in a similar manner. A positive covariance implies that both variables move in the same direction, while a negative covariance indicates that one variable increases while the other decreases.
- The Standard Deviation (sd) is a way to assess how scattered a group of numbers is by showing the usual gap between each number and the group's average. A greater typical spread implies more inconsistency in the numbers.
- The Variance (var) is the square of the standard deviation. It provides insight into the amount of variability, where a larger value of variance indicates greater inconsistency.

This equation entails dividing the covariance between the pair of variables by the product of their standard deviations. In this instance, it will be the S&P 500 and Bitcoin, which are the two continuous variables. The outcome is a value ranging between -1 and 1 that characterizes the intensity and direction of the linear association between the two continuous variables. A value of -1 signifies a flawless negative correlation, meaning that as one variable rises, the other descends in equal proportion. A value of 0 denotes no correlation whatsoever, and a value of 1 implies a flawless positive correlation where both variables exhibit precisely the same price movements.

Pearson's correlation coefficient is among the most prevalent methods for gauging correlation between variables since it is straightforward and can be computed using statistical software. By determining Pearson's correlation coefficient between the two return series, the outcome can be interpreted to comprehend the strength and direction of the linear association between the S&P 500 and Bitcoin during the designated timeframes.

3.4.2 GRANGER CAUSALITY TEST

The Granger causality test is a sophisticated statistical method employed to determine whether one time sequence can anticipate another time sequence (Granger, 1969). This test is grounded in autoregressive models and strives to assess if past values of one variable (x) can forecast future values of another variable (y).

To run the Granger causality test, two separate equations were used. Both equations were tested for three lags; equation 1 runs a regression of the variable Y, while equation 2 runs an equation for the variable X, which in this paper refers to the S&P 500 and Bitcoin. The two equations are:

$$\Delta Y_t = \alpha_1 + \beta_1 \times \Delta Y_{(t-1)} + \beta_2 \times \Delta Y_{(t-2)} + \beta_3 \times \Delta Y_{(t-3)} + \varepsilon_t$$

$$\Delta X_t = \alpha_1 + \beta_1 \times \Delta X_{(t-1)} + \beta_2 \times \Delta X_{(t-2)} + \beta_3 \times \Delta X_{(t-3)} + \varepsilon_t$$

Where:

- ΔY_t and ΔX_t These are the values of the variables Y and X at time t, where Δ signifies the difference from the previous period. The t subscript denotes the current time period.
- α_1: This is the intercept term for both equations. It shows the expected value of ΔY_t and ΔX_t when all other variables (the changes in Y or X at previous time periods) are zero.
- $\beta_1,\ \beta_2, \beta_3$: These are the coefficients of the lagged values of Y and X, respectively. They show the degree of influence that the changes in the value of Y (or X) in the previous periods have on the change in the current period. For example, $\beta_1 \times \Delta Y_{(t-1)}$ means that the change in Y at time period (t-1) is multiplied by β_1 to get its contribution to the current period's change in Y, ΔY_t.
- $\Delta Y_{(t-1)}$, $\Delta Y_{(t-2)}$, $\Delta Y_{(t-3)}$and $\Delta X_{(t-1)}$, $\Delta X_{(t-2)}$, $\Delta X_{(t-3)}$: These are the lagged differences of the variables Y and X respectively from the previous 1st, 2nd, and 3rd periods.
- ε_t: This is the error term at time t. It captures all other factors affecting ΔY_t and ΔX_tt that are not included in the models. It's assumed to be a random variable with a mean of zero.

To examine the causality between the S&P 500 and Bitcoin, a series of tests and evaluations were carried out to determine their features and connections. The subsequent steps outline the methodology utilized in this research:

1. Augmented Dickey-Fuller (ADF) test: Initially, ADF tests were performed to ascertain if the time series for the S&P 500 and Bitcoin were stationary. This step is crucial because stationarity is needed to conduct further analyses and derive dependable conclusions about the relationship between the two markets. To evaluate if our data is stationary, the static value was tested and contrasted with the critical value at our selected significance level of 5%. Then, a judgment was made if the test statistic value was more negative than this critical value. Furthermore, the p-value was investigated to see if it was less than our chosen significance level of 5%. By adhering to these criteria, we can draw conclusions about the stationarity of our data.
2. Two equations: After confirming the stationarity of the time series, a system of two equations was employed to model the relationship between the S&P 500 and Bitcoin. The first equation treated the S&P 500 as the dependent variable and Bitcoin as the independent variable, while the second equation used the opposite arrangement. This allowed us to analyze how the two variables impacted each other and test for Granger causality.
3. AIC and BIC: To select the best model, data from both the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) were examined to compare different models. These criteria assist in identifying the model that best describes the data while considering the model's complexity. Lower values of AIC and BIC indicate a better model. AIC and BIC are calculated using the following equations:

$$AIC = -3 \times \log(L) + 2 \times k$$

$$BIC = -3 \times \log(L) + k \times \log(n)$$

Where:

- log(L) is the logarithm of the likelihood (L) of the estimated model (model's likelihood).
- k is the number of parameters in the model.
- n is the number of observations in the dataset.

4. F-tests: Finally, F-tests were conducted to evaluate if the independent variables in the two equations were statistically significant and thus could predict the dependent variable. A low p-value (less than 0.05) in the F-test indicates that the independent variable is significant and can contribute to explaining the variation in the dependent variable, suggesting Granger causality.

Utilizing this methodology, this study delved into the connection between the S&P 500 and Bitcoin and ascertained if any Granger causality was present between the two variables.

In Granger causality testing, the p-value is used to determine whether two time series are causally related. If the p-value is less than the significance level, the null hypothesis of no Granger causality is rejected and a causal relationship is assumed. The p-value represents the probability of obtaining a result that is more extreme than the observed outcome under the null hypothesis. A lower p-value indicates a lower likelihood of observing the result if the null hypothesis is true. This study utilized a threshold of 0.05 for rejecting the hypothesis.

It is crucial to emphasize that the Granger causality test only supplies information on whether one time series can predict another but not if there is an actual causal mechanism between them. This implies that if we discover Granger causality between the S&P 500 and Bitcoin, we cannot conclusively assert that fluctuations in the S&P 500 trigger changes in Bitcoin or the other way around. We can only state that prior values of one time series can be employed to forecast future values of the other time series. To investigate the causal relationship between two variables, further research and analysis utilizing other methods and tools are necessary.

4 DATA AND ANALYSIS

In this chapter, the results of the empirical research are presented. The chapter begins with an overview of the descriptive statistics and preliminary tests for model selection for the time series. Furthermore, the results of the Pearson's correlation coefficient analysis and the Granger causality test are presented.

4.1 DATA OVERVIEW

In this segment, we offer an extensive examination of descriptive figures and visualizations concerning the price progression and price returns for the S&P 500 and Bitcoin during the 2018-2022 timeframe. By integrating these techniques, a foundational comprehension of the price fluctuations, distinguishing attributes, and volatility of the two assets throughout the investigation period is achieved.

4.1.1 DESCRIPTIVE STATISTICS AND GRAPHS

In this section, descriptive statistics and graphs for the S&P 500 and Bitcoin during the period 2018-2022 are presented, based on the data shown in Table 1.

Table 1. Descriptive Statistics for S&P 500 and Bitcoin (2018-2022)

Variable	obs	Mean	Std.dev.	Min	Max	Skewness	Kurtosis
S&P500	1008	3288.171	637.784	2237.4	4793.06	.864	2.431
Bitcoin	1462	18395.29	17770.76	3236.762	67566.83	1.300	3.143

During the period, the S&P 500 index displayed an average level of 3288.171 with a standard deviation of 637.784. The index's lowest value was 2237.4, while the highest value reached 4793.06. The S&P 500 demonstrates a skewness of 0.864, signifying that the distribution is somewhat skewed to the right. The kurtosis value of 2.431 indicates a marginally lower peak than a normal distribution.

Conversely, Bitcoin had an average value of 18395.29 and a standard deviation of 17770.76 during the same timeframe. The lowest value for Bitcoin was 3236.76, and the highest value was 67566.83. Bitcoin presents a skewness of 1.300, signifying that the distribution is more skewed to the right compared to the S&P 500. The kurtosis value for Bitcoin is 3.143, suggesting a marginally higher peak relative to a normal distribution.

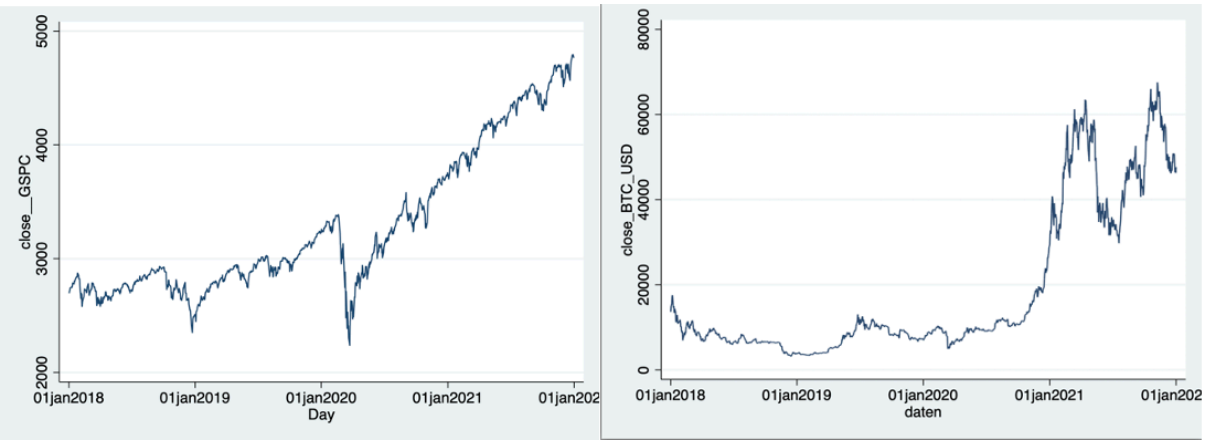
From the descriptive statistics, we can discern that Bitcoin has considerably greater volatility than the S&P 500 during the specified timeframe, as evidenced by the higher values for standard deviation, skewness, and kurtosis. Visualizations of the time series for the S&P 500 and Bitcoin can offer supplementary comprehension of how their values have progressed over time. Graph 1 illustrates the price development of Bitcoin and the

S&P 500, while graph 2 depicts the price returns of Bitcoin and the S&P 500. Both visuals reveal a general upward trend for both assets during the 2018–2022 period, but it is apparent that Bitcoin exhibits significantly increased volatility and more pronounced price shifts than the S&P 500.

4.1.2 GRAPHS

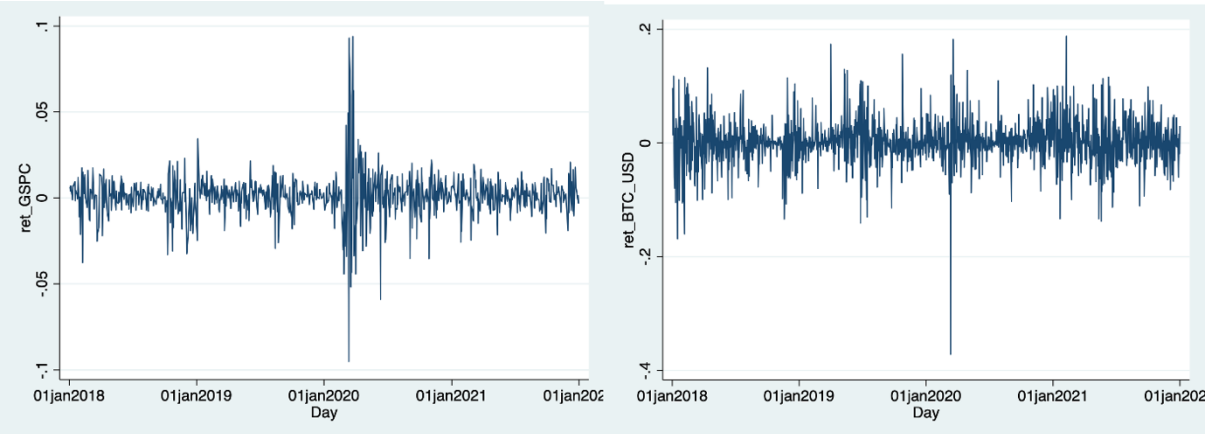
The following visuals illustrate the price progression and price yields for the S&P 500 and Bitcoin throughout the 2018–2022 timeframe. These diagrams offer a graphic portrayal of the price fluctuations and returns of both assets during the study period, providing supplementary comprehension of their distinct attributes and instability.

Graph 1. Price development for the S&P 500 and Bitcoin (2018–2022)



Graph 1 showcases the price progression for the S&P 500 and Bitcoin throughout the 2018–2022 timeframe. It is apparent that Bitcoin has experienced a considerably larger price surge compared to the S&P 500. Moreover, the price progression of Bitcoin demonstrates higher volatility, as evidenced by its significant price oscillations during the specified duration. Conversely, the S&P 500 displays steadier and sustained price growth, which is typical for a stock index representing a wide market.

Graph 2. Price returns for the S&P 500 and Bitcoin (2018–2022)



Graph 2 presents the price returns for the S&P 500 and Bitcoin throughout the 2018–2022 time span as a side-by-side comparison. The returns are portrayed as a percentage variation in price from one day to the next. The image demonstrates that Bitcoin displays considerably larger daily price shifts than the S&P 500, indicating increased volatility for the cryptocurrency. The S&P 500's price returns are typically more consistent, although there are moments of heightened volatility, especially during economically unsettled periods.

The descriptive statistics and visuals for price progression and price returns offer an in-depth overview of the S&P 500 and Bitcoin's performance during the research period. The findings verify that Bitcoin has undergone more substantial price growth and elevated volatility compared to the S&P 500.

4.2 Pearson's correlation coefficient

Within this portion, we showcase the findings from Pearson's correlation evaluation involving the S&P 500 and Bitcoin throughout the 2018–2022 timeframe. The analysis interval was partitioned into two segments to examine potential shifts in correlation prior to (2018–2020) and following the emergence of the COVID-19 pandemic (2020–2022). Furthermore, the correlation outcome during the complete duration is displayed in the table below to offer an all-encompassing appraisal. The table presents the correlation between the S&P 500 Index and Bitcoin closing prices across the three different time frames. It showcases the Pearson correlation coefficients and corresponding p-values for each period, on which the remainder of Chapter 4.2 will be based.

Table 2. Pearson's Correlation Coefficient (2018-2020, 2020-2022, and 2018-2022)

Time frame	**Variable**	**Variable**	**P-value**
2018-2020	S&P500	Bitcoin	
	1.000	0.309	0.000
2020-2022	S&P500	Bitcoin	
	1.000	0.877	0.000
2018-2022	S&P500	Bitcoin	
	1.000	0.910	0.000

4.2.1 Correlation between S&P 500 and Bitcoin (2018-2020)

In the initial segment of the investigation timeframe, spanning from 2018 to 2020, Pearson's correlation coefficient revealed a value of 0.309. This figure denotes a mild positive association between the S&P 500 and Bitcoin, insinuating that as the S&P 500 index rises, the worth of Bitcoin tends to grow too, albeit to a lesser degree. It is important to acknowledge that this outcome is substantially distant from an ideal correlation, which would require a value of 1.0 and a completely synchronized motion trend, indicating the presence of some unpredictability.

4.2.2 Correlation between S&P 500 and Bitcoin (2020-2022)

Throughout the latter segment of the investigation timeframe, extending from 2020 to 2022, Pearson's correlation coefficient escalated notably to 0.877. This implies a robust positive association between the S&P 500 and Bitcoin during these years. The heightened correlation between these two assets might be attributable to shared elements during the pandemic, encompassing financial market unpredictability, alterations in monetary strategy, and investors pursuing alternative investment avenues.

4.2.3 Correlation between S&P 500 and Bitcoin (2018-2022)

Upon evaluating the entire duration (2018–2022), Pearson's correlation coefficient yields a value of 0.910, signifying an exceptionally robust positive association between the S&P 500 and Bitcoin. This outcome implies that throughout the four-year examination period, the S&P 500 and Bitcoin generally moved in unison, particularly following the pandemic's onset.

4.3 Granger causality test

In this segment, we share the outcomes of the Granger causality analysis between the S&P 500 and Bitcoin throughout the 2018–2022 timeframe. The investigation period is separated into two portions to examine potential shifts in causality pre-pandemic (2018–2020) and post-pandemic (2020–2022). Additionally, causality results spanning the entire duration are showcased for a holistic evaluation. The results of the Granger causality test are detailed in the table found in Section 5.1.2.

Prior to performing the Granger causality examination, it is crucial to verify the stationarity of the time series. This can be accomplished using the Augmented Dickey-Fuller (ADF) test, as displayed below:

Table 3. Augmented Dickey-Fuller (ADF) Test, AIC and BIC values

	2018-2020	2020-2022	2018-2022
S&P500			
Test statistic	-15.703	-21.647	-28.348
Critical value			
1%	-3.457	-3.457	-3.430
5%	-2.879	-2.860	-2.860
10%	-2.570	-2.570	-2.570
P-value	0.000	0.000	0.000
Bitcoin			
Test statistic	-27.845	-29.477	-40.509
Critical value			
1%	-3.430	-3.430	-3.430
5%	-2.860	-2.860	-2.860
10%	-2.570	-2.570	-2.570
P-value	0.000	0.000	0.000
AIC	1027.519	1467.425	2603.096
BIC	1039.409	1477.606	2617.1

The ADF assessment reveals that both the returns of the S&P 500 and Bitcoin are stationary time series throughout the trio of investigated periods, indicating they don't exhibit any persistent trends or cyclical fluctuations. This is an essential prerequisite for carrying out the Granger causality examination.

This financial economics study seeks to explore Granger causality between the S&P 500 and Bitcoin in order to comprehend their reciprocal association and how it has evolved over time. After thorough evaluation, a three-

lag model was selected to scrutinize Granger causality between these two financial instruments across the three specified time frames (2018–2020, 2020–2022, and 2018–2022).

The AIC and BIC values for the 2018–2020 period suggested that a three-lag model offers the optimal model fit. Employing a three-lag model for this timeframe allows for a more precise and insightful analysis of Granger causality between the S&P 500 and Bitcoin. For the 2020–2022 and 2018–2022 periods, caution was exercised when considering a more complex model. By opting for a more conservative three-lag model, we averted overfitting, meaning the model's capacity doesn't overstate the need to explain variations in the data. This guarantees our findings are reliable and pertinent to the core economic issue.

In order to gain a coherent understanding of how Granger causality between the S&P 500 and Bitcoin has shifted over time, it is crucial to employ a uniform method across all timeframes. By utilizing the same number of lags, specifically three lags, throughout all periods, the results were evaluated in a more consistent fashion. This enabled us to observe how the connections between these two financial instruments alter over time and how they are impacted by shifts in economic circumstances. The selection of a three-lag model achieves a suitable balance between attaining a solid model fit and maintaining consistency in the analysis. This permits a meaningful comparison of outcomes across various timeframes and the drawing of conclusions about the underlying associations between the S&P 500 and Bitcoin.

4.3.1 Granger causality test between S&P 500 and Bitcoin (2018-2020)

The 2018–2020 period witnessed the S&P 500 and Bitcoin displaying constant averages and variances, suggesting stationarity. However, the p-values of 0.869 and 0.372 in the test between the two exceeded the 0.05 significance threshold. In this case, the direction of causality is neither from Bitcoin to the S&P 500 nor from the S&P 500 to Bitcoin, implying an absence of Granger causality.

4.3.2 Granger causality test between S&P 500 and Bitcoin (2020-2022)

For the period 2020–2022, the p-value of 0.004, when the S&P 500 is considered the dependent variable, falls below the 0.05 significance threshold. This evidence indicates that the direction of causality is from Bitcoin to the S&P 500, implying Granger causality, with Bitcoin acting as a forecast for the S&P 500. However, the p-value of 0.327, when Bitcoin is the dependent variable, surpasses the 0.05 significance level, demonstrating that the direction of causality is not from the S&P 500 to Bitcoin, indicating no Granger causality in this direction.

4.3.3 Granger causality test between S&P 500 and Bitcoin (2018-2022)

Throughout the 2018–2022 period, both the S&P 500 and Bitcoin maintained stationarity. The p-value of 0.0030, with the S&P 500 as the dependent variable, falls below the 0.05 significance threshold, suggesting that the direction of causality is from Bitcoin to the S&P 500, indicating Granger causality and Bitcoin's predictive role for the S&P 500. However, with Bitcoin as the dependent variable and a p-value of 0.0982 that

exceeds the 0.05 significance level, the direction of causality does not extend from the S&P 500 to Bitcoin, denoting no presence of Granger causality in this regard.

To summarize, there was no evidence of Granger causality between the S&P 500 and Bitcoin in the 2018–2020 period. In contrast, from 2020–2022, the direction of causality was from Bitcoin to the S&P 500, but not the other way around. Similarly, for the 2018–2022 period, the direction of causality was from Bitcoin to the S&P 500 but not from the S&P 500 to Bitcoin.

5 INTERPRETATION OF RESULTS AND DISCUSSION

The purpose of this chapter is to provide an interpretation of the results discovered in Chapter 4 as well as a discussion of the findings.

5.1 PRICE DEVELOPMENT AND VOLATILITY

The descriptive statistics and corresponding graphs presented in Section 4.1 show that Bitcoin experienced a significantly higher price increase than the S&P 500 during the examined period, despite its increased volatility and risk (Campbell, Lo, & MacKinlay, 1997). For investors inclined to accept higher risk, this could potentially indicate that Bitcoin might be a valuable asset to include in a diversified portfolio (Markowitz, 1952).

5.1.1 CORRELATION

Pearson's association coefficient signifies that the connection between the S&P 500 and Bitcoin intensified substantially after the emergence of the COVID-19 pandemic in comparison to the period prior to the pandemic. An augmented association indicates that the two assets have a tendency to move in a similar direction during both favorable and unfavorable market conditions. This insinuates that if one asset's value declines, it is probable that the other asset's value will also diminish, which is a vital element for investors pursuing positive price progression (Markowitz, 1952).

This heightened association between these two assets could imply that they are affected by shared economic aspects, such as fiscal uncertainty and shifts in monetary policy (Bouri et al., 2021). This strengthened correlation might influence diversification possibilities for investors seeking to distribute risk across distinct asset classes (Zhang, J., Zhao, W., Cheng, B., Li, A., Wang, Y., Yang, N., & Tian, Y., 2022). As a result, it is essential for investors to comprehend the importance of correlation and how it can impact their portfolio strategy in terms of both optimizing returns and reducing the likelihood of adverse price fluctuations.

5.1.2 GRANGER CAUSALITY TEST

The information provided in the following part, named "Table 5: Granger causality test", highlights the impact of implementing Granger's sequence influence examination, a statistical supposition check for ascertaining if one chronological sequence assists in projecting another. The findings are arrived at by deploying the Ordinary Least Squares (OLS) regression method in certain formulas, each relevant for different time durations.

The table includes parameter values and the results of Granger's sequence influence tests, providing insight into the connection between the S&P 500 and Bitcoin over particular periods. It records delayed factors (t=-1, t=-2, t=-3), which allude to the past periods quantities. The collective relevance of these delayed variables is illustrated through p-values, integral for comprehending the statistical importance of our discoveries.

The examination reveals no sequence influence, implying that preceding quantities of one factor don't impact the present quantity of another, is noticeable between the S&P 500 and Bitcoin during the 2018-2020 period. Nevertheless, this situation alters for the 2020-2022 period, where the data suggests a sequence influence between Bitcoin and the S&P 500. This infers that the historical amounts of Bitcoin might be used to estimate the current values of the S&P 500. This data could consequently be of use to investors on the lookout for preliminary indications of market fluctuations (Cheung, Roca, & Su, 2015).

The following table reports the results of the parameter coefficients and Granger causality tests in form the OLS regressions in the equations in p. 10 for different periods. P-values in the following table show the joint significance on the lagged t=-1, t=-2, t=-3 independent variables.

Table 4. Granger causality test

	S&P500 (1a)	Bitcoin (1b)	S&P500 (2a)	Bitcoin (2b)	S&P500 (3a)	Bitcoin (3b)
S&P500 $_{t-1}$	-0.0138 (0.1243)	-0.1993 (0.2706)	-0.1176 (0.1066)	-0.2292 (0.1589)	-0.2101 (0.0693)***	-0.2650 (0.1315)**
S&P500 $_{t-2}$	-0.1322 (0.1163)	-0.2636 (0.2768)	-0.1006 (0.0984)	-0.1961 (0.1519)	-0.1027 (0.0726)	-0.2097 (0.1301)
S&P500 $_{t-3}$	0.0956 (0.1357)	0.3792 (0.2873)	-0.0401 (0.0929)	-0.0486 (0.1451)	0.0040 (0.0702)	0.0532 (0.1303)
Bitcoin $_{t-1}$	-0.0090 (0.0246)	-0.0332 (0.0597)	-0.1025 (0.0287)***	-0.0983 (0.0486)*	-0.0630 (0.0176)***	-0.0669 (0.0368)*
Bitcoin $_{t-2}$	0.0166 (0.0259)	0.1269 (0.0588)**	-0.0025 (0.0323)	0.0822 (0.0450)*	0.0082 (0.0208)	0.0939 (0.0351)**
Bitcoin $_{t-3}$	0.0100 (0.0245)	0.1235 (0.0586)**	-0.0625 (0.0419)	0.1112 (0.0560)*	-0.0208 (0.0222)	0.1098 (0.0400)**
Constant	0.0292 (0.1052)	0.5047 (0.2417)**	0.1226 (0.1402)	0.0924 (0.2142)	0.0653 (0.0870)	0.2928 (0.1589)*
R squared	0.027	0.069	0.346	0.104	0.215	0.074
P-value from the Granger causality tests	0.869	0.372	0.004	0.327	0.003	0.009
Time period	2018-2020	2018-2020	2020-2022	2020-2022	2018-2022	2018-2022

Note: 1) Standard errors are in parentheses. 2) The significance levels are indicated as follows: * for $p < 0.1$, ** for $p < 0.05$, *** for $p < 0.01$.

5.2 DISCUSSION

In the prior section, we explored the primary outcomes and observations stemming from the examination of the association between the S&P 500 and Bitcoin from 2018 to 2022. The discourse delves into the ramifications for investors, financial markets, and prospective inquiries on the subject matter.

The findings illustrate that the linkage between the S&P 500 and Bitcoin intensified markedly in tandem with the COVID-19 pandemic's emergence. This insinuates that these two assets tend to shift in parallel during this period. This can be partially accounted for by shared economic elements influencing both the stock market and cryptocurrencies, such as financial market unpredictability and alterations in monetary strategy (Bouri et al., 2021). For investors, this heightened connection implies that diversification prospects between conventional stock indices and cryptocurrencies like Bitcoin might be restricted under specific economic circumstances, a factor to contemplate in portfolio development and hazard management (Zhang, J., Zhao, W., Cheng, B., Li, A., Wang, Y., Yang, N., & Tian, Y., 2022).

Also, the reinforced linkage between the S&P 500 and Bitcoin may suggest that cryptocurrencies, despite their unconventional and decentralized essence, are not entirely impervious to the economic phases and factors that impact traditional financial markets. This crucial insight is beneficial for investors contemplating the inclusion of cryptocurrencies in their portfolios and for policymakers devising regulations surrounding cryptocurrencies and their influence on established financial markets (Bouri et al., 2021).

On top of that, it is crucial to acknowledge that this investigation solely scrutinized the association and causal links between the S&P 500 and Bitcoin. Additional research is required to examine the connections between other cryptocurrencies, the stock market, and various financial assets. Investigating how the relationship and causality between the S&P 500 and Bitcoin transform during distinct economic cycles and how these shifts are influenced by political and regulatory factors would be valuable. Such research would contribute to a more profound understanding of cryptocurrencies role in the financial system and their potential to craft diversified and resilient portfolios.

Besides, the outcomes from Granger's causality test indicate that Bitcoin emerged as a predictive factor for the S&P 500's fluctuations during the 2020–2022 period. This could suggest that cryptocurrencies, previously deemed detached from traditional financial markets, are progressively integrating into the global financial system, and their impact on market movements is growing (Cheung et al., 2015). This insight could have significant implications for investors contemplating the inclusion of Bitcoin in their portfolios, as it may offer a level of predictability, thereby aiding more informed decision-making. However, this result should be treated cautiously, as Granger causality does not inherently imply causation, and further research is essential to explore the underlying mechanisms of this relationship.

Lastly, this study has implications for the regulation and oversight of cryptocurrencies. The increased correlation between the S&P 500 and Bitcoin, coupled with the demonstrated Granger causality, implies that cryptocurrencies are gaining relevance within the financial system and can affect financial stability and investor behavior. This observation further encourages regulatory frameworks and supervisory authorities to contemplate introducing suitable regulations and monitoring mechanisms for the cryptocurrency market, ensuring its stability and safeguarding investors from excessive risks (Böhme et al., 2015; Auer & Claessens, 2018).

Within the context of these findings, it is essential to acknowledge the limitations of this investigation. Primarily, it focuses exclusively on Bitcoin and the S&P 500, and the outcomes may not be applicable to other cryptocurrencies and financial instruments. Secondly, the investigation is based on a specific timeframe, implying that the results could be influenced by the prevalent economic and political conditions during this

period. Lastly, it is important to note that correlation analyses and Granger causality assessments do not inherently suggest causation, and further research is necessary to understand the underlying mechanisms driving these connections.

Despite the constraints of this research, it still offers meaningful perceptions into the realm of digital currency and fiscal economics, scrutinizing the link between Bitcoin and the S&P 500. This carries potential consequences for market participants, fiscal robustness, and oversight. Earlier scholarly work has proposed that ensuing inquiries might extend these results to probe connections between alternative digital currencies and fiscal devices, surveying the impacts of economic trends, political and regulatory elements (Ahnert, Assenmacher, Hoffman, Leonello, Monnet and Porcellacchia, 2022).

Further, the prospect of inspecting the interplay between digital currencies and diverse fiscal tools like bonds and commodities constitutes a significant pathway for future investigation. A thorough comprehension of their place within the global fiscal structure can then be gained. Concurrently, another beneficial facet for future probes could be the review of how digital currencies and their underlying technologies like blockchain might sway the conventional fiscal sector. This could engage sectors like banking, payment systems, and insurance, focusing on how these transformations could refashion the risk landscape and create opportunities for market participants and financial establishments.

Moreover, it might be advantageous for future inquiries to concentrate on crafting inventive investment approaches and hazard management methods that take into account the unique traits of digital currencies and their relationships with other fiscal tools. This could encompass creating algorithms for dynamic portfolio enhancement capable of adjusting to market variations and utilizing traditional and digital currency-based assets to maximize returns and mitigate risk.

This research casts light on the association between Bitcoin and the S&P 500 in the 2018–2022 span, which could be significant for market participants, financial markets, and future probes. It was discovered that the correlation between these two assets grew following the COVID-19 outbreak, and this could have implications for diversification possibilities and risk management. Intriguingly, the Granger causality examination implies that Bitcoin transformed into a predictive component for movements in the S&P 500 during the 2020–2022 span, presenting potentially useful perceptions for investors seeking early signs of market shifts. These findings also insinuate the need for further examination in terms of oversight and supervision of digital currencies, as they demonstrate that cryptocurrencies are becoming increasingly incorporated into the fiscal system and can impact financial stability and investor conduct.

An additional crucial element to ponder for future research is the effect of technological and security apprehensions on digital currency valuations and their relationships with traditional fiscal tools. Events like cyberattacks, platform interruptions, or technical upgrades of crypto protocols could affect their value and association with equity markets, necessitating further exploration.

Future probes could also examine the role of digital currency volatility in relation to traditional financial instruments. Evaluating how price changes in digital currencies influence their correlation with equity markets could offer investors enhanced comprehension and management of the hazards linked to these assets.

The involvement of institutional investors in the digital currency market signifies an intriguing area for future investigation. The utilization and adoption of digital currencies by major institutions such as pension funds, insurance firms, and asset managers could reshape their value and connection with conventional financial tools.

In conclusion, given the ongoing discussions about climate change and sustainability, the environmental footprint of digital currencies is a pertinent area to explore. The energy usage of crypto networks, such as

Bitcoin, and its influence on valuation and relationships with traditional financial tools could offer fresh viewpoints on the environmental sustainability of digital currencies as enduring investments.

Perpetual examination of these and other facets of digital currencies and their relationships with financial markets can contribute to a detailed and comprehensive understanding of the role of digital currencies within the financial framework. The resulting knowledge can guide investors, regulators, and policymakers in making informed decisions on managing and encouraging the use of digital currencies, ensuring a stable and innovative financial marketplace.

5.2.1 Addressing hypothesis 1

The initial hypothesis speculated a significant change in the relationship between the S&P 500 and Bitcoin during the COVID-19 health crisis compared to the period preceding the outbreak. Our inquiry and numerical examinations affirm this notion.

Certainly, Pearson's correlation factor indicates a substantial amplification in the bond between the S&P 500 and Bitcoin during the time of COVID-19 compared to the pre-crisis era. This is showcased by the escalated value of the correlation coefficient during the health crisis, pointing to a stronger likelihood of these assets experiencing a synchronized movement in both favorable and adverse market scenarios.

The escalated bond market during the COVID-19 period implies that these assets could be swayed by shared economic aspects, such as market fluctuations and shifts in fiscal policy, which became more dominant during this phase. This insight carries implications for portfolio diversification tactics, hinting that the advantages of spreading risk across varied asset types might lessen under certain conditions, such as during widespread market volatility and uncertainty.

5.2.2 Addressing hypothesis 2

The subsequent hypothesis suggested that a causal link exists between the S&P 500 and Bitcoin, and that this link has been influenced by the COVID-19 pandemic. The Granger causality assessments implemented lend support to this hypothesis, although with notable subtleties.

Before the onset of the COVID-19 pandemic, throughout the 2018-2020 timeline, there was no evidence of Granger causality between the S&P 500 and Bitcoin. This suggests that shifts in the value of one asset did not consistently herald changes in the other asset’s value. However, during the pandemic era, 2020-2022, a Granger causality link was found from Bitcoin to the S&P 500. This denotes that alterations in Bitcoin's value could precede and predict alterations in the S&P 500 index during this timeline.

It's vital to emphasize, however, that the causality detected in the Granger test doesn't certify that Bitcoin's price shifts provoke changes in the S&P 500. It might be that some hidden factors are influencing the price of both Bitcoin and the S&P 500, and Bitcoin merely reacts to these elements more swiftly. So, while the Granger test points towards predictive power, it's crucial to be cautious when interpreting these outcomes as indications of causality.

Collectively, our analyses endorse both of our hypotheses, indicating a significant alteration in the correlation and causality between the S&P 500 and Bitcoin during the COVID-19 pandemic. These insights offer valuable perspectives for investors contemplating portfolio strategies and risk management. They also highlight the necessity for further exploration of the dynamic interplay between traditional financial markets and cryptocurrencies, especially during times of substantial market upheaval, like the COVID-19 pandemic.

5.3 Exploring the dynamic relationship between the S&P 500 and Bitcoin: The impact of futures and real-time news events

In our examination of the thesis, we have meticulously analyzed the association and causation between the S&P 500 and Bitcoin throughout various timeframes. Our findings reveal that, at times, the S&P 500 appears to follow Bitcoin's lead. However, it is crucial to acknowledge the limitations of our investigation and potential factors that may have influenced these outcomes.

One specific element we recently contemplated was the omission of S&P 500 futures from our study. Futures constitute financial contracts obligating the buyer to acquire an asset or the seller to dispose of one, such as a physical commodity or a financial instrument, at a predetermined future date and price. In relation to our research, this could substantially affect the perceived correlation between the S&P 500 and Bitcoin.

Our oversight of futures in the analysis might create the impression that Bitcoin acts as a harbinger for the S&P 500. This could be attributed to Bitcoin's capacity to react more swiftly to current news events, while the S&P 500's response may be delayed or less conspicuous due to its broad market representation and the variety of financial instruments, including futures. In reality, the S&P 500 may be reacting to the same news occurrences, but the response could be delayed or muted due to the impact of futures contracts.

It is vital to address this constraint in our thesis deliberation and ponder the potential implications of futures on the observed association between the S&P 500 and Bitcoin. By doing so, we can present a more polished understanding of the interplay between these two financial instruments and provide a comprehensive interpretation of our findings. Future inquiries could delve into integrating futures data into the analysis to further elucidate the relationship between the S&P 500 and Bitcoin, supplying additional perspectives for investors and market participants.

6 CONCLUSION

In this chapter, the study's contribution, limitations, and areas for future research are discussed. Lastly, a thorough conclusion will finish this thesis.

6.1 EVOLUTION OF THE RELATIONSHIP BETWEEN S&P 500 AND BITCOIN AMIDST COVID-19 AND ITS IMPLICATIONS FOR INVESTORS AND REGULATORS

This thesis has explored the relationship between the S&P 500 and Bitcoin during the period 2018–2022, with a particular focus on how the correlation and causality between these two assets have changed before and after the outbreak of the COVID-19 pandemic. The study employed descriptive statistics, graphs, Pearson's correlation coefficient, and Granger's causality test to analyze and interpret the results. The main conclusions from the study are as follows:

1. Descriptive statistics and graphs reveal that Bitcoin has experienced a greater price increase and higher volatility compared to the S&P 500 during the study period. This suggests that Bitcoin carries a higher risk, but at the same time, the cryptocurrency has significantly outperformed the S&P 500 over time.

2. Pearson's correlation analysis shows a positive correlation between the S&P 500 and Bitcoin during the study period, which strengthened after the outbreak of the COVID-19 pandemic. This indicates that over the four-year study period, the S&P 500 and Bitcoin tended to move in the same direction, especially after the pandemic's onset.

3. Granger's causality test provides no evidence of causality between the S&P 500 and Bitcoin during the period 2018–2020. For the period 2020–2022, there is evidence of Granger causality between Bitcoin and the S&P 500, but not between the S&P 500 and Bitcoin. Finally, for the period 2018–2022, there is evidence of Granger causality between Bitcoin and the S&P 500 but not between the S&P 500 and Bitcoin.

In conclusion, this investigation has demonstrated that the association between the S&P 500 and Bitcoin has evolved over time, particularly in the wake of the COVID-19 pandemic's onset. This awareness is crucial for those investing in and considering the integration of cryptocurrencies into their holdings, as well as for authorities formulating rules around digital currencies and their effects on conventional finance markets.

It is vital to fathom how digital currencies interact with other fiscal instruments and how these connections are impacted by economic, political, and legislative elements to fully harness the potential of cryptocurrencies while mitigating related risks. By intensifying our understanding of these intricacies, we can strive to develop a sturdier and more flexible financial domain, primed to address upcoming challenges.

Apprehending the interactions between digital currencies and traditional financial instruments, as well as the aspects influencing these associations, can aid investors in making informed choices regarding portfolio diversification and hazard management. Moreover, this data can be employed by authorities to devise regulations that encourage stability and expansion in both digital currency and conventional financial markets.

As the fiscal landscape perpetually evolves, it becomes crucial to monitor the ongoing progress in the links between digital currencies and traditional assets. With the rise of novel cryptocurrencies and financial tools, further research and examination will be necessary to understand their influence on well-established markets and investment strategies. This continuous research will help guarantee that investors and regulators have the required knowledge to navigate the ever-changing financial milieu.

6.2 LIMITATIONS AND FUTURE RESEARCH

This investigation presents certain constraints, including the scrutiny of merely two investment vehicles (the S&P 500 and Bitcoin) and focusing on a particular timeframe (2018–2022). Subsequent inquiries could broaden this assessment by incorporating additional investment vehicles and examining extended timeframes. Moreover, supplementary techniques might be utilized to enhance comprehension of the interconnections among these investments, including cointegration assessments and chronological series evaluations (Brooks, 2019).

In conclusion, this investigation offers a rudimentary comprehension of price progression, fluctuation, and the interrelationship between the S&P 500 and Bitcoin throughout 2018–2022. To acquire a more profound understanding of these occurrences, upcoming studies could delve into an assortment of factors that impact these investments price evolution and fluctuation, including political and economic incidents, technological tendencies, and regulatory measures.

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