ASSESSING BITCOIN'S DYNAMICS: AN EMPIRICAL ANALYSIS OF BITCOIN'S RISK AND RETURN RELATIONSHIPS WITH THE S&P 500 AND GOVERNMENT BONDS

by

Tien "Jessiny" Ly

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Project Approved:

Supervising Professor: Vassil Mihov, Ph.D.

Department of Finance

Grant Farnsworth, Ph.D.

Department of Finance

David Weltman, Ph.D.

Department of Business Information Systems and Supply Chain

ABSTRACT

This study investigates the dynamics of risk and return relationships among Bitcoin, the S&P 500 Index, and government bonds using a vector autoregression approach, covering the period from 2020 to 2024. Employing daily return data, the analysis utilizes a vector autoregression of two lags model to explore return relationships between the aforementioned assets. For the risk analysis, a Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model is applied to the daily returns, followed by first differencing of the GARCH outputs for each variable and subsequent analysis of vector autoregression of two lags. The results indicate an absence of significant risk and return relationships between Bitcoin and both the S&P 500 and government bonds. The lack of significant findings prompts further investigation into the unique characteristics of Bitcoin. Additional analyses are conducted on Bitcoin's risk and return dynamics with meme stocks and its return relationship with macroeconomic indicators. The findings contribute to understanding the complex interplay between traditional financial assets and cryptocurrencies, highlighting the distinctive behavior of Bitcoin in the financial markets. This study enriches the existing literature on asset class interactions under different market conditions and advances our comprehension of the underlying factors influencing these relationship.

Content

Introduction

Bitcoin (BTC) stands at the forefront of digital finance innovation, marking the inception of decentralized digital currencies free from central bank oversight. Satoshi Nakamoto's groundbreaking work in 2008 introduced this first-of-its-kind currency, designed to enable secure, peer-to-peer transactions through cryptographic principles. In the evolving landscape of modern finance, BTC occupies a central role, igniting discussions on digital money's digitization, its implications for monetary policy, and its emergence as a new asset class.

From its 2009 inception, BTC has undergone a meteoric evolution, emblematic of technology's transformative impact on finance. This journey reflects broader historical patterns where innovation precedes regulation and disrupts established financial frameworks. BTC's story evolves through stages of curiosity, speculative interest, extreme volatility, and, notably, increasing institutional adoption.

This study delves into BTC's volatility and return patterns, essential for assessing its viability as both a medium of exchange and a store of value. Analyzing BTC's performance alongside traditional assets, like equities and bonds, yields insights into its investment potential and role in portfolio diversification and risk management. Despite comparisons to "digital gold" due to its limited supply and value storage potential, BTC's price fluctuations starkly contrast with traditional safe havens like gold and government bonds. Meanwhile, equities reflect corporate ownership stakes, influenced by earnings, economic conditions, and market sentiment.

The period from 2020 to 2023 stands out for its analytical richness, marked by bull and bear markets, regulatory actions, blockchain advancements, and significant global events impacting market dynamics and investor behavior. We aim dissect the return and risk

relationships between BTC, the S&P 500, and government bond indices during this period. Employing a vector autoregression (VAR) model, it scrutinizes the return data series of these assets to deduce BTC's volatility and return performance in relation to traditional financial instruments.

Exploring whether BTC's returns can partially derive from its time-series relationships with equities and bonds, we seek to understand how these interactions have evolved. It aims to contextualize BTC's market behavior within the broader framework of financial markets, comparing and contrasting its dynamics with those of equities and bonds—assets with established investment portfolio roles. Understanding BTC's market behavior and its asset correlation is paramount for finance professionals and researchers. It informs asset allocation, risk assessment, and financial product development, while also guiding regulators and policymakers integrating digital currencies into financial systems.

The thesis defines BTC's asset class characteristics, reviewing literature on its volatility, and comparing it with equities and bonds. Utilizing return data from 2020 to 2023, it applies a VAR model to elucidate BTC's relationships with these traditional assets. The analysis synthesizes empirical findings, addresses literature gaps, and suggests avenues for future research. This comprehensive review aims to enhance understanding of BTC's role in contemporary finance and its potential trajectory.

Literature Review

BTC’s Market Dynamics and Theoretical Foundations

BTC's introduction to the market in 2009 marked the beginning of a new era in digital currencies. Initially, BTC met skepticism from investors, and its use largely catered to niche online communities. The digital currency's early years composed of by significant volatility, attributable to both its speculative nature and the novelty of the concept of a decentralized currency (Glaser et al., 2014). This period also saw BTC's price being highly sensitive to news about security breaches, regulatory announcements, and its potential for facilitating illicit activities (Böhme et al., 2015). Nevertheless, these years laid the foundation for BTC’s underlying market dynamics and theoretical frameworks that would influence its later integration into financial markets.

The period between 2013 and 2017 witnessed BTC's transition from an obscure digital curiosity to a recognized financial asset. With increasing media coverage and the advent of BTC exchanges, BTC surged in both its price and investor interest. Notably, the establishment of professional trading platforms provided a semblance of legitimacy and invited comparisons with traditional financial assets, which include stocks and bonds. During this phase, BTC's market cap reached a point at which its movements began to stand alongside established financial assets, although the correlation was typically weak or non-existent, reflecting its idiosyncratic nature (van Wijk, 2013).

Studies during this period began to evaluate BTC's potential as a portfolio diversifier due to its low correlation with traditional assets, suggesting that it could offer benefits in terms of risk-adjusted returns (Dyhrberg, 2016). However, despite its integration into broader financial

discourse, BTC remained highly volatile, with its valuation driven by speculative trading and market sentiment rather than intrinsic value (Cheah & Fry, 2015).

The pre-COVID years of 2018 and 2019 saw a stabilization phase for BTC. The market witnessed the maturation of BTC with increased institutional interest, the development of futures markets, and the entry of traditional financial firms into cryptocurrency space (Corbet et al., 2019). During this period, BTC began to exhibit characteristics of a more mature asset, including somewhat reduced volatility and the emergence of more clear-cut market behaviors in response to macroeconomic signals (Nadarajah & Chu, 2017). Despite these signs of maturation, BTC's price actions remained unpredictable, challenging traditional financial theories that sought to explain its market dynamics. The period also saw the introduction of various theoretical models attempting to capture the complex nature of BTC's valuation, including the application of the Efficient Market Hypothesis (EMH) and behavioral finance theories. Studies examining the fractal nature of BTC's price fluctuations pointed to a market that was, in many ways, still distinct from those of more traditional financial instruments (Urquhart, 2016).

The most significant moment for BTC came during the pandemic. The literature on BTC's market dynamics and theoretical foundations during the COVID-19 period and its aftermath reveals a rich exploration of its volatility, adoption trends, and regulatory impacts. Several studies have highlighted the pandemic's role in enhancing BTC's market appeal, positioning it as a digital safe haven amid global financial uncertainty. Baur and Dimpfl (2021) examined the volatility transmission between BTC and traditional financial assets, concluding that the pandemic increased investors' interest in BTC as a diversification tool. Furthermore, Corbet et al. (2020) analyzed the correlation between BTC and other financial assets during COVID-19, finding temporary increases in correlations during market stress but a general trend

of BTC acting as a diversifier. BTC's perceived role in the digital economy significantly influenced its rate of adoption, with Kristoufek (2022) suggesting that the accelerated digital transformation due to COVID-19 has bolstered BTC's integration into financial and non-financial sectors. On the regulatory front, studies have shown that the evolving legal and policy environment surrounding cryptocurrencies has a profound impact on market dynamics. Auer and Claessens (2022) provided an extensive overview of global regulatory responses to cryptocurrencies, emphasizing the balance between fostering innovation and mitigating risks.

BTC and Equities

The inception of BTC in 2009 ushered in a novel asset class that initially exhibited little to no correlation with traditional equities. Limited studies focused on BTC's relationship with traditional financial markets, making it a non-driver in volatility impacts on traditional financial markets.

As BTC matured as an asset class and its market capitalization grew, the narrative around its correlation with traditional stock markets began to change. From 2013 to 2019, BTC's user base expanded beyond tech enthusiasts and speculators to include retail investors and, increasingly, institutional participants. This shift was pivotal in linking BTC's market movements more closely with traditional financial indicators. Gurdgiev and O'Loughlin (2020) documented a gradual increase in the correlation between BTC and equities, particularly during market downturns, suggesting a creeping "financialization" of BTC.

Furthermore, Kristoufek (2015) found that while BTC had begun to exhibit some of the characteristics of traditional assets, it was also influenced by investor sentiment and market exuberance, akin to risky equities, albeit not for the long-term. This period also witnessed BTC's increased presence in the mainstream financial press, which correlated with its trading volumes

and market valuation, underscoring the impact of media sentiment on its correlation with equities (Glaser et al., 2014).

The onset of the COVID-19 pandemic in early 2020 was a watershed moment for global financial markets, and BTC was no exception. The initial market crash saw BTC falling alongside equities, challenging the narrative that it could act as a 'safe-haven' asset during times of crisis (Conlon & McGee, 2020). However, as the pandemic progressed and the global economy entered a period of uncertainty, BTC's correlation with equities, especially technology stocks, began to increase significantly (Corbet et al., 2020). This shift was due to a combination of factors, including the influx of institutional money into BTC, the rise of retail trading platforms, and the aggressive monetary policies adopted by central banks worldwide.

Additionally, the pandemic period witnessed an increasing overlap of investor demographics between BTC and equities, further aligning their market movements (Auer & Claessens, 2020). The phenomenon of “pandemic trading”, marked by increased retail investor activity facilitated by mobile trading apps, contributed to the synchronized price dynamics between BTC and the stock market.

As the pandemic waned and the world entered the post-COVID phase, BTC continued to display a complex relationship with equities. While the correlation remained elevated compared to the pre-pandemic era, the dynamics were nuanced. Economic recovery efforts, inflationary pressures, and the discussion about BTC as an inflation hedge were key factors influencing its correlation with equity markets (Goodell & Goutte, 2021).

The changing landscape of the correlation between BTC’s and equities’ returns during the period from 2020 to 2023 has brought to light the intricate dynamics of market sentiment,

regulatory developments, and economic factors. The pandemic era has certainly highlighted BTC's sensitivity to macroeconomic stimuli and changes in investor behavior, drawing increased scrutiny from both researchers and market participants.

As governments and financial institutions navigated the complexities of a global health crisis, the narrative about digital currencies evolved. BTC, once seen as a fringe asset, began to be discussed as a potential mainstream investment vehicle, particularly as large institutional investors entered cryptocurrency space. The correlation with equities, especially technology stocks, suggested that BTC was increasingly being treated as a risk asset rather than a distinct alternative investment (Watson, 2021).

Moreover, BTC's reactions to policy announcements, such as those pertaining to the Federal Reserve's monetary stimulation and regulation, demonstrated a maturing market that responded to the same cues as traditional equities. This was a departure from the earlier years, where BTC's market movements were predominantly driven by technology adoption cycles and speculation (Yermack, 2023). Dong et al. (2023) also found that the Federal Reserve's monetary policy responses during COVID-19 had some influence on BTC's prices, as rate cuts encouraged institutional investors to enter BTC's market, and rate hikes led institutional investors to exit BTC's market.

In summary, the period from 2020 to 2023 marked a significant shift in BTC's relationship with equity markets. This era solidified BTC's presence in the financial conversation, not only as a novel investment but also as a reflective asset that mirrors broader market sentiments and economic conditions. The ongoing research into the dynamic relationship between BTC and equities is critical, as it offers insights into market dynamics, risk management, and the future of diversification strategies in the age of digital finance.

BTC and Bonds

The embryonic years of BTC from 2009 to 2013 showcased its pronounced non-correlation, where an asset's behavior does not relate to the other examined assets' behavior, with traditional financial assets, including the bond market. BTC's independence from conventional financial assets signified one of its fundamental attributes during this period. Dyhrberg (2016) highlighted BTC's distinct behavior, noting its potential as a diversification tool, as it did not exhibit a significant correlation with other asset classes, including government bonds. This was a period of experimentation and novelty, with BTC seen more as a technological curiosity than a financial asset, and the major players in its market were technophiles and libertarians, rather than institutional investors or financial professionals.

As BTC gained recognition and its market ecosystem developed, its perceived role began to shift. From 2013 to 2019, researchers and investors started to explore BTC's potential as a hedge against traditional financial market movements, including the bond market. Baur and Lucey (2010) proposed the concept of an 'alternative investment' class, suggesting that assets like BTC could act as a hedge or even a safe haven during periods of financial stress or inflationary pressures that would typically lead to bond market fluctuations. Although BTC's hedging capabilities were still up to debate, its non-correlation with bonds suggested that it could provide portfolio diversification benefits.

The increasing integration of BTC into the broader financial landscape also began to change its relationship with bonds. As central banks around the world continued their quantitative easing programs, some investors started to look to BTC as a potential hedge against the inflationary risk associated with these policies, which could negatively impact bond markets (Brière et al., 2015).

The correlation between BTC and bond yields became more pronounced during the COVID-19 pandemic, with significant economic and market upheavals. As governments and central banks implemented unprecedented fiscal and monetary measures to mitigate the economic impact of the pandemic, bond yields fell to historic lows, and in some cases, turned negative. This environment prompted some investors to turn to BTC as an alternative investment. BTC's price surged during this period, leading to speculations that it was beginning to act more like a traditional safe-haven asset, much like gold, which traditionally moves inversely to bond yields (Auer & Claessens, 2020).

However, the relationship between BTC and bond yields is complex. On one hand, the low-interest-rate environment diminished the appeal of bonds, potentially making BTC more attractive. On the other hand, BTC's price volatility remained high, challenging the notion of it being a stable store of value during times of economic uncertainty (Conlon & McGee, 2020). Moreover, the increased institutional interest in BTC led to its behavior becoming more interlinked with traditional financial market dynamics, including the bond market (Baker et al., 2020).

The interplay between BTC and bond yields has been further complicated by the inflationary pressures that emerged as economies started to recover from the initial shocks of the pandemic. The subsequent rise in bond yields, prompted by expectations of tightening monetary policy to combat inflation, presented a new dynamic in the BTC-bond relationship, as investors consider both to be barometers of investor sentiment towards inflation (Demir et al., 2020). This period of the BTC-bond relationship underscores the evolving nature of BTC as an asset class. While it began as a non-correlated entity, BTC has increasingly shown that it cannot be viewed through the lens of traditional financial market behaviors, particularly in relation to bonds. The

ongoing fluctuations in bond yields, driven by macroeconomic changes and monetary policies, continue to shape the narrative around BTC's place in the financial market ecosystem.

The nuanced interaction between BTC and bond markets during the latter stages of the COVID-19 pandemic has been a subject of intense scrutiny. The correlation patterns observed between BTC prices and bond yields have prompted a re-examination of the role of digital assets in the context of traditional fixed-income securities. As governments and central banks shifted towards recovery and inflation management, the yields on bonds began to rise, suggesting a reflation trade that could potentially compete with BTC for the status of an inflation hedge.

Economic recovery has caused concerns for inflation due to the significant stimulus measures. BTC, often touted as 'digital gold', has seen debates around its value proposition as a hedge against inflation reignited (Baur & McDermott, 2020). As bond yields rise in anticipation of inflation, investors might be expected to pivot away from non-interest-bearing assets like BTC. However, the actual market behavior has been more complex. The digital currency has shown moments of both positive and negative correlation with bond yields, reflecting its sensitivity to investor sentiment and risk preferences (Goodell & Goutte, 2021).

Comparative Analysis of Volatility Patterns

The investment landscape has been dynamically altered by BTC's introduction, particularly regarding how different economic events uniquely influence its volatility compared to traditional assets like stocks and bonds. The differential impact is a subject of intense scrutiny, with studies revealing disparate sensitivity patterns among these asset classes (Bouri, Gupta, & Roubaud, 2021).

For BTC, significant announcements from the Federal Reserve, geopolitical tensions, and even tweets from influential figures have resulted in immediate and pronounced price swings, indicating a higher level of reactivity compared to more established assets (Aysan, Demir, Gozgor, & Lau, 2019). Conversely, equities and bonds traditionally respond to economic events through the lens of company performance, interest rates, and economic indicators like GDP growth or unemployment rates, exhibiting less volatility in comparison to cryptocurrencies (Corbet, Larkin, & Lucey, 2020).

Empirical studies utilizing GARCH models have attempted to quantify these differences in volatility. The findings generally underscore BTC's unique volatility profile, which does not consistently correlate with that of stocks or bonds, suggesting a distinct market structure (Dyhrberg, 2016). Moreover, the sensitivity of BTC to global uncertainty, which is measured by the volatility index in prominent stock markets around the world, points to its evolving status and investor base, which differs markedly from those of traditional asset classes (Bouri et al., 2017). Understanding the transmission of volatility across different financial markets is essential for both risk management and investment diversification strategies. The cross-market volatility transmission has been the focus of numerous studies seeking to untangle the complex interplay between BTC, equities, and bonds (Katsiampa, Corbet, & Lucey, 2019).

The autoregressive conditional heteroskedasticity (ARCH) and GARCH methodologies have been a popular tool to model and analyze the volatility transmissions between assets (Engle, 2001; Bollerslev, 1986). They provide insight into the propagation of shocks across markets and how volatility in one market can spill over into another. The literature suggests that while BTC has exhibited periods of decoupling from traditional markets, there are instances where

significant events lead to an increase in cross-market volatilities, especially during market downturns or financial crises (Koutmos, 2018).

The interconnectivity between BTC and traditional asset markets has evolved, with more recent research indicating that, as BTC becomes more mainstream, its market movements have begun to echo those of equities and, to a lesser extent, bonds (Corbet, Meegan, Larkin, Lucey, & Yarovaya, 2021). This linkage implies a shift in investor perception, treating BTC as part of the broader financial market ecosystem, influencing and being influenced by other asset classes' volatility.

Implications of Findings for Investors and Policy Makers

The unique volatility profile of BTC carries significant implications for both investors and policymakers. Investors seeking to harness BTC's potential as a diversification tool must carefully consider its volatility dynamics in relation to other assets (Demir, Gozgor, Lau, & Vigne, 2019). The inconsistent correlation between BTC and traditional assets could offer diversification benefits, yet the stark volatility could also mean heightened risk levels.

For policymakers, the integration of BTC into the financial market poses challenges for regulatory frameworks and financial stability monitoring. The ability of BTC to affect and receive shocks from other asset classes necessitates a comprehensive understanding of its volatility patterns and transmission mechanisms to inform policy decisions (Bianchi, 2019).

Moreover, the findings from volatility studies are crucial for the development of market infrastructure and investment products that cater to the specific needs of investors involved with BTC, potentially paving the way for novel financial instruments and risk management practices (Eisl, Gasser, & Weinmayer, 2015).

The literature underscores the importance of BTC in contemporary finance, an asset class that market participants or researchers can no longer ignore. The reviewed studies not only elucidate past and present market dynamics but also lay the groundwork for future research, especially in areas influenced by regulatory changes, long-term market correlations, and technological advancements. The risk and return relationships between BTC and traditional assets remains a vibrant area of research, reflecting the complexities of an interconnected global financial system.

Data Collection

This study investigated the relationships in returns and risk among BTC (BTC), the S&P 500 ETF Trust (SPY), and the S&P Global U.S. Government Bond Index (GBI) over the period from March 2, 2020, to February 5, 2024. This period encompasses a range of significant global financial phenomena, including the unprecedented impacts of the COVID-19 pandemic, adjustments in monetary policy, and heightened market volatility. The starting date captures the financial markets' reactions to these extraordinary events, offering insights into asset behavior during periods of economic stress and recovery.

The return data for BTC comes from publicly accessible cryptocurrency exchange platforms, while the SPY ETF data, representing the broader U.S. equity market via the S&P 500 Index, is from the official S&P 500 website. The GBI data, reflecting the performance of U.S. government bonds, is from Standard & Poor's official website. All data account for dividends and splits where applicable.

In contrast to the logarithmic returns used in some analyses, this study employs simple returns, calculated using the formula $Rt = \frac{P_t - P_{t-1}}{P_{t-1}}$, where Rt is the return at time t, Pt is the price at time t, and $Pt-1$ is the price at time $t-1$. This formula facilitates the straightforward comparison of return magnitudes across the assets.

Methodology

Return Relationship Analysis

To examine the return relationships between BTC and SPY, as well as between BTC and GBI, we apply Vector Autoregression (VAR) models to the simple returns of these asset pairs. The VAR model is a robust statistical approach that models the linear interdependencies between multiple time series. For this study, VAR elucidates how the returns of each asset are influenced by their own past values and by the past values of the other asset in the pair. We use the VAR(2) model, which goes back 2 lags, for our model. The reason is that we only try to examine how recent past values of the independent variable affect the dependent variable.

Risk Relationship Analysis

The study assesses the risk relationships among BTC, SPY, and GBI through a series of steps beginning with the estimation of volatility using GARCH models for each asset. The GARCH model captures the time-varying volatility characteristic of financial time series, making it suitable for assessing the risk dynamics of BTC, SPY, and GBI.

Following the GARCH model estimation, we compute the first difference of the GARCH series for each asset. This step transforms the volatility series to emphasize changes in volatility over time, providing a basis for analyzing volatility relationships.

Finally, we apply VAR models with two lags to the first difference GARCH series of BTC, SPY, and GBI. This model investigates the interdependencies in volatility among the three assets, offering insights into how shocks to the volatility of one asset might influence the volatility of the others. This methodological framework, combining simple return analysis with advanced volatility modeling, enables a comprehensive examination of both the return and risk

relationships among BTC, SPY, and GBI, highlighting the dynamic interactions that characterize these assets in the study period.

Empirical Results

Return Analysis

The VAR(2) model applied to both sets of asset pairs revealed significant insights into their return interactions. See Figure 1 and Figure 2 for a detailed summary of VAR results on BTC's and SPY's relationship and BTC's and GBI's relationship.

BTC & SPY

For BTC and SPY returns, the VAR results indicated a complex interplay, with lag-1 values of SPY returns demonstrating a significant influence on current BTC returns. On the other hand, BTC returns appear to have a more subdued impact on SPY returns, with no coefficients reaching statistical significance.

BTC & GBI

GBI returns do not exhibit a significant influence on BTC returns at any lag, suggesting a indiscernible return relationship between the two variables. Similarly, BTC returns seem to have an insignificant impact on Bond returns, with no coefficients reaching p-value of less than 0.05.

Risk Analysis

In examining the risk dynamics among BTC returns, SPY returns, and GBI returns, this study employed a methodological framework that integrates GARCH models and VAR analysis. Initially, we apply GARCH models to the return series of BTC, SPY, and GBI to capture and quantify the time-varying volatility inherent in these assets. The GARCH methodology is

particularly suited for this purpose, given its effectiveness in modeling financial time series characterized by periods of varying volatility, a common feature of asset returns.

Subsequently, the study progresses by calculating the first differences of the obtained GARCH series. This differentiation process focuses on the changes in volatility over time, rather than the levels of volatility themselves, thereby highlighting the dynamics of risk in the asset returns under consideration. The first difference of a series is a transformation that provides insights into the volatility shocks and their persistence over time, crucial for understanding the risk profile of financial assets.

Upon deriving the first differences of the GARCH series, we then apply the VAR(2) models to the pairs of BTC and SPY, as well as BTC and GBI. This analytical approach, combining GARCH models with VAR analysis on the first differences of the volatility series, offers a comprehensive framework for understanding the risk relationships between the assets in question. By examining the volatility dynamics and their interactions, the study uncovered significant insights into how risk propagates in the context of influences among BTC, SPY, and GBI. Such an investigation is pertinent for both theoretical and practical considerations in finance, providing valuable information for portfolio management, risk diversification strategies, and the broader understanding of financial market behavior.

BTC & SPY

Figure 3 showcases the result of the VAR model applied to BTC's and SPY's GARCH first-difference series. The regression results for the equation representing BTC volatility dynamics reveal that the coefficients for both the first and second lags of BTC and SPY volatility differences are not statistically significant at conventional levels. Specifically, the coefficients for the lagged variables of BTC volatility differences indicate minimal autoregressive effect in

BTC's own volatility. Similarly, the cross-effects from SPY's volatility differences on BTC's volatility show positive coefficients but fail to reach statistical significance, suggesting limited immediate impact from SPY volatility changes on BTC's volatility.

Conversely, the equation for SPY volatility dynamics presents significant findings. Notably, the first lag of BTC's volatility difference demonstrates a positive and statistically significant effect on SPY's volatility difference. This result indicates that past changes in BTC's volatility exert a notable impact on subsequent SPY volatility movements. Furthermore, the second lag of BTC's volatility difference also shows a significant positive effect on SPY's volatility, underscoring the persisting influence of BTC's volatility changes on the equity market's volatility. We will look further into the significant VAR results of BTC to SPY through the impulse response function's graph to determine whether these significant results are worthwhile to investigate, or they are noises.

BTC & GBI

Figure 4 showcases the result of the VAR model applied to BTC's and GBI's GARCH first-difference series. The VAR results for BTC volatility differences highlight a complex interplay with its own past values as well as with the lagged values of bond volatility differences. Notably, coefficients for lagged variables of BTC's own volatility differences are not statistically significant, suggesting minimal autoregressive influence. Conversely, GBI's volatility differences equation reveals a nuanced response to those of BTC's volatility differences. The first lag of BTC's volatility differences shows a directional influence on GBI volatility, as it is statistically significant. Similar to the case of BTC & SPY volatility, we want to find out whether this significant result shows any insight into BTC & GBI volatility in the later section about impulse response function graphs.

Impulse Response Functions

Impulse response functions (IRFs) serve as an essential tool in the econometric analysis of risk and return relationships among financial assets, particularly in the context of VAR framework. When applied to this study, IRFs provide a dynamic perspective on how each examined asset's returns respond over a specified period to shocks of one standard deviation in the other asset's data.

Through IRFs, we gain a nuanced understanding of the temporal dimension of risk and return spillovers, allowing us to trace the path and magnitude of a shock from one asset class and observe its evolving effects on the others. This temporal unfolding of impacts is vital in assessing the risk interdependencies and diversification potential within a portfolio context. Specifically, for assets like BTC, which are hypothesized to behave differently from traditional assets, IRFs can elucidate whether shocks to BTC returns impart significant disturbances to SPY and GBI returns, and vice versa. In our study, we set the time period for the IRFs to be 15 trading days, which is approximately 2 weeks. As we are interested in investigating if recent past values of the independent variable can forecast future values of the dependent variable, the length of the IRFs' period is sufficient to see the impact from the independent variable to the dependent variable in the short-term.

BTC & SPY Return Relationship

Figure 5 shows the IRFs for the return relationship between BTC and SPY. The IRFs generated from the VAR model of BTC and SPY returns present an econometric visualization of how each variable responds over time to shocks in the other variable and itself. The VAR(2) model, with data spanning from 2020 to 2024, serves as a foundation for these IRFs, depicting the intertemporal dynamics of BTC and SPY returns.

For BTC, the orthogonalized IRFs indicate shocks to SPY returns demonstrate a more variable influence on BTC returns, as depicted by the oscillatory response with no clear trend, suggesting that the impact of SPY shocks on BTC is not immediate or persistent over the period considered. Conversely, the response of SPY returns to BTC shocks is initially noticeable but tends to taper off, highlighting a potential short-term influence of BTC on the stock market, which aligns with the lack of significant coefficients in VAR(2) findings.

BTC and GBI Return Relationship

The IRFs in Figure 6 provide a visual elucidation of the dynamic interactions between BTC returns and GBI returns, as elucidated by the VAR(2) model. The orthogonalized IRFs also reveal that shocks to GBI returns impart a minimal and statistically insignificant impact on BTC returns, which is coherent with the VAR findings where the GBI returns' impact on BTC returns are not statistically significant at conventional levels. Conversely, the response of GBI returns to shocks in BTC returns is similarly subdued, echoing the VAR(2) results that show an inconsequential impact of BTC returns on GBI returns, with high p-values suggesting no significant relationship.

BTC and SPY Risk Relationship

The orthogonalized IRFs in Figure 7, derived from the VAR analysis of the GARCH-differenced series for BTC and SPY, elucidate the dynamic response of each asset's volatility to shocks in the other's series. The upper right graph in Figure 7, which portrays the response of BTC volatility to shocks in SPY volatility, shows a muted and transitory effect, implying that traditional equity volatility exerts limited and fleeting influence on BTC's volatility. Conversely, the lower left graph indicates the response of SPY volatility to shocks in BTC volatility, where we observe an initial reaction that decays quickly. This aligns with the VAR model results,

particularly the significant coefficient at the first lag, which denotes that BTC's volatility has a detectable yet quickly diminishing impact on SPY's volatility.

BTC and GBI Risk Relationship

The orthogonalized IRFs in Figure 8 depicted illustrate the dynamic responses between the GARCH-based volatility differentials of BTC and GBI. The reaction of BTC to GBI's shock shows a statistically insignificant response, suggesting that traditional bond market volatility has a limited influence on BTC volatility. On the other hand, the response of GBI to BTC's shock shows only minor fluctuations, further confirming the isolated nature of BTC's market movements from traditional bond markets. These response patterns are coherent with the VAR model results, where there are no significant coefficients for BTC's two-lag values as a function of GBI's current values.

Discussion

In the discourse of this thesis, we embark upon an introspective examination of the empirical findings, specifically addressing the absence of statistically significant outcomes in the interplay of volatilities across BTC, SPY, and GBI. The null findings of this study align with the findings from Dong et al. (2023) and Meegan et al. (2017). The elucidation of null results serves as a pivotal juncture for scholarly reflection on the multifaceted nature of financial markets and the analytical frameworks employed to decipher them. This segment of the discussion focuses on a critical analysis of the factors contributing to the non-significant findings, exploring the intricate confluence of market dynamics, data characteristics, and methodological considerations that may underpin these results.

BTC's Complex Market Dynamics as a Cryptocurrency

In the realm of financial assets, BTC distinguishes itself by functioning simultaneously as a digital currency and a vehicle for speculative investment within the cryptocurrency market. Distinct from traditional financial instruments such as SPY and GBI, BTC's market dynamics are driven by its dual role. A notable aspect of BTC's market structure is its high concentration of ownership. Research by Makarov and Schoar (2021) reveals that the top 10,000 BTC holders command approximately one-third of the total circulating cryptocurrency, suggesting that significant market fluctuations may be attributed to the activities of these major holders rather than general market volatility. Further, Makarov and Schoar (2021) elucidate that a mere 10% of miners possess 90% of BTC's mining capacity, indicating a centralized control over the supply, which potentially exacerbates market instability and susceptibility to manipulation.

Moreover, the anonymous and decentralized characteristics of BTC facilitate transactions associated with illicit and illegal undertakings. According to Makarov and Schoar (2021), in

2020, funds flowing to blockchain addresses identified with scams amounted to approximately $550 million, with identified ransom payments and transactions related to dark net payments and services exceeding $1.6 billion. Additionally, transactions related to gambling and mixing services accounted for approximately $1.7 billion and $1.4 billion, respectively. Despite these activities constituting a mere 0.5 percent of BTC's total market transactions in 2021—an increase from the previous year—Chainalysis (2024) reports a reduction in the proportion of illicit activities, accounting for only 0.34% of total cryptocurrency transactions in 2024.

The presence of non-KYC (Know Your Customer) entities, which perform minimal client due diligence, raises concerns over the facilitation of dubious transactions. While existing literature predominantly focuses on criminal activities, the extent of transactions associated with other forms of illicit activities, such as tax evasion and money laundering, remains uncertain. Makarov and Schoar (2021) propose that illicit motives predominantly drive BTC transactions, further distinguishing it from traditional financial assets and underscoring the unique challenges and considerations in regulating and understanding cryptocurrency market.

Bitcoin as a Speculative Investment

The discussion on the decoupling of BTC's market behavior from traditional financial assets such as the S&P 500 and government bonds warrants an in-depth exploration of its characteristics as a speculative investment. The findings from the analysis underscore BTC's unique position in the financial ecosystem, predominantly driven by speculative trading, its detachment from intrinsic value norms, and the distinct investor sentiment that parallels gambling behavior. This section elucidates the factors contributing to BTC's non-correlation with traditional financial markets, bolstered by pertinent academic literature.

Firstly, the foundational aspect of BTC's value, or the apparent lack thereof, is its detachment from intrinsic value determinants. Traditional financial theory posits that the value of an asset is fundamentally anchored to its intrinsic properties—cash flows, dividends, or economic utility (Damodaran, 2012). However, BTC's valuation primarily stems from speculative demand, inherently volatile and decoupled from such economic fundamentals. As described by Kristoufek (2015), BTC's price dynamics are significantly influenced by speculative trading, making its behavior unpredictable and divergent from traditional assets like the S&P 500 index and government bonds, which are more closely tied to economic indicators and policies. This speculative nature renders BTC's price sensitivity distinct from that of assets whose values are grounded in economic realities, thereby explaining its non-correlation with the S&P 500 and government bonds.

Secondly, investor sentiment in BTC exhibits similarities to gambling behavior, further distinguishing it from conventional investment assets. According to Gandal et al. (2018), the speculative rush towards BTC is often driven by a 'get-rich-quick' mentality, akin to gambling, where the thrill of potentially high returns overshadows the high risk of loss. This sentiment diverges markedly from the more measured, fundamental analysis-based approach typically associated with investments in the S&P 500 or government bonds. The gambling-like behavior of BTC investors contributes to its erratic price movements, as noted by Dwyer (2015), who highlights the role of investor sentiment in driving BTC's price volatility. This volatility is not as pronounced in the more stable, traditionally valued markets of the S&P 500 and government bonds, thus contributing to the observed non-correlation.

Additionally, past research demonstrated that the transmission of information predominantly flows from cryptocurrency returns to sentiments, rather than the reverse. This

suggests that market movements within cryptocurrencies are more influenced by their own dynamics, such as trading behaviors and investor sentiment within the market, rather than external economic conditions or performances of traditional financial assets. The detailed analysis provided by Akyildirim et al. (2021) on the interconnectedness and the directional influence within cryptocurrency market further supports the assertion that intrinsic factors, such as market capitalization and sentiment within cryptocurrency space, play a critical role in shaping BTC's price movements. Li and Yang (2023) emphasize the internal dynamics of cryptocurrency markets, particularly the influence of larger cryptocurrencies and altcoins on the overall market connectivity and price movements. They argue that the dominant role of cryptocurrencies with higher market capitalization, especially in terms of sentiment spillovers, indicates a self-contained market environment where external economic fundamentals have minimal impact. Li & Yang (2023) attributed this insularity to the cryptographic and technological underpinnings of cryptocurrencies, which foster a distinct ecosystem driven by factors internal to the crypto market. Therefore, the observed non-correlation between BTC and traditional financial assets such as SPY and S&P 500 bond indices can be due to the predominant influence of market-internal factors, including the significant role of market capitalization and investor sentiments within cryptocurrency domain.

Finally, BTC's market dynamics align more closely with those of “meme stocks” than with traditional market indices or government bonds. “Meme stocks”, characterized by their tendency to experience rapid price changes due to social media hype rather than underlying fundamentals, share BTC's susceptibility to speculative bubbles (Aloosh et al., 2022). This resemblance underscores the influence of collective investor behavior driven by speculation and social media on asset prices, as opposed to the economic indicators and corporate performance

that guide investments in the S&P 500 and government bonds. The parallel between BTC and meme stocks, in terms of their speculative nature and the factors influencing their valuation, accentuates the rationale behind BTC's non-correlation with traditional financial assets.

Using the same analysis conducted with the relationships between BTC, SPY, and GBI, Appendix C explores whether popular meme stocks' movements resemble those of BTC, given that the investing rationale behind these names are quite similar to that of crypto investors. Using ChatGPT and Bing to browse Reddit and Twitter for a list of popular meme stocks, we came up with 9 stocks: AMC Entertainment Holdings (AMC), BlackBerry Limited (BB), GameStop Corp. (GME), Virgin Galactic Holdings Inc. (SPCE), Rivian Automotive Inc. (RIVN), Palantir Technologies Inc. (PLTR), SoFi Technologies Inc. (SOFI), and Tesla Inc. (TSLA). What we found is that, despite sharing relatively the same investing sentiment with BTC, 'meme stocks' still do not receive any significant risk and return relationships with BTC. It seems that some of the meme stocks' past values explain BTC's future value. For example, TSLA's return series at lag 1 explains BTC's today's value, but both TSLA's risk series at lag 1 and lag 2 does not explain BTC's today's value. With results showing inconsistent relationships between BTC and meme stocks, it is safe to say that BTC remains independent asset from traditional financial assets post-COVID.

Recognizing BTC's limited relationship with traditional assets, we investigated BTC as an extraordinary asset in a broader scale, analyzing BTC returns' relationships with macro indicators, including unemployment rate, Federal Funds rate, and inflation rate. In the context of understanding BTC's (BTC) sensitivity to macroeconomic indicators, our findings suggest a noteworthy relationship between the Federal Funds rate and BTC returns. Utilizing the VAR(2) model, similar to the analysis we did, it was determined that the Federal Funds rate is the only

macroeconomic indicator among unemployment and inflation rates that consistently forecasts the future values of BTC returns at both one and two lag periods. Further analysis through IRFs reaffirmed the unique position of the Federal Funds rate, demonstrating a persistent impact on BTC returns in response to shocks. Specifically, shocks equivalent to one standard deviation in the Federal Funds rate exhibited a discernible influence on BTC returns over a twelve-month horizon.

This ancillary finding aligns with recent literature, particularly the work of Dong et al. (2023), which underscored the significant impact of Federal Open Market Committee (FOMC) decisions on BTC returns. This congruence emphasizes the potential of monetary policy changes, as reflected through Federal Funds rate adjustments, to serve as a predictor of BTC return volatility. This relationship underscores the interconnectedness of BTC with traditional financial markets and monetary policy, reinforcing the need for investors to monitor Federal Reserve actions closely as part of their investment strategy in cryptocurrencies. Therefore, despite the non-correlation to traditional assets, BTC still experiences influence from the Federal Reserve's interest-rate decisions.

Implications

Bitcoin as a Diversification Tool

The empirical investigation into BTC's relationship with traditional financial markets, notably the S&P 500 and government bonds, reveals an insignificant correlation and volatility spillovers, suggesting BTC's potential role as a diversification tool within investment portfolios. This section elucidates how BTC's unique market behavior and its detachment from traditional financial dynamics underscore its utility in enhancing portfolio diversification, drawing upon scholarly studies to substantiate these assertions.

BTC's emergence as a digital asset class introduces a novel dimension to the asset diversification discourse, primarily due to its distinctive value-drivers compared to traditional financial assets. Unlike equities and bonds, whose returns are significantly influenced by economic indicators, corporate performance, and monetary policy actions, BTC operates within a decentralized framework, responding to factors such as technological advancements, regulatory changes, and shifts in investor sentiment (Bouri, Jalkh, Molnár, & Roubaud, 2017). This fundamental difference in market dynamics is pivotal in rendering BTC a potentially valuable component in diversified investment strategies, particularly as its price movements exhibit minimal correlation with those of traditional assets.

The concept of portfolio diversification, rooted in Modern Portfolio Theory (Markowitz, 1952), advocates for the allocation of investments across diverse asset classes to mitigate risk without proportionately reducing expected returns. In this context, BTC's low correlation with traditional assets can be instrumental in constructing portfolios that are less susceptible to market-wide shocks, thereby reducing overall portfolio volatility. A study by Bouri, Molnár, Azzi, Roubaud, and Hagfors (2017) confirms this perspective, highlighting BTC's role in

diversification strategies, particularly during periods of market stress when traditional asset correlations tend to converge.

Furthermore, the burgeoning body of empirical research exploring cryptocurrencies' portfolio implications reinforces the notion of BTC as a diversification instrument. Guesmi, Saadi, Abid, and Ftiti (2019) demonstrate through a dynamic conditional correlation analysis that the inclusion of BTC in mixed-asset portfolios can indeed enhance risk-adjusted returns, underscoring its utility in achieving a more efficient portfolio frontier. Similarly, Dyhrberg (2016) draws parallels between BTC and gold, noting BTC's capacity to act as a hedge against stock market movements and financial uncertainty, further attesting to its diversification benefits.

Despite BTC’s potential as a diversification tool, it is imperative to acknowledge the associated risks, notably its price volatility and regulatory uncertainties. However, the strategic allocation of BTC, even in minimal proportions within a portfolio, can contribute to diversification benefits without disproportionately amplifying the portfolio’s risk profile (Shahzad et al., 2019). This delicate balance between risk and diversification underscores the importance of comprehensive portfolio management strategies that consider the unique attributes and risk factors of including assets like BTC.

Bitcoin as a Hedging Tool

The empirical findings of BTC's insignificant correlation and lack of volatility spillovers with traditional financial markets illuminate its potential as a diversification tool and foreground its viability as a hedging instrument against market uncertainties. This section delves into the theoretical underpinnings and empirical evidence supporting BTC's role in hedging strategies, emphasizing its utility in mitigating risks associated with traditional asset fluctuations.

Hedging, a cornerstone of modern investment strategies, involves taking a position in one asset to offset potential losses in another, thereby reducing the overall risk of portfolio volatility. The principle of hedging aligns with Markowitz's (1952) portfolio theory, which posits diversification as a means to achieve more stable returns over time. BTC's emergence as a digital asset with unique properties has prompted scholars and practitioners to explore its hedging capabilities against traditional market instruments.

The non-correlation of BTC with mainstream financial assets like the S&P 500 and government bonds is particularly noteworthy in the context of hedging. Bouri et al. (2017) have documented BTC's effectiveness as a hedge against fluctuations in stocks and commodities markets, attributing this capability to its distinct market dynamics and investor base. Furthermore, Dyhrberg (2016) draws parallels between BTC and gold, one of the quintessential hedging tools, suggesting that BTC can similarly serve as a "digital gold" in providing protection against currency and stock market risks.

Recent studies have expanded on this premise, examining BTC's hedging properties during periods of financial turmoil. Corbet et al. (2018) found that BTC exhibited hedging capabilities during specific episodes of economic uncertainty, though its effectiveness can vary across different temporal and geopolitical contexts. This variability underscores the importance of strategic deployment of BTC within investment portfolios, where its role as a hedge needs to work against prevailing market conditions and for investor risk profiles.

The nuanced understanding of BTC's hedging potential is further enriched by its speculative nature, which, while contributing to its price volatility, also decouples its performance from that of traditional financial assets (Glaser et al., 2014). This decoupling is central to BTC's utility as a

hedging tool, as it allows investors to safeguard their portfolios against market-specific shocks that might adversely impact traditional asset classes.

Investment strategies incorporating BTC for hedging purposes must, however, navigate its high volatility and the regulatory uncertainties surrounding cryptocurrencies. The risk management framework within which BTC is deployed should account for these factors, adopting a dynamic allocation approach that can adapt to changing market conditions and regulatory landscapes (Yermack, 2015).

Policies and Regulations in the Crypto Market

The regulatory landscape about cryptocurrencies, and BTC in particular, has been rapidly evolving and has had a noticeable impact on the performance of BTC. The introduction of new regulations, specifically those targeting taxation of crypto transactions, may indeed heighten the spillover risks from traditional financial markets to the crypto market. Recent actions by global standard-setters, such as the Financial Stability Board and the Financial Action Task Force (FATF), reflect a push towards more robust policy frameworks at a global level. These bodies have emphasized the need for regulations that could provide clarity and reduce the risks associated with crypto assets (PwC, 2023). With the European Union moving towards finalizing new markets in crypto-assets regulation, we observe a trend towards the establishment of formal regulatory policies surrounding cryptocurrencies.

In the United States, the regulatory environment remains in flux, with the Securities and Exchange Commission (SEC), Commodities Futures Exchange Commission (CFTC), and the Internal Revenue Service (IRS) having different interpretations of how cryptocurrencies should be classified and regulated. The SEC treats cryptos as securities, the CFTC views them as

commodities, while the IRS considers them taxable assets. Additionally, transactions involving cryptocurrencies above a certain threshold require reporting to the IRS, as part of the Treasury Department's efforts to curb illegal activities (Thomson Reuters, 2021).

These developments suggest that as cryptocurrencies become more regulated and more aligned with traditional financial oversight mechanisms, the potential for spillover risks could increase. The rationale is that as BTC becomes subject to similar regulatory scrutiny as traditional financial assets, its behavior might start to resemble those assets more closely. This could lead to a scenario where shocks in traditional markets could have more pronounced effects on BTC, changing its previously observed behavior as an uncorrelated asset.

Therefore, while regulations may bring stability and legitimacy to the crypto market, they could also lead to increased interconnectedness with traditional financial markets. This increased correlation could reduce BTC's effectiveness as a diversification tool and increase the spillover of risks between these markets. Investors and regulators alike will need to closely monitor these trends to effectively manage potential risks.

Conclusion

This thesis has systematically explored the intricate dynamics between BTC and traditional financial markets, specifically examining its correlation and volatility spillovers with the S&P 500 and S&P 500 government bonds. The empirical findings show a pronounced non-correlation between BTC and these conventional asset classes, underscoring BTC's distinctive market behavior and its potential role as both a diversification and hedging tool within modern investment portfolios.

The theoretical and empirical analyses presented herein contribute to the burgeoning field of financial economics by providing a nuanced understanding of BTC's position within the broader financial market ecosystem. The evidence of BTC's insignificant risk and return relationships with traditional financial assets, coupled with its unique volatility profile, offers compelling insights into its capacity to enhance portfolio diversification and mitigate specific financial risks. This thesis underscores the importance of considering digital assets in contemporary investment strategies, highlighting the evolving nature of asset allocation in the face of technological advancements and market innovation.

Moreover, these findings invite a reevaluation of traditional financial theories and models, challenging scholars and practitioners alike to integrate the dynamics of cryptocurrencies into their analytical frameworks. As the financial landscape continues to evolve, the inclusion of BTC and other digital assets will necessitate a more adaptable and nuanced approach to portfolio management, risk assessment, and regulatory oversight.

Future research should aim to further elucidate the complex interactions between digital assets and traditional financial instruments, exploring the conditions under which BTC can serve as an effective hedge against economic uncertainties. Additionally, longitudinal studies would

provide valuable insights into the long-term implications of incorporating digital assets into diversified portfolios, particularly in the context of changing regulatory environments and technological advancements.

In sum, this thesis enhances our understanding of BTC's role within financial markets and sets the stage for continued exploration into the integration of digital assets into traditional investment paradigms, contributing to a more resilient and dynamic financial system.

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Appendix A: Variable Definitions

This appendix delineates the methodology employed for variable computation integral to the primary analyses. The calculation of returns is predicated upon the delineation of a trading day, which conforms to the standard trading hours of the stock market, spanning from 9:30 AM to 4:00 PM EST. Moreover, the closing price is established as of 4:00 PM EST on the respective day.

Variable	Definition
btc_returns	Simple returns of BTC, calculated by taking the adjusted close price divided by the opening price minus one
spy_returns	Simple returns of S&P 500, calculated by taking the adjusted close price divided by the opening price minus one
bond_returns	Simple returns of S&P 500 Government Bond Index, calculated by taking the adjusted close price divided by the opening price minus one
BTC	Volatility series of BTC's GARCH, calculated by taking the first difference of BTC's GARCH data
spy_vol_diff	Volatility series of SPY's GARCH, calculated by taking the first difference of SPY's GARCH data
GBI	Volatility series of S&P 500 Government Bond Index's GARCH, calculated by taking the first difference of its GARCH data

Appendix B: Models' Results from Python

Figure 1: Summary of Regression Results for BTC's and SPY's VAR Return Relationship Model in Python.

The VAR(2) model analysis on BTC (BTC) and S&P 500 (SPY) returns from 2020 to 2024 reveals a statistically significant inverse relationship between lagged SPY returns and current BTC returns at lag 1 (p-value: 0.012).

Summary of Regression Results

Metric	Value
Model	VAR
Method	OLS
Date	Tue, 09 Apr 2024
Time	15:28:30
No. of Equations	2.00000
Nobs	988.000
Log likelihood	-4348.90
BIC	3.19748
HQIC	3.16678
FPE	23.2878
AIC	3.14793
Det(Omega_mle)	23.0539

Results for equation btc_returns

Variable	Coefficient	Standard Error	t-stat	Prob
const	0.211360	0.119247	1.772	0.076
L1.btc_returns	0.040059	0.034481	1.162	0.245
L1.spy_returns	-0.231661	0.092180	-2.513	0.012
L2.btc_returns	-0.013884	0.034481	-0.403	0.687
L2.spy_returns	0.153288	0.091947	1.667	0.095

Results for equation: spy_returns

Variable	Coefficient	Standard Error	t-stat	Prob
const	0.063061	0.044434	1.419	0.156
L1.btc_returns	-0.000800	0.012848	-0.062	0.950
L1.spy_returns	-0.160449	0.034348	-4.671	0.000
L2.btc_returns	0.007416	0.012848	0.577	0.564
L2.spy_returns	0.081137	0.034262	2.368	0.018

Figure 2: Summary of Regression Results for BTC's and S&P Global Government Bond Index's VAR Return Relationship Model in Python.

The VAR(2) model analysis for BTC (BTC) and S&P Global Government Bond index returns from 2020 to 2024 provides a detailed examination of the interaction between these two assets over the specified period. As seen from the results, there are no significant lags for the return relationship between BTC and Bond returns.

Summary of Regression Results

Metric	Value
Model	VAR
Method	OLS
Date	Tue, 09 Apr 2024
Time	21:58:13
No. of Equations	2.00000
Nobs	988.000
Log likelihood	-3021.49
BIC	0.510420
HQIC	0.479712
FPE	1.58545
AIC	0.460868
Det(Omega_mle)	1.56952

Results for equation: btc_returns

Variable	Coefficient	Standard Error	t-stat	Prob
const	0.207976	0.119809	1.736	0.083
L1.btc_returns	0.001387	0.031885	0.044	0.965
L1.bond_returns	-0.266797	0.356995	-0.747	0.455
L2.btc_returns	0.015537	0.031849	0.488	0.626
L2.bond_returns	0.131660	0.356139	0.370	0.712

Results for equation: bond_returns

Variable	Coefficient	Standard Error	t-stat	Prob
const	-0.010484	0.010664	-0.983	0.326
L1.btc_returns	0.000443	0.002838	0.156	0.876
L1.bond_returns	-0.031626	0.031777	-0.995	0.320
L2.btc_returns	0.004300	0.002835	1.517	0.129
L2.bond_returns	-0.096942	0.031700	-3.058	0.002

Figure 3: Summary of Regression Results for BTC's and SPY's risk relationship VAR model in Python.

The VAR(2) model analysis on the first difference GARCH series for BTC and SPY from 2020 to 2024 demonstrates how past volatility changes influence current volatility in both series. Notably, the model reveals significant lagged effects: L3.spy_vol_diff's impact on BTC with a p-value of 0.002, and L2.BTC's influence on spy_vol_diff with a p-value below 0.05 at 0.000.

Summary of Regression Results

Metric	Value
Model	VAR
Method	OLS
Date	Tue, 09 Apr 2024
Time	12:16:27
No. of Equations	2.00000
Nobs	987.000
Log likelihood	1194.83
BIC	-8.02703
HQIC	-8.05776
FPE	0.000310720
AIC	-8.07662
Det(Omega_mle)	0.000307596

Results for equation: BTC

Variable	Coefficient	Standard Error	t-stat	Prob
const	-0.002889	0.006120	-0.472	0.637
L1.BTC	0.010634	0.032912	0.323	0.747
L1.spy_vol_diff	0.055267	0.066160	0.835	0.404
L2.BTC	-0.000197	0.033014	-0.006	0.995
L2.spy_vol_diff	0.088617	0.065829	1.346	0.178

Results for equation: spy_vol_diff

Variable	Coefficient	Standard Error	t-stat	Prob
const	-0.003064	0.003008	-1.018	0.308
L1.BTC	0.043901	0.016179	2.713	0.007
L1.spy_vol_diff	-0.030530	0.032524	-0.939	0.348
L2.BTC	0.064939	0.016229	4.001	0.000
L2.spy_vol_diff	0.067857	0.032361	2.097	0.036

Figure 4: Summary of Regression Results for BTC's and GBI's Risk Relationship VAR Model in Python.

In the VAR(2) model analyzing BTC's and GBI's GARCH volatility series from 2020 to 2024, impulse response functions reveal that significant volatility spillovers occur at specific lags. Lagged Bond volatility data does not have any significant impact on BTC volatility. Conversely, Bond volatility shows significant responses to BTC volatility shocks at lag 2 ($p = 0.035$).

Summary of Regression Results

Metric	Value
Model	VAR
Method	OLS
Date	Tue, 09 Apr 2024
Time	22:00:29
No. of Equations	2.00000
Nobs	987.000
Log likelihood	2523.81
BIC	-10.7200
HQIC	-10.7507
FPE	2.10293e-05
AIC	-10.7696
Det(Omega_mle)	2.08178e-05

Results for equation: BTC

Variable	Coefficient	Standard Error	t-stat	Prob
const	-0.003353	0.006121	-0.548	0.584
L1.BTC	0.018782	0.031887	0.589	0.556
L1.GBI	-0.004041	0.258448	-0.016	0.988
L2.BTC	0.013229	0.031909	0.415	0.678
L2.GBI	0.018935	0.257739	0.073	0.941

Results for equation: GBI

Variable	Coefficient	Standard Error	t-stat	Prob
const	-0.000242	0.000756	-0.320	0.749
L1.BTC	0.006376	0.003940	1.618	0.106
L1.GBI	0.053271	0.031931	1.668	0.095
L2.BTC	0.008335	0.003942	2.114	0.035
L2.GBI	0.014706	0.031844	0.462	0.644

Figure 5: IRFs' Charts for the Return Relationship between BTC and S&P 500 for 15 trading days

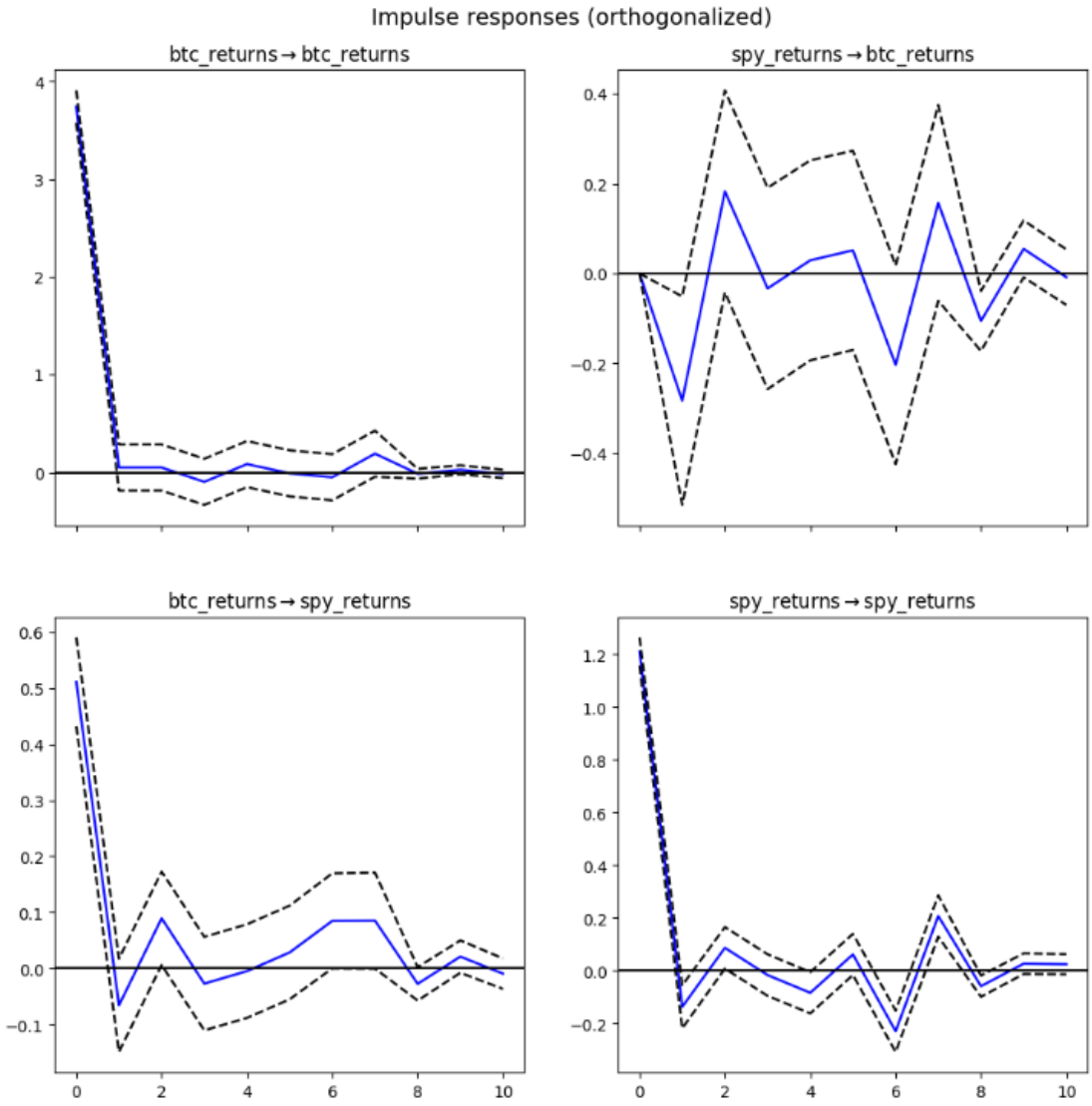


Figure 6: IRFs' Charts for the Return Relationship between BTC and S&P 500 Government Bond Index

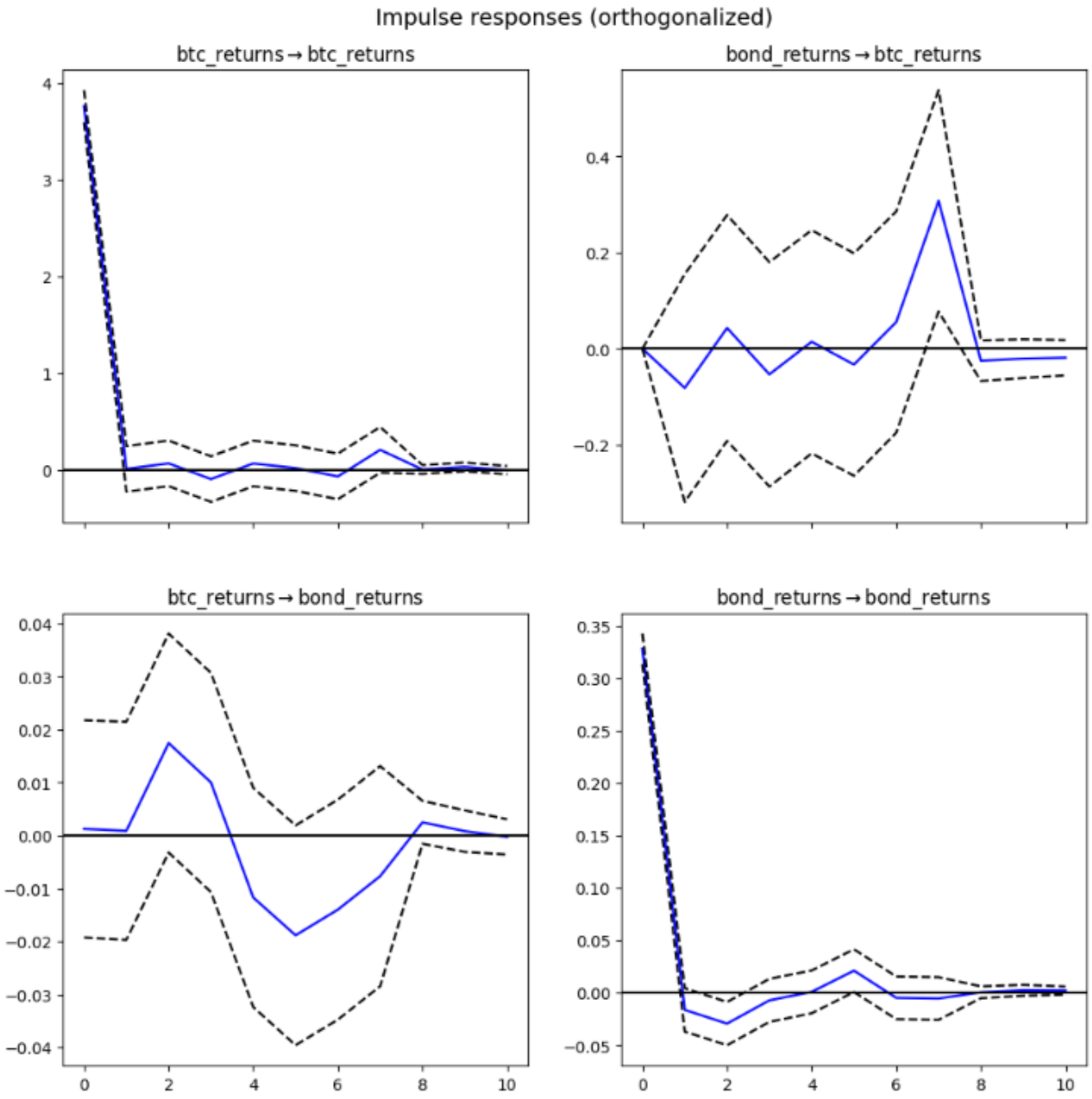


Figure 7: IRFs' Charts for the Risk Relationship between BTC and S&P 500

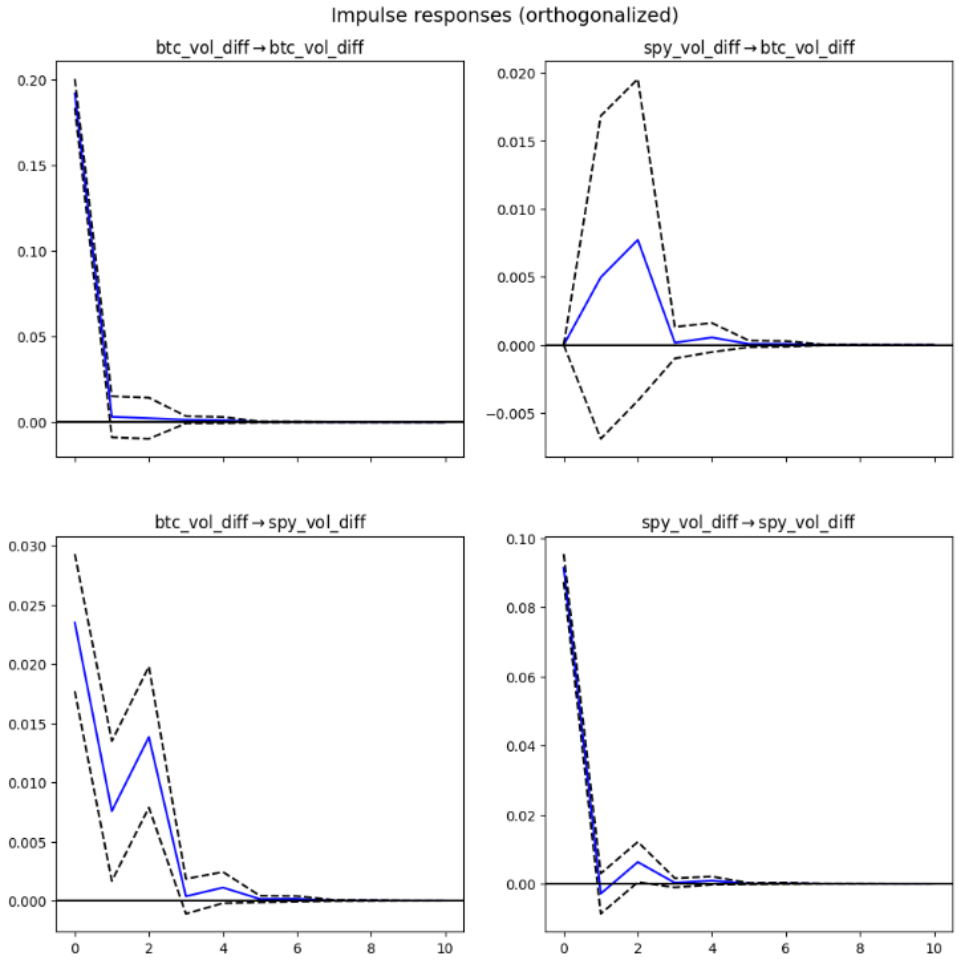
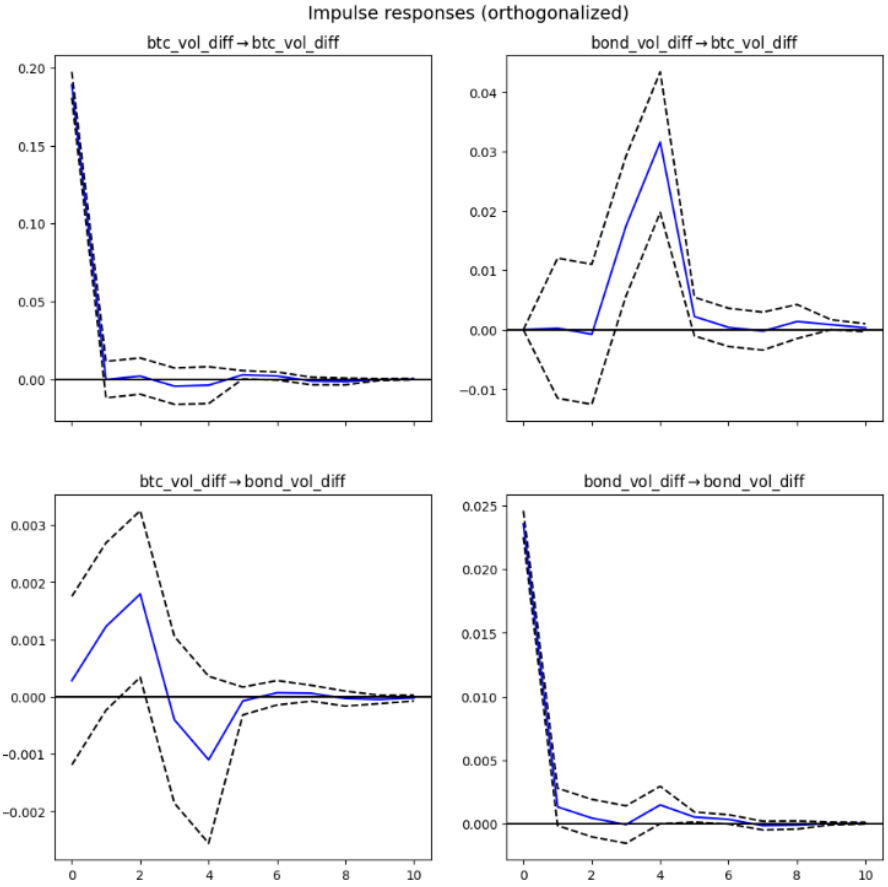


Figure 8: IRFs' Charts for the Risk Relationship between BTC and S&P 500 Government Bond Index



Appendix C: Analysis of Meme Stocks' Return Relationships, Risk Relationships, and Correlation with BTC.

To figure out which meme stock BTC has the most pronounced risk and return relationships with, we gathered 9 different popular meme stocks by using ChatGPT and Bing to browse Reddit and Twitter. The meme stocks' list includes AMC Entertainment Holdings (AMC), BlackBerry Limited (BB), GameStop Corp. (GME), Virgin Galactic Holdings Inc. (SPCE), Rivian Automotive Inc. (RIVN), Palantir Technologies Inc. (PLTR), SoFi Technologies Inc. (SOFI), and Tesla Inc. (TSLA). Using the same methodology stated for this thesis, we explore whether meme stocks have more pronounced risk and return relationships with BTC than SPY and S&P Global Government Bond Index. The results show that, despite having a higher correlation with BTC, meme stocks largely do not receive significant impacts from BTC's market movement. For the purpose of consistency, we use VAR(2) model to conduct our analysis.

Return Relationship Analysis Findings

Variable	Significant Lag
AMC	None
BB	None
GME	Lag 2 (BTC to GME)
SPCE	None
RIVN	None
PLTR	None
SOFI	None
TSLA	BTC to TSLA: Lag 2 TSLA to BTC: Lag 1

Risk Relationship Analysis Findings

Variable	Significant Lag
AMC	None
BB	BTC to BB: Lag 2
GME	GME to BTC: Lag 1
SPCE	None
RIVN	None
PLTR	None
SOFI	None
TSLA	None

Correlation with BTC Returns

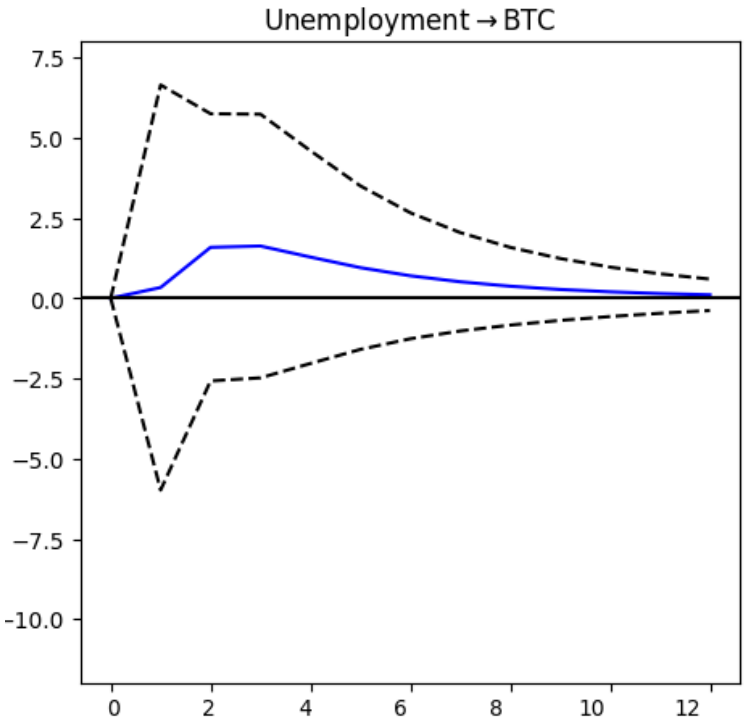
Stock	Correlation
AMC	0.07
BB	0.18
GME	0.10
SPCE	0.24
RIVN	0.22
PLTR	0.24
SOFI	0.24
TSLA	0.31

Appendix D: BTC Returns' Relationship with Macro Indicators, including Unemployment Rate, Federal Funds Rate, and Inflation Rate

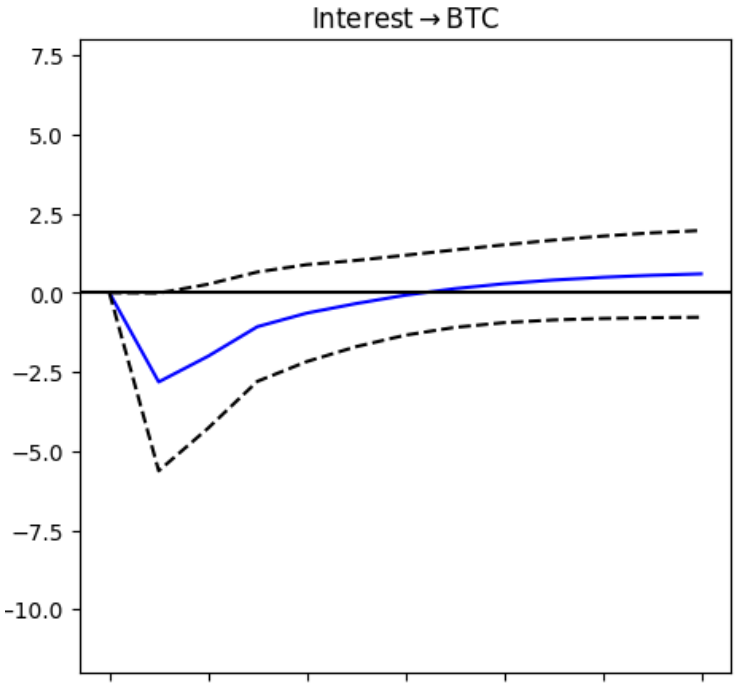
Results of VAR(2) models:

Variable	**Significant lags**
Fed Fund Rate (FFR)	FFR to BTC: Lag 1 and Lag 2
Unemployment	Unemployment to BTC: None
Inflation	Inflation to BTC: None

IRF Graph: Unemployment Rate's Shock to BTC Returns



IRF Graph: FFR's Shock to BTC Returns



IRF Graph: Inflation's Shock to BTC Returns