School of Economics and Management

Bitcoin spot ETF approval: Correlation, diversification and risk-return effects.

Master Thesis Finance

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1. Introduction

In less than two decades, Bitcoin has evolved from an obscure digital asset into a financial instrument held and traded by some of the world's largest companies and institutions. A defining moment in this evolution was the approval of spot Bitcoin exchange-traded funds (ETFs) by the U.S. Securities and Exchange Commission (SEC) on January 10, 2024. This is a major development as it allows investors to gain direct exposure to Bitcoin through a regulated financial instrument. It marks Bitcoin's deeper integration into the financial system.

Historically, Bitcoin has shown low or even negative correlations with traditional asset classes such as equities and bonds, making it attractive for diversification purposes (Brière et al., 2015). However, the approval of spot ETFs is expected to expand Bitcoin's investor base, particularly among institutional investors, as it allows easy exposure to Bitcoin without relying on exchanges vulnerable to cyberattacks (Babalos et al., 2025). As institutional investments grow, Bitcoin will likely become more sensitive to the same macroeconomic variables that drive traditional assets, potentially increasing its correlation with them. Gorman & Hughen (2024) outline a similar reasoning: "if the same institutions and investors are involved in both cryptocurrency and traditional markets, we should expect shocks which hit those investors to be reflected in both markets", thereby increasing correlations. From the perspective of modern portfolio theory (Markowitz, 1959), higher correlations between Bitcoin and other assets would reduce its beneficial effect on the efficient frontier, as its ability to lower portfolio variance declines. This shift may have an impact on Bitcoin's historically high diversification benefits and its role in optimal portfolios for both retail and institutional investors.

While past correlations and diversification benefits of Bitcoin are well researched, no research has yet examined how the approval of Bitcoin spot ETFs has affected Bitcoin's correlations, risk, return, and diversification benefits. This study contributes to the literature by performing correlation and efficient frontier analyses to fill this gap. By comparing Bitcoin's risk-return trade-off and portfolio diversification properties in the pre- and post-ETF, this research informs both retail and institutional investors about Bitcoin's role as a diversifier in a post-ETF environment.

To fill the gap in literature, this study examines two interrelated hypotheses. The first hypothesis states that the approval of Bitcoin spot ETFs increased the correlation between Bitcoin and traditional assets such as stocks and bonds. This hypothesis aims to confirm the reasoning that Bitcoin's further integration into traditional markets through the ETF approval

leads to increased correlations of Bitcoin with traditional assets. The second hypothesis states Bitcoin's beneficial role within portfolios reduced. This hypothesis informs investors about implications of the ETF approval for portfolio optimization. To test the first hypothesis, the study uses a structural break test. And for the second hypothesis, an efficient frontier comparison is used. The following paragraphs explain these empirical tests in more detail.

First, a nonparametric break test developed by Wied et al. (2012) is applied to detect significant changes in the correlation between Bitcoin and traditional assets around the ETF approval dates. This test is conducted for Bitcoin-equities and Bitcoin-bonds correlations in the U.S., Canada, and Germany. The test does not require prior knowledge of when a structural break may occur; it identifies the most plausible break date itself, making it well suited for this purpose. Additionally, the test is robust to non-normality and heteroskedasticity, which are common in financial return series (Wied et al., 2012).

Second, to translate correlation changes into portfolio implications, an efficient frontier comparison following Markowitz (1959) is conducted. The analysis includes four efficient frontiers: a bond + equity only frontier, a pre-ETF frontier, a post-ETF frontier, and a hybrid frontier. The hybrid frontier is constructed with post-ETF returns and volatilities but pre-ETF correlations. These frontiers visually show the benefit of Bitcoin-inclusive portfolios, the pre- versus post-ETF comparison, and the hybrid versus post-ETF comparison. The hybrid-post-ETF comparison isolates the effect of changed correlations. This framework offers an intuitive way to show how asset correlations affect portfolio diversification. In addition to the visual insight, a bootstrap test proposed by Ledoit and Wolf (2008) is used to test whether the Sharpe ratio of the hybrid frontier is statistically different from the post-ETF frontier.

For this analysis, daily return data from January 20, 2018 to May 29, 2025 are used. Daily data are used to pinpoint breaks in correlations more precisely to specific dates. The dataset includes daily returns for Bitcoin (represented by the Bitcoin spot price), U.S. equities (represented by the S&P 500 Total Return Index), and U.S. bonds (represented by the ICE BofA 7-10 year U.S. Treasury Index). The analysis primarily focuses on the impact of Bitcoin spot ETFs in the U.S. To ensure the results are ETF-driven rather than country-specific events, Canada and Germany are also included. In these countries, Bitcoin spot ETFs were approved at different points in time under varying economic conditions. However, although this strengthens the results, investors are not restricted to their domestic markets, which could partly blur the country-specific effects of the ETF approval. Thus, the dataset also includes Canadian equities

(represented by the S&P/TSX Composite Total Return Index), Canadian bonds (represented by the ICE BofA 7-10 year Canada Government Index), German equities (represented by the Deutsche Boerse DAX Index), and German bonds (represented by the ICE BofA 7-10 year German Government Index). The sample period was chosen to provide sufficient data before and after the ETF approval for each country. It starts in January 2018, as ICE BofA bond data begins then. All data were downloaded via Refinitiv Workspace. Lastly, the risk-free rate (represented by the Daily U.S. Treasury Bill rate) from the Kenneth and French data library is included for the Sharpe ratio bootstrap test.

The empirical results offer insights into Bitcoin's evolving role within investment portfolios. First, the structural break test reveals a statistically significant shift in the correlation between Bitcoin and U.S. equities at the 1% significance level. However, the break date between Bitcoin and U.S. equities do not match the ETF approval date. Instead, they coincide with the onset of the COVID-19 crisis. Similarly, the structural break test reveals a statistically significant shift in correlation between Bitcoin and German bonds at the 5% significance level, but the break date coincides with a period of central banks raising interest rates rather than the ETF approval. When examining pre- and post-ETF correlations specifically, modest increases are observed for four of the six Bitcoin-asset pairs. Only BTC-U.S. bond and BTC-German equities exhibit a modest decrease. The magnitudes of these changes are small and statistically insignificant, suggesting that the impact of the ETF approval on Bitcoin's co-movement with traditional assets remains limited.

Secondly, the efficient frontier analysis reveals several findings. First, Bitcoin exhibits higher average returns and lower volatility post-ETF compared to pre-ETF, indicating an improved risk-return profile. Second, when comparing the hybrid frontier to the post-ETF frontier, the post-ETF frontier is marginally less efficient. The hybrid frontier, constructed with post-ETF returns and volatilities but pre-ETF correlations, shows Bitcoin's ability to shift the efficient frontier outward has slightly decreased as a result of modestly increased correlations. Third, all portfolios, including Bitcoin outperform equity + bond only portfolios, underscoring Bitcoin as a meaningful diversifying asset. Finally, the bootstrap test of Sharpe ratio differences reveals that the visually observed reduction in diversification benefits due to increased correlations is statistically insignificant. Economically, this implies that while Bitcoin's correlation with traditional assets may have risen slightly after the ETF approval, the effect is too small to meaningfully change optimal portfolio allocations in the short run.

These findings, although statistically insignificant, contribute to the literature on Bitcoin as a diversifying asset. Foundational work by Brière et al. (2015) documented that Bitcoin provided strong diversification benefits in its early years. Analyzing a sample period spanning from 2010 to 2013, they report low, sometimes even negative correlations between Bitcoin and traditional asset, which significantly improved the efficient frontier and Sharpe ratios of diversified portfolios. The results of this thesis partly confirm their conclusions. Even in a more mature market from 2018 to 2025, Bitcoin continues to enhance portfolio efficiency relative to a portfolio including only equities and bonds. However, while Brière et al. (2015) observed Bitcoin to be almost uncorrelated with other assets, this study finds correlations between Bitcoin and traditional assets have increased. Worldwide adoption of Bitcoin likely integrates it more closely with traditional financial markets, increasing correlations over time. The approval of Bitcoin spot ETFs can be seen as an important step toward further adoption, although its direct impact on correlations appears minimal.

A more recent study by Babalos et al. (2025) examines the impact of U.S. Bitcoin spot ETF approvals on Bitcoin's return and volatility. Their findings indicate that Bitcoin's return increased while its volatility decreased after the ETF approval, suggesting ETFs elevate returns while also enhancing stability. The results of this thesis are consistent with these findings: the post-ETF period exhibits higher daily average returns (0.2476% vs. 0.1515%) and lower volatility (2.9737% vs. 4.0367%). While both studies show Bitcoin's risk-return profile became more attractive, this study extends the analysis to portfolio-level implications. It shows that despite improved individual performance, Bitcoin's diversification benefits within traditional portfolios decreases slightly due to modestly increased correlations after the ETF approval. Therefore, this study adds to the literature by clarifying Bitcoin's diversification benefits in a more mature stage and by providing evidence on the impact of the Bitcoin spot ETFs on these benefits.

In conclusion, this thesis finds that the approval of U.S. Bitcoin spot ETFs has not led to significant changes in Bitcoin's correlation with traditional assets, although it appears to be a factor in enhancing Bitcoin's risk-return profile. The main lesson is that Bitcoin continues to meaningfully improve portfolio efficiency post-ETF relative to equity-bond portfolios, with its contribution driven more by improved performance than by persistently low correlations.

The remainder of the thesis is organized as follows. Section 2 summarizes related literature. Section 3 describes the data. Section 4 develops the hypotheses. Section 5 explains the methodology. Section 6 presents the empirical results. Section 7 concludes.

2. Literature Review

This literature review aims to give an overview of existing research on the diversification benefits of Bitcoin and to indicate the gap in existing literature this study aims to address. The literature review is split into three sections. First, section 2.1 examines the role of Bitcoin as a portfolio diversifier. Second, section 2.2 describes the correlation dynamics of Bitcoin. Third, section 2.3 discusses the impact of the Bitcoin spot ETFs approval.

2.1 Bitcoin as a portfolio diversifier: historical evidence

Satoshi Nakamoto created Bitcoin as a digital cash system enabling online payments to be sent directly from one party to another without going through a financial institution (Nakamoto, 2008). However, "users buying Bitcoin for the first time are likely to keep these Bitcoins in their exchange wallet for speculation purposes and do not have the intention to use these acquired Bitcoins for paying goods or services" (Glaser et al., 2014). As users use Bitcoin as an investment, rather than a payment method, research explored Bitcoin's role within investment portfolios.

One foundational study is by Brière et al. (2015), who analyze Bitcoin investments from the standpoint of a U.S. investor holding a diversified portfolio consisting of both traditional assets (namely stocks, bonds, and currencies) and alternative assets (namely commodities, hedge funds and real estate). First, they find Bitcoin exhibits a low correlation with other assets over the sample period being 2010-2013, which suggests Bitcoin offers diversification benefits for investment portfolios. Additionally, using mean-variance spanning tests, which determines whether adding an asset improves a portfolio's investment opportunities, Brière et al. (2015) found a second important result: Bitcoin significantly spans all three portfolios considered (being only traditional assets, only alternative assets, and both). A third finding indicates that adding Bitcoin dramatically improves the Sharpe ratio and the efficient frontier. All in all, the paper concludes that even a small allocation of Bitcoin in a well-diversified portfolio may dramatically improve risk-return characteristics.

Kajtazia and Moro (2019) also explored the role of Bitcoin in well diversified portfolios in a sample period spanning from February 2012 until January 2017. Apart from the U.S., this study adds to Brière et al. (2015) as it also explores the portfolio diversification benefits for European and Chinese markets. Similarly to Brière et al. (2015), they find portfolio performance in terms

of risk-return trade-off to improve. An important nuance mentioned is that including Bitcoin in a portfolio improves returns, but it also tends to increase portfolio volatility, therefore the benefit of including Bitcoin comes from the return that compensates for the increase in portfolio risk. For the above-mentioned results, no major differences in Bitcoin's role were found between the U.S., Europe, and China, indicating Bitcoin behaves similarly across countries.

These papers do, however, report some limitations and doubt especially around the relatively early sample periods. Brière et al. (2015) make the note that their results should be taken with caution as Bitcoin is new and the data might be subject to early-stage behavior that may not continue in the future. And Kajtazia and Moro (2019) conclude that the benefit of Bitcoin's inclusion in portfolios is mainly linked to a single period being 2013 in which Bitcoin's value showed a big increase. Although more recent studies, such as Bakry et al. (2021), also find that Bitcoin offers diversification benefits, this study addresses the limitations of earlier work by using the most recent sample period (January 2018 to May 2025). This allows to examine whether Bitcoin's diversification benefits still hold when using more recent data. The results of this study show that Bitcoin continues to offer diversification benefits, similar to the findings of the foundational studies. In Figure 3 it is clearly visible that all Bitcoin-inclusive efficient frontiers lie entirely to the left of the equity-and-bond only frontier, similar to Brière et al. (2015), where the BTC (Bitcoin)-inclusive frontier is much steeper than the BTC-free frontier. All in all, the reported results suggest Bitcoin is an asset that can be used for meaningful portfolio diversification and performance improvement.

2.2 Correlation Dynamics of Bitcoin

Although Bitcoin historically demonstrates low correlation with traditional assets and valuable diversification benefits, such properties are not fixed and may change under different market conditions. Erb et al. (1994) examined cross-equity correlations in G7 countries and demonstrated that correlations between equities tend to rise during periods of market stress, peaking particularly during recessions. Similarly, more recent research suggests that these dynamics also apply to Bitcoin's correlation with other assets. Nguyen (2022) found the S&P 500 and Bitcoin become more correlated during periods of heightened uncertainty, using two complementary tests. First, using a quantile regression analysis, Nguyen showed that the co-movement between Bitcoin and equity returns intensifies during periods of uncertainty, especially during the COVID-19 crisis. Secondly, Nguyen analyzed how stock market shocks

spilled over into Bitcoin's volatility by using a VAR(1)-GARCH(1,1) spillover model. This revealed a volatility spillover effect from the stock market to Bitcoin during COVID-19 and other periods of high uncertainty. The results from this thesis support this, as the pre-structural-break correlation between for example U.S. equity and Bitcoin is 0.035, while the post-structural-break correlation, likely triggered by COVID-19, is 0.385. It is reasonable to make this conclusion, as all structural break dates for BTC-equity pairs occur at the onset of the COVID-19 crisis. Additionally, studies such as Gorman and Hughen (2024) also find a structural break between BTC and equities during the COVID-19 crisis.

In addition to increasing correlations during periods of distress, worldwide adoption of Bitcoin leads to overlap with traditional assets and integration into mainstream markets, potentially impacting Bitcoin's correlation with other assets. Gorman and Hughen (2024) argue retail and institutional investors have become more involved in the cryptocurrency market. One of the reasons for this increased involvement are events that offered further access to cryptocurrency exposure. Examples include Micro Bitcoin futures contracts introduced by the (Chicago Mercantile Exchange) CME, the stock listing of cryptocurrency exchange Coinbase, and the approval of the Bitcoin spot ETFs. This integration between traditional and cryptocurrency markets could have important implications for Bitcoin. As Gorman and Hughen (2024) explain: "If the same institutions and investors are involved in both cryptocurrency and traditional markets, then we should expect shocks which hit those investors to be reflected in both markets and reduce diversification benefits." This study aims to provide evidence for this reasoning by exploring the effects on the correlation and diversification properties of Bitcoin with regard to a macroeconomic event or so-called shock, being the ETF approval. This section highlights that Bitcoin's historical low correlations with traditional assets can increase in times of uncertainty or due to the growing integration and adoption of Bitcoin. This trend of growing integration and adoption could reduce Bitcoin's effectiveness as a portfolio diversifier.

2.3 Bitcoin ETFs approval and its impact

This study focuses on one specific event that aligns the investor base of traditional markets and the cryptocurrency market. This event is the approval of spot Bitcoin ETFs in the U.S. at January 10, 2024, marking a critical step in Bitcoin's financialization. Unlike the already existing futures-based ETFs, spot ETFs allow investors to gain direct exposure to Bitcoin through a regulated product. ETFs are not new; the first ETF was introduced in the 1990s. Literature explored what impact ETFs make, for example, Ben-David et al. (2018) examine if

ETFs increase volatility. They found that stocks with higher ETF ownership have significantly higher volatility. ETFs generally have low trading costs, attracting short-horizon liquidity traders who seem to impact the volatility. Apart from possible implications of non-Bitcoin related ETFs, recent literature also focuses on the implications of the Bitcoin spot ETF approval. Babalos et al. (2025) provide evidence on how the U.S. spot Bitcoin ETFs affected the returns and volatility of Bitcoin. Their analyses showed Bitcoin experienced a significant positive impact on its returns and a decrease in volatility. Similarly, this thesis also finds the return of Bitcoin increased, and the volatility decreased after the ETF approval. Although not tested for statistical significance, the differences seem convincing for this sample period, where the pre-ETF daily average return was 0.1515% compared to 0.2476% post-ETF, while the pre-ETF volatility was 4.0367% compared to 2.9737% post-ETF.

While early correlations and diversification benefits of Bitcoin are well researched, correlations tend to increase as worldwide adoption results in growing similarities in investor bases for traditional and cryptocurrency markets. The approval of the Bitcoin spot ETF could accelerate this trend as it brings in a lot of new capital, potentially further aligning the cryptocurrency investor base with that of traditional markets, leading to macroeconomic shocks being reflected in both markets. A realization of this trend potentially further pushes correlations to higher levels, and therefore diminishing the historically high diversification benefits. However, current literature lacks investigations into how the Bitcoin spot ETF approval affects Bitcoin's properties in investment portfolios. This is crucial for investors and therefore a critical gap. This study aims to fill this gap by examining the correlations, risk-return trade-off, and diversification benefits of Bitcoin pre and post-ETF.

3. Data

This thesis focuses on whether the role of Bitcoin within investment portfolios has changed by comparing the pre- and post-ETF periods. To answer this, daily return data for Bitcoin and traditional asset classes are used. Daily data are used, because it captures the short-term dynamics. This allows observation of immediate reactions to the ETF approval and enables precise identification of potential structural breaks in correlations around the approval dates.

The dataset contains daily return data of the U.S., Canada, and Germany. Canada and Germany are included to strengthen the analysis with cross-country evidence. These markets approved Bitcoin spot ETFs at different points in time under different macroeconomic conditions. If a reaction to the ETF approval is found in all three countries it's more likely the ETF caused this rather than other market-wide events. Daily returns are calculated as: (new closing price/old closing price) – 1. Table 1 informs on the dataset.

Table 1: Overview of assets in the dataset and their representation

Asset	Representation
Bitcoin	Bitcoin Spot Price
U.S. Equity	S&P 500 Total Return Index
U.S. Bond	ICE BofA 7-10 Year U.S. Treasury Index
CA Equity	S&P/TSX Composite Total Return Index
CA Bond	ICE BofA 7-10 Year Canada Government Index
GE Equity	Deutsche Boerse DAX Index
GE Bond	ICE BofA 7-10 Year German Government Index
Risk-Free Rate	Daily U.S. Treasury Bill Rate

This table provides an overview of all assets included in the analysis and their representations. Bitcoin is represented by its spot price, while traditional assets are represented by country-specific equity and bond indices. For the remainder of this paper, in all tables CA refers to Canada, while GE refers to Germany.

All data were obtained from Refinitiv Workspace, except the risk-free rate, which comes from the Kenneth French Data Library. The sample period spans from January 20, 2018 to May 29, 2025, ensuring sufficient data before and after the ETF approval date for each country. The sample period starts at January 20, 2018, as ICE BofA bond data begins then. For each test,

only dates with available data for all assets are included. That means weekends, national holidays, and other market closure days are excluded.

Table 2: Descriptive statistics of daily returns (%)

Asset	Obs.	Mean	Std. Dev	Skew	Kurt.
BTC	2,684	0.146%	3.536%	-0.313	8.383
U.S. Equity	1,848	0.055%	1.273%	-0.331	13.279
U.S. Bond	1,830	-0.006%	0.449%	0.129	2.182
CA Equity	1,845	0.043%	1.041%	-1.048	36.316
CA Bond	1,828	-0.004%	0.418%	0.155	1.811
GE Equity	1,866	0.039%	1.228%	-0.414	12.064
GE Bond	1,872	-0.010%	0.383%	0.574	5.800

This table reports summary statistics for the daily returns of Bitcoin, equities, and bonds across the U.S., Canada, and Germany. For each asset, the table provides the number of observations, mean return, standard deviation, skewness, and kurtosis.

The descriptive statistics in Table 2 show that BTC offers a high average daily return (0.146%) making it an interesting asset for investors. However, investing in BTC comes with a lot of volatility, indicated by BTC's high standard deviation (3.536%). Furthermore, the daily equity returns of U.S., Canada, and Germany all show a positive average daily return, with average daily returns of respectively 0.055%, 0.043%, and 0.039%. Remarkably, the average daily return of the U.S. is more than 0.015% higher than that of Germany, showing the outperformance of the S&P 500 relative to the DAX during this sample period. Additionally, it is notable that investing in U.S., Canadian, or German bonds resulted in negative average daily returns during this sample period. Lastly, the extremely high kurtosis of Canadian equity returns indicates a sharp peak and heavy tails, meaning there is an unusually high probability of extreme daily movements.

4. Hypotheses Development

This study investigates whether the approval of U.S. Bitcoin spot ETFs has altered the correlation, diversification benefits, and risk-return profile of Bitcoin in traditional investment portfolios. To examine this, two hypotheses are formulated.

Prior research shows that adding Bitcoin to a portfolio offers significant diversification benefits due to its low or even negative correlations with traditional asset classes (Brière et al., 2015). However, the approval of Bitcoin spot ETFs makes Bitcoin more accessible to investors. Easier accessibility attracts a broader range of investors, potentially increasing the overlap between participants in traditional and crypto markets. If investor bases become more aligned, market shocks are likely reflected in both markets, leading to greater integration and stronger co-movement between Bitcoin and traditional financial assets. This reasoning leads to the following hypothesis:

H1: The correlation between Bitcoin and traditional assets increased after the approval of Bitcoin spot ETFs.

This hypothesis will be tested using a nonparametric structural break test (Wied et al., 2012) to detect significant changes in the correlation between Bitcoin and traditional assets (equities and bonds) around the ETF approval dates.

From a modern portfolio perspective (Markowitz, 1959), higher correlations between Bitcoin and traditional assets would, all else equal, reduce the diversification benefits of a portfolio with those three assets. At the same time, changes in Bitcoin's own risk or return profile also affect portfolio efficiency. Nevertheless, Bitcoin's volatility and return are expected to remain similar post-ETF. Therefore, if Bitcoin's correlation with stocks and bonds increases, its ability to enhance portfolio efficiency is expected to decline. This leads to the following hypothesis:

H2: Bitcoin's beneficial role within portfolios reduced after the approval of Bitcoin spot ETFs.

This hypothesis will be visually examined with an efficient frontier analysis, comparing pre-ETF and post-ETF periods. Additionally, a bootstrap test of Sharpe ratio differences by Ledoit and Wolf (2008) provides statistical insight.

5. Methodology

This section presents the two main analytical methods used to answer the hypothesis. First, section 5.1 describes a test for structural breaks in correlations. Section 5.2 complements section 5.1 by outlining a cross-country validation of structural breaks in correlation. Second, section 5.3 describes the efficient frontier analysis. Section 5.4 adds to section 5.3 by providing statistical evidence.

5.1 Test for structural breaks in correlations

To evaluate whether the approval of Bitcoin spot ETFs has significantly changed Bitcoin's correlation with traditional asset classes, this study applies the nonparametric structural break test proposed by Wied et al. (2012). This method detects structural breaks in correlations between two assets, without a priori specification of the potential break date.

In this study, the analysis focuses on the correlation between Bitcoin and traditional asset classes: equities (represented by the S&P 500 total return index) and bonds (represented by the ICE BofA 7-10 year U.S. Treasury Index). Daily return data are used for all three assets, spanning from January 2018 to May 2025. Let X_t denote the daily return series of Bitcoin and Y_t the return series of either U.S. equities or bonds, where t = 1, … , T, represents all days in the sample. The approval of U.S. Bitcoin spot ETFs on January 10, 2024, is expected to be a trigger for a structural break in correlations. Statistical evidence of a break near this date would support hypothesis 1.

The test statistic proposed by Wied et al., is defined as:

$$Q_T(X,Y) = \widehat{D} \underbrace{max}_{2\leq j\leq T} \frac{\mathrm{j}}{\sqrt{T}} \left|\hat{\rho}_j - \hat{\rho}_T\right|$$

Where:

- $\hat{\rho}_j = \frac{\sum_{t=1}^{j}(X_t-\bar{X}_j)(Y_t-\bar{Y}_j)}{\sqrt{\sum_{t=1}^{j}(X_t-\bar{X}_j)^2} * \sqrt{\sum_{t=1}^{j}(Y_t-\bar{Y}_j)^2}}$ is the Pearson correlation from the start of the sample up to time j. With $\bar{X}$ and $\bar{Y}$ being the sample means of X and Y over the first j observations.

- $\hat{\rho}_T = \frac{\sum_{t=1}^{T}(X_t-\bar{X}_T)(Y_t-\bar{Y}_T)}{\sqrt{\sum_{t=1}^{T}(X_t-\bar{X}_T)^2} * \sqrt{\sum_{t=1}^{T}(Y_t-\bar{Y}_T)^2}}$ is the full sample Pearson correlation coefficient. With $\bar{X}$ and $\bar{Y}$ being the sample means of X and Y.
- $\frac{\mathrm{j}}{\sqrt{T}}$ is a weighting factor scaling down deviations at the beginning of the sample where the $\hat{p}_j$ are more volatile as they use fewer datapoints, this dampens the effect of early fluctuations.
- $\widehat{D}$ is a scalar needed for the asymptotic null distribution.
- T is the number of days in the sample period.

This process measures the absolute difference between the correlation estimate for the first j observations and the full-sample correlation. If this deviation gets too large it suggests that the correlation in the first j observations differs from the overall sample, indicating a possible structural break at that point.

Statistical significance of the potential structural break date is determined by comparing Q_t with critical values from the Kolmogorov distribution. If Q_t exceeds the critical value levels, the null hypothesis of constant correlations is rejected, indicating a significant structural break. Only when the break occurs around January 10, 2024, the hypothesis that the ETF approval increased Bitcoin's correlation with traditional assets is supported.

This test is performed twice. Once using Bitcoin and U.S. equities, and once using Bitcoin and U.S. bonds.

5.2 Cross-country validation of structural breaks in correlation

A potential limitation of the U.S.-focused analysis is that observed differences in correlation after the ETF approval might be driven by other events within the sample period rather than the ETF approval itself. To address this concern, the structural break analysis is extended to two additional countries, Canada and Germany, where Bitcoin spot ETFs were approved at different times under different macroeconomic conditions.

The same nonparametric structural break test of Wied et al. (2012) is applied to daily return data for Canada and Germany. By examining whether these other countries also exhibit a structural break in Bitcoin's correlation with traditional assets around their respective ETF approval dates, the conclusions based on the U.S. analysis can be more confidently attributed to the ETF approval rather than unrelated events. This approach strengthens, but does not confirm the conclusion as each country's market is accessible to all investors, which could partly blur the country-specific effects of the ETF approval.

For Canada, the analysis focuses on the two largest Bitcoin spot ETFs: the Purpose Bitcoin ETF (BTCC), approved on February 18, 2021, and CI Galaxy Bitcoin ETF (BTCX), approved on March 9, 2021. For Germany, the test is conducted for the ETC Group Physical Bitcoin (BTCE), approved on June 8, 2020. In both cases, a structural break in correlation around these ETF approval dates would provide supporting evidence for this study's first hypothesis.

5.3 Efficient frontier analysis

To evaluate the diversification benefits and risk-return trade-off of Bitcoin before and after the approval of Bitcoin spot ETFs, this study conducts an efficient frontier analysis based on the mean-variance optimization framework introduced by Markowitz (1959). This method allows for a direct comparison of the efficient frontier in both periods, thereby showing investors the practical implications of changes in Bitcoin's correlation with traditional assets. The efficient frontier represents a set of portfolios that deliver the highest expected return for a given level of risk.

For portfolio construction, the analysis considers three asset classes: Bitcoin (X1), U.S. equities (X2, represented by the S&P 500 index) and U.S. bonds (X3, represented by the ICE BofA 7-10 Year U.S. Treasury Index). Daily return data for each asset will be split into two periods: pre-ETF (January 2018 – January 9, 2024) and post-ETF (January 10, 2024 – May 2025).

The following components are needed to construct the efficient frontiers.

- The mean return vectors contain the average daily returns of Bitcoin, equities and bonds, and are defined as: μ' = [μ1, μ2, μ3]. (' means the vector is transposed from vertical to horizontal.)
- The covariance matrices contain the variance of each asset and the covariance between assets, and are defined as:

$$\Sigma = \begin{pmatrix} \sigma^2_{btc} & \sigma_{btc,stocks} & \sigma_{btc,bonds} \\ \sigma_{stocks,btc} & \sigma^2_{stocks} & \sigma_{stock,bonds} \\ \sigma_{bonds,btc} & \sigma_{bonds,stocks} & \sigma^2_{bonds} \end{pmatrix}$$

- The weight vectors contain the portfolio weight in Bitcoin, equities and bonds, and is defined as: w' = [w1, w2, w3].

In accordance with standard portfolio analyses, this study employs two constraints. First, no short-selling, meaning $w1 \geq 0$, $w2 \geq 0$, and $w3 \geq 0$, because constraining portfolio weights to be nonnegative can reduce the risk in estimated optimal portfolios even when the constraints are wrong (Jagannathan & Ma, 2003). Second, full investment, meaning the sum of the weights should be equal to 1.

The efficient frontier is constructed by solving the following optimization problem for a range of target returns (Rt).

$$minimize\ w'\Sigma w\ with\ respect\ to\ w,\ \ subject\ to\text{:}\ \ w'\mu = \mathrm{Rt},\ \ \text{sum of wi} = 1, \text{and wi} \geq 0\ .$$

This optimization leads to the minimum variance portfolio for each target return (Rt). The resulting set of portfolios forms the efficient frontier. This process is done for both the pre- and post-ETF periods.

To examine the difference in Bitcoin's role within portfolios, both the pre- and post-ETF efficient frontiers are plotted in the same graph, with portfolio standard deviation on the x-axis and expected return on the y-axis. Both frontiers are influenced by the correlation between the three assets. When correlations increase, the frontier shifts inward keeping other factors constant, indicating lower diversification benefits as investors receive a lower return for the same risk level. This allows for a visual comparison of portfolios containing the same assets in a pre- and post-ETF environment. In addition to the standard pre- and post-ETF frontiers, this study also introduces two further efficient frontiers. The first is a hybrid frontier, designed to isolate the impact of correlation changes from changes in Bitcoin's return or volatility. For this frontier, Bitcoin's post-ETF mean and variance are retained, but its correlations with other assets are set to their pre-ETF values. This allows the analysis to identify the extent to which changed correlations influence the efficient frontier, and thus diversification benefits. The second is an equity-bond frontier constructed using only U.S. equities and U.S. bonds. This frontier serves to evaluate how adding Bitcoin to a portfolio can enhance the set of efficient portfolios. Differences in the location and shape of the efficient frontier offer a practical insight on how Bitcoin's traditionally beneficial role within portfolios has changed after the ETF approval.

5.4 Sharpe ratio comparison

Lastly, in addition to the visual insight, this study also statistically evaluates whether the diversification benefits of Bitcoin have significantly changed following the approval of Bitcoin spot ETFs. Specifically, the Sharpe ratio of the tangency portfolio from the post-ETF efficient frontier is compared with that of the hybrid frontier, in which Bitcoin's correlations are set to their pre-ETF values.

The Sharpe ratio measures the excess return per unit of risk (Sharpe, 1994), and is defined as:

$$SR = \frac{E(R_p) - R_f}{\sigma_p}$$

Where $E(R_p)$ is the expected return of the portfolio, R_f is the risk-free rate, and σ_p is the standard deviation of portfolio returns.

To test whether the two Sharpe ratios differ significantly, this study applies the Ledoit and Wolf (2008) test for equality of Sharpe ratios. This procedure constructs a studentized time-series bootstrap confidence interval to examine if the two ratios differ. This test does not assume normality of returns and time series independence, making it suitable for financial return data, which often exhibit serial correlation and fat tails (Ledoit & Wolf, 2008). The hypothesis of this test are formally stated as:

- H_0*: The Sharpe ratios of the two tangency portfolios are equal.*
- H_1*: The Sharpe ratios of the two tangency portfolios differ.*

A rejection of H_0 would indicate a statistically significant difference in Sharpe ratios. To support this study's expectation, the Sharpe ratio of the adjusted post-ETF frontier would need to be significantly lower than that of the pre-ETF frontier. As this would imply that increased correlations have reduced Bitcoin's diversification benefits in traditional investment portfolios.

6. Results

This section presents the empirical results, organized by the two hypotheses. Section 6.1 presents the results of hypothesis 1, which tests whether Bitcoin's correlation with traditional assets changed. Section 6.2 presents the result of hypothesis 2, which examines whether Bitcoin's beneficial role within portfolios changed after the approval of Bitcoin spot ETFs.

6.1 Empirical results hypothesis 1

Table 3: Structural break test results

Asset Pair	Break Date	Q_t Statistic
BTC – U.S. Equity	2020-02-21	1.807 ***
BTC – U.S. Bond	2022-02-22	0.997
BTC - CA Equity	2020-03-11	1.169
BTC - CA Bond	2022-04-04	1.068
BTC - GE Equity	2020-02-21	0.903
BTC - GE Bond	2022-04-01	1.588 **

This table reports the results of the nonparametric structural break tests for correlations between Bitcoin and traditional assets. For each BTC–asset pair, the table reports the identified break date and the corresponding test statistic Q_t. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, based on critical values from the Kolmogorov distribution (1.224, 1.358, and 1.628, respectively).

The findings of the nonparametric structural break in Table 3 revealed two statistically significant structural breaks in correlation. First, for Bitcoin-U.S. equities, the Q_T value of 1.807 confirms that there is a significant break on February 21, 2020. However, this structural break date does not coincide with the ETF approval (2024-01-10), indicating that although a structural change existed, it is not due to the ETF approval. This contradicts hypothesis 1. The break date instead likely falls into the start of the COVID-19 crisis, when worldwide financial markets crashed as investors panic-sold their assets. Almost all asset classes experienced comparable sharp price falls, leading to spikes in correlations. From an economic point of view, it shows that financial distress during the COVID-19 crisis, rather than fundamental changes like the ETF approval, was the key driver of the change in correlation. This result aligns with

Gorman and Hughen (2024), which also detects a structural break in correlation between equities and Bitcoin.

Second, for Bitcoin-German bonds, there existed a notable break on April 1, 2022, with a Q_T statistic of 1.588. Again, this break date is not aligned with the ETF approval (2020-06-08). Instead, it likely has to do with central banks signaling and reducing interest rates because inflation is too high. Bonds are less attractive with higher yields, and this policy likely also contributed to selling pressure on other assets such as Bitcoin, thereby increasing the co-movement between Bitcoin and bonds.

Other asset pairs, although statistically insignificant, show break dates around the same macroeconomic events. For equities, Canada and Germany experienced breaks at the onset of COVID-19 (2020-03-11 and 2020-02-21, respectively). For bonds, the break dates of Canada (2022-04-04) and the U.S. (2020-02-21) coincide with the increases in interest rates. The observation that these break dates are uniform across countries implies that Bitcoin's correlation is driven primarily by major global macroeconomic shocks, rather than domestic ones such as ETF approvals.

Table 4: Average correlations before and after structural breaks

Asset Pair	Break Date	Pre-Break Correlation	Post-Break Correlation
BTC – U.S. Equity	2020-02-21	0.035	0.385
BTC – U.S. Bond	2022-02-22	-0.037	0.062
BTC - CA Equity	2020-03-11	0.073	0.372
BTC - CA Bond	2022-04-04	-0.038	0.063
BTC - GE Equity	2020-02-21	0.023	0.247
BTC - GE Bond	2022-04-01	-0.053	0.080

This table displays the average correlations between Bitcoin and traditional assets before and after the identified structural break dates. For each BTC–asset pair, the table shows the break date, the average correlation in the pre-break period, and the average correlation in the post-break period.

Table 5: Average correlations before and after ETF approvals

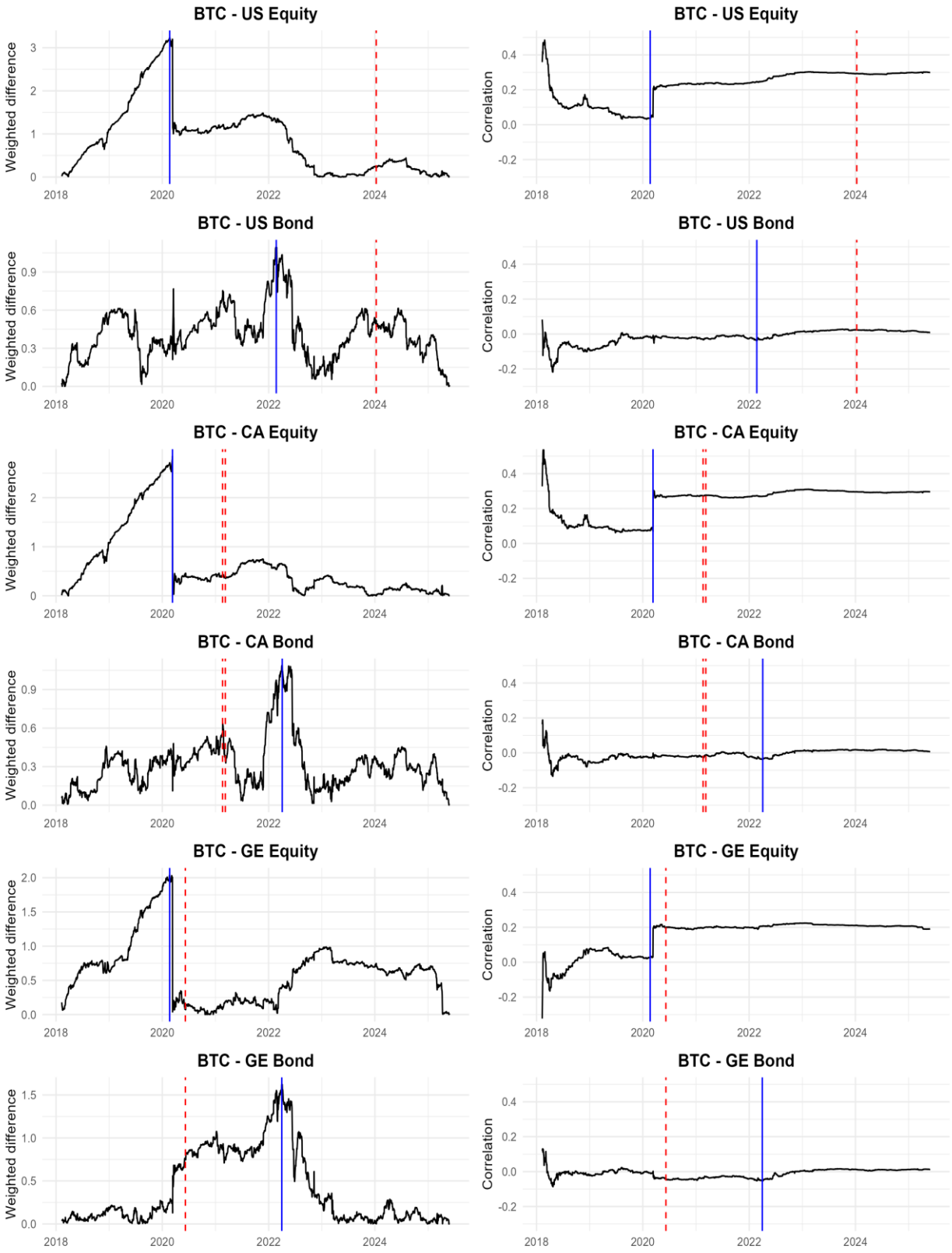
Asset Pair	ETF Approval Date	Pre-ETF Correlation	Post-ETF Correlation
BTC – U.S. Equity	2024-01-10	0.293	0.343
BTC – U.S. Bond	2024-01-10	0.024	-0.083
BTC - CA Equity	2021-03-09	0.276	0.330
BTC - CA Bond	2021-03-09	-0.014	0.020
BTC - GE Equity	2020-06-08	0.196	0.186
BTC - GE Bond	2020-06-08	-0.042	0.034

This table presents the average correlations between Bitcoin and traditional assets before and after the approval dates of Bitcoin spot ETFs in the U.S., Canada, and Germany. For each BTC-asset pair, the table reports the ETF approval date, the pre-ETF average correlation, and the post-ETF average correlation.

Table 4 reports average correlations before and after the structural break dates identified in Table 3. The correlation between U.S. equity and BTC rises sharply from 0.035 to 0.385, implying an increase in co-movement of Bitcoin and the S&P 500. Similar increases are observed for Canadian and German equities. Furthermore, all bond pairs shift from negative to positive correlations. Economically, this suggests that during periods of distress and monetary tightening, Bitcoin becomes more integrated with traditional financial assets, thereby reducing its diversification potential.

Table 5 narrows the focus to the ETF approval dates for each country. Here, correlation changes are smaller. For example, BTC-U.S. equity correlation increases modestly from 0.293 to 0.343. Canadian equities, Canadian bonds, and German bonds also exhibit modest post-ETF increases, consistent with the expected sign of hypothesis 1. These changes may reflect that easier access through ETFs aligns Bitcoin's performance more closely with traditional financial markets. On the other hand, the BTC-U.S. bonds and BTC-German equities show small post-ETF declines, indicating that any ETF-related effect is not consistent across all asset pairs. Taken together, consistent with the structural break test, the results of these tables inform investors with the implication that correlation risk for Bitcoin is driven primarily by major macroeconomic shocks rather than fundamental changes in Bitcoin, such as ETF introduction.

Figure 1: Plots on rolling cumulated deviation and expanding correlations



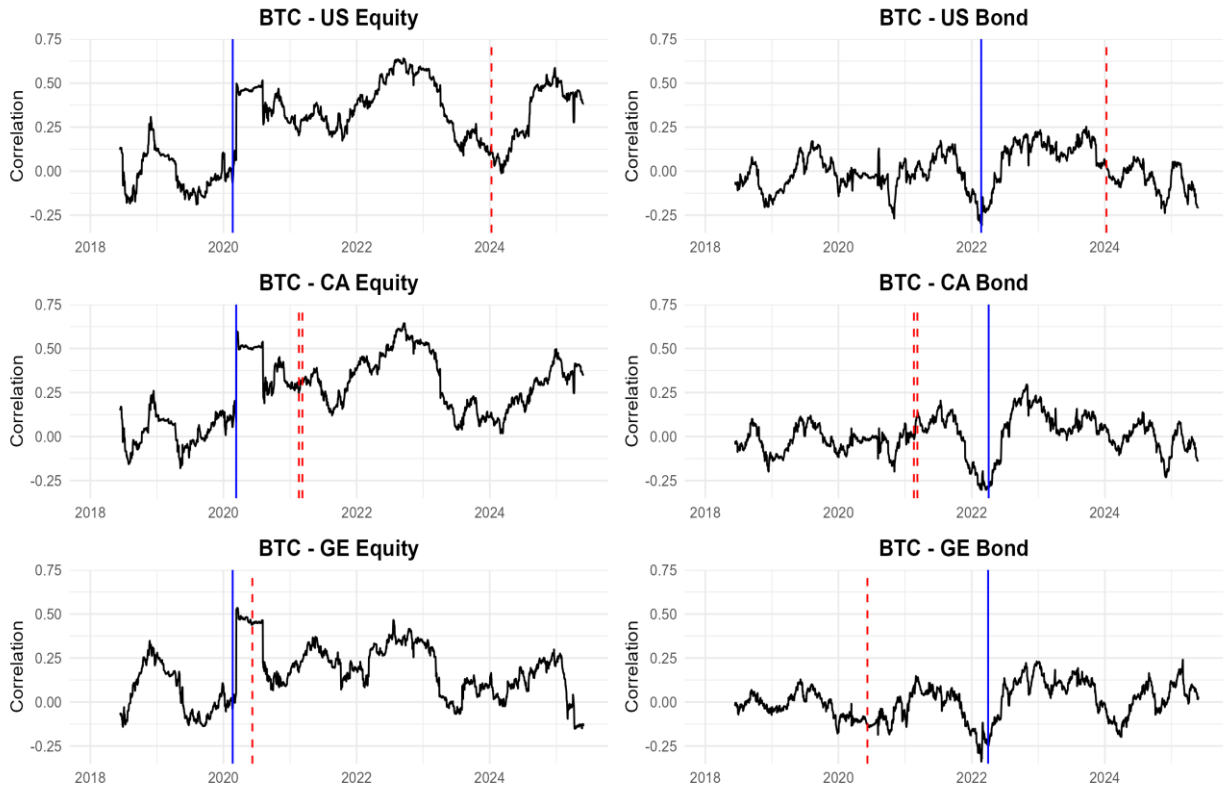
This figure shows the evolution of expanding correlations and cumulative deviations between Bitcoin and traditional assets over the sample period. The graphs on the left side show the cumulative deviation from the full-sample correlation ($\frac{j}{\sqrt{T}}\left|\hat{\rho}_j - \hat{\rho}_T\right|$), with peaks indicating potential structural breaks. The

right panels display the rolling correlations ($\hat{\rho}_j$) for each j. The blue line marks the most likely structural break date and the dashed red line marks the ETF approval dates, allowing visual comparison of correlation dynamics around these events.

In the left-hand plots, the peaks, and thus the identified break dates, cluster around February-March 2020 for equity pairs and February-April 2022 for bonds. As mentioned, this timing likely corresponds with the onset of the COVID-19 crisis and interest rate hikes by central banks. The right-hand correlation plots clearly mark an upward shift in BTC-equity correlations after the break date. Bond pairs show smaller and less persistent shifts, with correlations remaining near zero, suggesting that Bitcoin's relationship with bonds remains weak.

Importantly, the ETF approval dates (dashed red lines) do not coincide with any visually abrupt correlation changes. While small changes are visible in some series, they are minor compared to the shifts observed during the structural break events. This finding is inconsistent with the expectation under hypothesis 1. The visual evidence complements the statistical tests as both indicate that Bitcoin's correlation primarily responds to major macroeconomic shocks rather than the introduction of spot ETFs. For investors, this implies the risk to Bitcoin's diversification role comes primarily from major macroeconomic shocks.

Figure 2: Plots on rolling correlations



This figure displays rolling correlations between Bitcoin and traditional assets using a fixed window of the last 100 observations at each point in time. The blue line marks the most likely structural break date, and the red dashed line mark the ETF approval dates. This observation-based rolling window provides insight into recent short-term dynamics in the correlation structure.

Figures 2 provide a complementary perspective by showing cumulative deviation, which detects structural breaks, and the expanding correlations, which capture long-term shifts. However, fluctuations in the correlation are smoothed as the window increases. Therefore, Figure 3 on rolling correlations is used to highlight shorter-term fluctuations, allowing us to observe reactions to the structural breaks and ETF approval that might be averaged out in the expanding window plots.

For Bitcoin-equity pairs, a sharp upward shift in correlation after the structural break dates is clearly visible, and the higher correlation appears to persist. This pattern is consistent with the reasoning that Bitcoin increasingly moves together as it becomes more integrated into these markets. The rolling correlation plots reveal continuous movement, whereas they appear constant in the expanding window plots.

For Bitcoin-bond pairs, more gradual short-lived spikes in correlation are observed, followed by a reversion to slightly positive levels. This indicates that Bitcoin's relationship with bonds tends to mean revert after macroeconomic shocks and remains weak under normal conditions. Across all asset pairs, no direct reaction to the ETF approval is observed, and therefore also the rolling correlation plots fail to support hypothesis 1.

6.2 Empirical results hypothesis 2

Table 6: Descriptive statistics of daily returns (%)

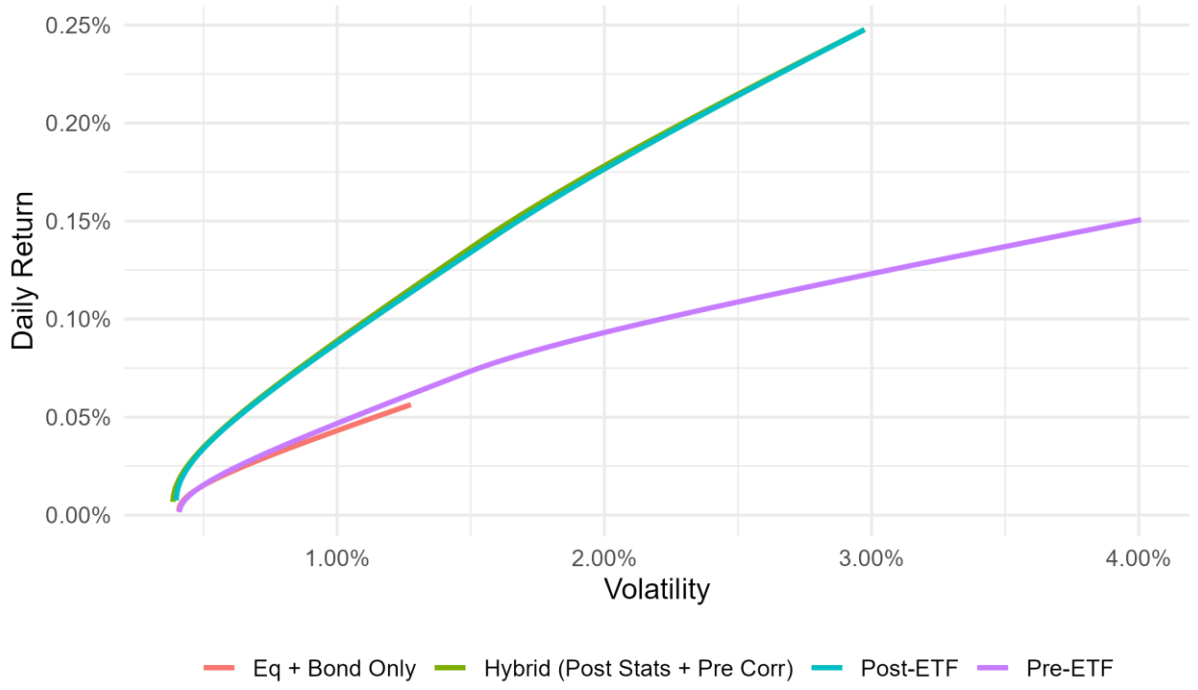
Period	Asset	Obs	Mean	Std_Dev	Skew	Kurt
Pre-ETF	BTC	1,486	0.152%	4.037%	-0.410	7.979
Pre-ETF	U.S. Equity	1,486	0.054%	1.308%	-0.500	12.641
Pre-ETF	U.S. Bond	1,486	-0.007%	0.453%	0.197	2.467
Post-ETF	BTC	342	0.248%	2.974%	0.334	1.160
Post-ETF	U.S. Equity	342	0.067%	1.130%	0.825	16.675
Post-ETF	U.S. Bond	342	-0.004%	0.432%	-0.211	0.577

This table presents summary statistics for the daily returns of Bitcoin, U.S. equities, and U.S. bonds before and after the approval of Bitcoin spot ETFs. For each asset and period, the table reports the number of observations, mean return, standard deviation, skewness, and kurtosis.

Table 6 reports descriptive statistics for Bitcoin, U.S. equities, and U.S. bonds in the pre- and post-ETF periods. This split allows comparison of the risk-return profile of each asset before and after the ETF approval. For Bitcoin, the post-ETF period shows improvement in its risk-return characteristics. Bitcoin's average daily return increases from 0.152% to 0.248%, while volatility decreases from 4.037% to 2.974%. This combination implies a more favourable Sharpe ratio, making Bitcoin attractive for mean-variance optimized portfolios. The ETF approval likely contributed to this improved risk-return trade-off. Regulatory clarity as a result of the ETF approval may have strengthened investor confidence in Bitcoin, reducing its volatility. Regarding return, the ETF approval offered a regulated financial instrument to gain exposure to Bitcoin. This potentially leads to increased demand, especially from institutional investors. Given Bitcoin's limited daily supply, the demand pressure supported higher prices. For example, in the first two months after approval, the net daily inflow was $250 million, which is 500% of Bitcoin's daily production (Mazur & Polyzos, 2024). Positive skewness in the post-ETF period (0.334 vs -0.410 pre-ETF) suggests a greater probability of positive outliers, further improving its appeal. Nevertheless, the approval of spot ETFs is recent, and the post-ETF sample coincides with a bull market in Bitcoin as well as advantageous monetary policy expectations, such as anticipated rate cuts. Therefore, these observations should be interpreted with caution, as their persistence is uncertain.

U.S. equities and U.S. bonds exhibit small improvements post-ETF, with slightly higher returns and reduced volatility. These changes cannot be attributed to the Bitcoin ETF approval, but they provide a more favourable scenario for post-ETF risk-return trade-offs for portfolios.

Figure 3: Efficient frontiers



This figure displays efficient frontiers. The plot includes four frontiers: one using only equities and bonds, one from the pre-ETF period, one from the post-ETF period, and one hybrid frontier combining post-ETF return characteristics with pre-ETF correlations. The frontiers illustrate how Bitcoin affects the portfolio's risk-return trade-off in different scenarios.

Table 7: Efficient frontier summary statistics

Scenario	Portfolios	Min_Return	Max_Return	Min_Risk	Max_Risk	Max_risk-return ratio
Eq+Bond Only	200	0.00223%	0.05637%	0.40786%	1.27593%	0.04418
Hybrid	200	0.00677%	0.24763%	0.38525%	2.97368%	0.09096
Post-ETF	200	0.00750%	0.24763%	0.39818%	2.97368%	0.08945
Pre-ETF	199	0.00153%	0.15070%	0.40985%	4.00856%	0.04898

This table summarizes the characteristics of efficient frontiers under four different scenarios: (1) a portfolio of equities and bonds only, (2) a pre-ETF portfolio including Bitcoin, (3) a post-ETF portfolio

including Bitcoin, and (4) a hybrid portfolio using post-ETF asset returns and volatilities with pre-ETF correlations. For each scenario, the table reports the number of simulated portfolios, minimum and maximum expected returns, minimum and maximum portfolio risk (standard deviation), and the maximum risk-return ratio.

Table 7 summarizes the characteristics of four efficient frontier scenarios, while Figure 3 visualizes the efficient frontiers in a graph. Both show that the equity-bond-only frontier has the lowest risk-return ratio (0.04418) and is positioned entirely to the right of the other frontiers, meaning it delivers the lowest return for any given level of risk. This indicates that adding Bitcoin improves portfolio risk-adjusted returns.

In Figure 3, the post-ETF frontier lies clearly above the pre-ETF frontier and has a substantially higher maximum risk-return ratio (0.08945 vs. 0.04898). This improvement is primarily driven by Bitcoin's enhanced post-ETF performance (see Table 6), rather than changes in correlations. Thus, in the short term, the ETF approval's main portfolio effect is that it made Bitcoin individually more attractive to investors, as its risk-return trade-off improved.

The hybrid frontier offers the highest risk-return ratio (0.09096). This scenario uses post-ETF return and volatility characteristics but reverts correlations to their pre-ETF levels, thereby isolating the effect of correlations when comparing the frontier to the post-ETF scenario. The hybrid frontier marginally outperforms the post-ETF frontier. Building on the intuition of risk-adjusted performance interpretation proposed by Modigliani and Leah (1997), the difference in Sharpe ratio can be expressed as an additional return at a chosen risk level. Setting the risk-free rate to zero and using a hypothetical daily market volatility of 1%, the hybrid frontier offers an additional 0.0015% daily return compared to the post-ETF scenario. This indicates that Bitcoin's diversification benefits as result of correlations have slightly decreased post-ETF. The sign is consistent with expectations under hypothesis 2.

Table 8: Bootstrap test for Sharpe ratio difference

Sharpe Ratio Difference	95% CI (Lower)	95% CI (Upper)	Bootstrap p-value
0.00054	-0.0021	0.0032	0.7160

This table presents the results of a bootstrap test comparing the Sharpe ratios of tangency portfolios from the hybrid and post-ETF efficient frontiers. The table includes the estimated Sharpe ratio difference, the 95% confidence interval bounds, and the corresponding p-value.

Table 8 reports the results of a bootstrap test comparing the tangency portfolio Sharpe ratios from the hybrid and post-ETF efficient frontiers. This analysis complements the efficient frontier results by testing whether the Sharpe ratio difference between the hybrid and post-ETF frontiers is statistically significant. The estimated difference is 0.00054, with a 95% confidence interval of (-0.0021, 0.0032). Since the confidence interval includes zero and the bootstrap p-value is 0.7160, there is no statistical evidence that the two Sharpe ratios differ. This indicates that the observed outperformance is too small to be distinguished from random variation in simulated returns. This suggests that the modest correlation increases observed after the ETF approval have not statistically reduced Bitcoin's diversification benefits. For investors, this implies that Bitcoin's role as a portfolio diversifier remains intact post-ETF, and portfolio allocation decisions should not be driven by concerns over correlation changes following the approval.

6.3 Robustness test

In the main analysis, Bitcoin's strong risk-return characteristics leads to very high optimal weights in Bitcoin, especially for the post-ETF frontier (). Such allocations are unrealistic for the risk-profile of most investors. To address this, the efficient frontier analysis is recomputed under the additional constraint that limits Bitcoin's portfolio weight to a maximum of 10%.

This robustness test has two advantages. First, it provides a more realistic view of efficient frontiers for the average investor. Second, it reduces the impact of Bitcoin's improved individual performance, thereby offering a more conservative perspective on diversification benefits.

The results of this robustness test are shown in Figure 1A and Table 1A of the appendix. The results show that all Bitcoin-inclusive portfolio's still outperform the equity + bond only portfolio. In addition, the hybrid and post-ETF frontier still lie above the pre-ETF frontier, with the hybrid frontier being the most efficient with the highest Sharpe ratio. However, the accessible return and volatility is much lower in the Bitcoin weight cap case. Therefore, the absolute performance differences between the frontiers are smaller due to the limiting effect of Bitcoin's strong individual contribution. This indicates that while the unconstrained results may be out of perspective, the main conclusions still hold: Bitcoin enhances the risk-return trade-off of portfolios, and slightly increased correlations did not eliminate its diversification benefits.

7. Conclusion

7.1 Summary of findings

This thesis examined how the approval of Bitcoin spot ETFs affected Bitcoin's correlation with traditional assets, its risk-return trade-off, and its diversification benefits, over a sample period spanning from 2018 to 2025. Structural break tests were applied to explore correlations, while efficient frontier analyses complemented by a Sharpe ratio comparison were used to assess Bitcoin's risk-return characteristics and diversification effects. The main findings are as follows.

First, both statistical and visual evidence show that Bitcoin's correlations with traditional assets did not meaningfully change as a result of the ETF approval. Thus, hypothesis 1 is not supported. Instead, correlations increased during major macroeconomic events. For Bitcoin-equity pairs during the COVID-19 crisis, and for Bitcoin-bond pairs during central bank interest rate hikes.

Second, Bitcoin's risk-return trade-off improved in the post-ETF period. Average daily returns increased while volatility declined, resulting in more favourable portfolio outcomes than in the pre-ETF period. This improvement is likely linked to regulatory clarity from the ETF approval, which strengthened investor confidence and reduced volatility. Additionally, easier access to Bitcoin via ETFs boosted institutional demand, driving its returns up. However, these findings must be interpreted cautiously, as the ETF approval is recent and the post-ETF period coincides with a Bitcoin bull market alongside advantageous monetary policy expectations.

Lastly, the efficient frontier analysis shows that adding Bitcoin improves the efficiency of equity-bond portfolios. Additionally, it shows that modest correlation increases suggest slightly weaker diversification benefits, a bootstrap test confirmed that these changes are not significant. Overall, Bitcoin's diversification benefits remain intact post-ETF.

This study contributes to the literature by filling a gap on the effects of Bitcoin spot ETF approval on Bitcoin's properties in traditional investment portfolios. It also informs investors by demonstrating that Bitcoin continues to serve as a diversifier post-ETF, with portfolio improvements driven by enhanced individual performance of assets rather than by structural changes in correlations.

7.2 Limitations and recommendations for future research

This study has several limitations. First, the post-ETF window is relatively short, which limits the reliability of the results. For example, the data may capture a single part of a full market cycle, which seems to be the case for Bitcoin's post-ETF period coinciding with a Bitcoin bull market. Second, the investment set is limited to equity and bonds, whereas real-world portfolios generally include a wider range of assets. Third, the analysis does not fully isolate ETF approval effects, as these fall into insignificance with larger macroeconomic shocks.

Future research could address these issues by extending the post-ETF sample, broadening the investment set, and employing event study methodologies around the approval dates. In addition, instead of using a simplified first look at correlation dynamics one could use a more complex statistical model such as DCC-GARCH. Another interesting direction for future research would be to examine how the introduction of spot ETFs influences investor behaviour toward Bitcoin.

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Appendix

Transparency statement: Use of AI

AI tools were used to support the research process in the following ways:

- Coding assistance: AI was used to generate R code, to execute the method. All code was reviewed, adapted and executed by me.
- Checking purposes: AI was used to check outcomes. When I had doubts about values in the results, AI was used to make a reasonable estimate of what the values could be. The outcome of these estimates were carefully analysed by me.
- Language support: AI was used to check spelling and grammar. Additionally, AI was used to improve clarity and flow of written sections. All improvements were edited and approved by me.

Robustness test

Figure 1A: Efficient frontiers with 10% weight cap on Bitcoin

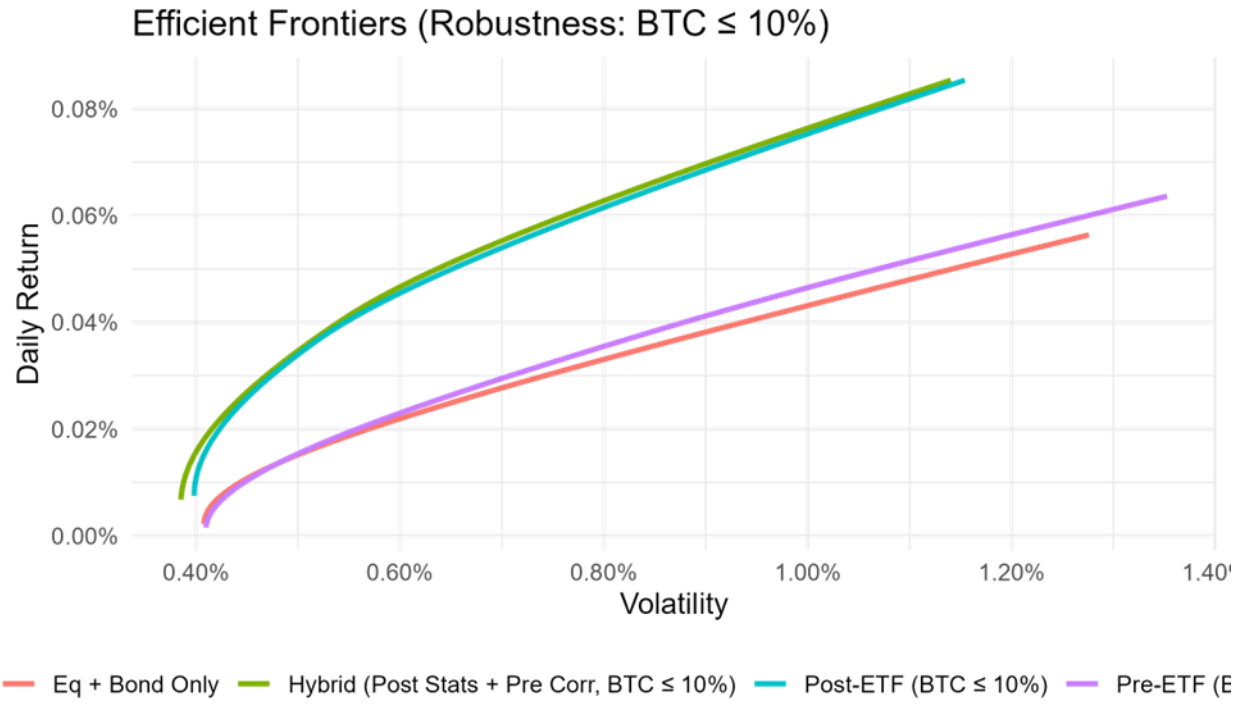

Table 1A: Efficient frontier summary statistics with 10% weight cap on Bitcoin for the hybrid, post-ETF and pre-ETF frontier

Scenario	Portfolios	Min_Return	Max_Return	Min_Risk	Max_Risk	Max_Sharpe
Eq + Bond Only	200	0.00223%	0.05637%	0.40786%	1.27593%	0.04418
Hybrid	200	0.00677%	0.08535%	0.38525%	1.14049%	0.07896
Post-ETF	200	0.00750%	0.08535%	0.39818%	1.15416%	0.07713
Pre-ETF	200	0.00153%	0.06361%	0.40985%	1.35252%	0.04704