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Should People Invest in Bitcoin?

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Abstract. I analyzed the historical performance of Bitcoin using its daily price data from October 2017 to January 2023, focusing on its unique characteristics and risk-return profile. The analysis began with an in-depth examination of Bitcoin's metrics, emphasizing factors such as maximum drawdown (MaxDD), a key measure of risk, and volatility, which highlights the asset's price fluctuations. Next, I extended the analysis to include four additional assets: GLD (gold), SPY (SPDR S&P 500 ETF Trust), DXY (U.S. dollar index), and QQQ (Invesco QQQ Trust). I evaluated these assets using metrics such as average return, volatility, Sharpe ratio, and maximum drawdown, comparing them directly to Bitcoin. This comparison revealed the relative strengths and weaknesses of Bitcoin against traditional and alternative assets, highlighting its potential for high returns at the cost of elevated risk and drawdowns. Following this, I constructed a portfolio of all five assets, optimizing for the highest Sharpe ratio, which balances return and risk. The analysis delved into why this specific asset combination produced the most optimal Sharpe ratio, considering factors like asset correlations and individual contributions to the portfolio's risk-return tradeoff. To further understand Bitcoin's role, I compared the optimized portfolio with and without Bitcoin, evaluating differences in Sharpe ratio, return, and volatility. This analysis underscored the conditional value of including Bitcoin, as its contribution depends on an investor's risk tolerance and market conditions. Ultimately, I concluded that Bitcoin can be a worthwhile investment, but only under specific conditions where its high risk is offset by its potential for outsized returns and diversification benefits.

Keywords: cryptocurrency, portfolio diversification, portfolio management, performance evaluation

1. Introduction

Being a cryptocurrency invented more than 16 years ago, Bitcoin is well-known worldwide, and even people who do not invest might probably hear about this high-price investment. As the value of Bitcoin has soared thousands of times since it was first introduced, more and more people are trying to make some money in this market, even though the threat and danger have been rife all the time. Bitcoin has a high volatility [1]. 124 relevant papers were published in academic journals between January 2017 and March 2019 [2]. The arbitrage spreads are much larger for exchanges across different countries than within the same country [3]. In another way, it is related to the investor's attention to decide whether to trade Bitcoin properly, as investors' attention is one of the elements by which cryptocurrency can be predicted [4]. Price manipulation can have substantial distortive effects on cryptocurrencies as well [5]. There is significant ICO (initial coin offering) underpricing and factors such as liquidity, market capitalization, and 40% of all ICOs are overpriced [6]. Given all the uncertainties and threats caused by investing in Bitcoin, one of the questions that people care about is, should we invest in Bitcoin? Vojtko and Javorská concluded that it's prudent to cap allocation to Bitcoin (or the whole pool of cryptocurrencies as an asset class) to maximally 2-3% of the portfolio [7]. It is optimal to hold a small allocation to BTC with utility functions that exhibit a preference for positive skewness [8]. To find the result, I simulate a portfolio with 5 different kinds of assets, including BTC(Bitcoin), QQQ(Invesco QQQ Trust), SPY(SPDR S&P 500 ETF Trust), DXY(US Dollar Index DX-Y.NYB), and GLD(gold). This is because of Bitcoin's low correlation with traditional asset classes, making it a candidate for diversification [9]. I use the data from Yahoo finance from October 2017 to January 2023. Since Yahoo Finance extracts the data from Binance and all other centralized crypto exchanges, I am trying to eliminate the bias caused by using non-traded price data. This paper is also motivated by literature focusing on the macroeconomic factors that might influence Bitcoin's price [10-12].

The reason I chose these five assets is that they differ to some extent from the various performance metrics discussed in the data and description section. Overall, I found that Bitcoin, as a store-chain technology, represents high instability but offers potentially high returns. Gold serves as a stable, low-return store asset. The higher the return of the DXY, the more Bitcoin is

traded in U.S. dollars. Both SPY and QQQ provide moderate returns with lower volatility, though QQQ focuses solely on the technology sector.

From 2017 to 2023, the correlations between Bitcoin and the other four assets were generally lower than during the COVID-19 period, particularly from February 2020 to June 2020. This difference can be attributed to the detrimental impact of financial market shutdowns and the subsequent recovery driven by U.S. fiscal policies during that time.

Regarding portfolio diversification, my main finding is that the Sharpe ratio of my portfolio is higher when Bitcoin is excluded compared to when it is included. Using the solver model, I observed that the allocation of assets in the portfolio is largely determined by their returns and volatility. Furthermore, portfolio stability is more critical than achieving high returns for long-term performance.

The remainder of my paper is organized as follows. Section 2 discusses the data and methodology and provides variables I am going to use during calculation. Section 3 analyzes the data and variables I calculated and the relation between Bitcoin and other 4 equities during the specific period. Section 4 concludes the paper.

2. Data and methodology

2.1. Data Description

The data used in this study is sourced from Yahoo Finance, specifically from the historical data section covering the period from October 2017 to January 2023. My sample consists of five financial instruments: Bitcoin (BTC), the U.S. Dollar Index (DXY), and three exchange-traded funds (ETFs) — the SPDR S&P 500 ETF (SPY), the Invesco QQQ ETF (QQQ), and the SPDR Gold Shares ETF (GLD). Using daily open, close, high, and low values, I calculate key performance metrics, including daily returns, volatility, Sharpe ratios, and higher moments such as kurtosis and standard deviation. These measures are employed to assess the individual performance and potential interrelationships between these assets.

2.2. Solver Model

To find the portfolio with the maximum Sharpe ratio, I used Excel's Solver tool. In this case, I am solving a linear optimization problem to determine the optimal mix of asset percentages in a portfolio based on its return and risk. For linear optimization, I need to consider three key components: decision variable cells, objective cells, and the solving method. My objective is to maximize the Sharpe ratio, so the decision variable cell will contain this ratio. The objective cells will represent the percentage of each asset (BTC, QQQ, SPY, DXY, GLD) in the portfolio, as well as its average return over a specified period, such as monthly or weekly. To maximize the portfolio's monthly Sharpe ratio, I need to assign a weight to each asset that sums to 1, respecting the constraint that the total portfolio allocation is 100%. Then, for each period, I calculate each asset's monthly return and multiply it by its assigned weight. This will give us the portfolio's weighted monthly return for each period. From here, I can calculate the portfolio's average weighted monthly return and weighted monthly standard deviation. Using the Sharpe ratio formula outlined in Appendix A, I can compute the weighted monthly Sharpe ratio. The solver then uses this equation to find the optimal portfolio weights that maximize the Sharpe ratio. When setting up Solver in Excel, it is important to constrain the sum of the portfolio weights to exactly 1. After selecting the correct objective cells, simply plug in the necessary formulas to calculate weighted average return, standard deviation, and Sharpe ratio, and Solver will identify the optimal portfolio composition based on these parameters.

3. Portfolio Management Involving Bitcoin and Other Assets

3.1. Preliminary Analysis of Bitcoin and Other Equities and Their Interconnections

Bitcoin is primarily used as a store of value rather than a medium of exchange due to its high volatility. This volatility means that traders may incur losses when exchanging Bitcoin, which makes it less effective as a currency for everyday transactions. Additionally, Bitcoin is not a fiat currency because it is decentralized and has a finite supply. Although gold is not typically used directly for payments, it can be converted into cash in almost any currency, facilitating transactions. While Bitcoin is often held for its potential to preserve value, like gold, gold is more readily converted to fiat currency.

Both gold and Bitcoin are considered valuable stores of wealth, but they serve different purposes. By comparing the skewness columns in Table 4 and Table 5, I conclude that Bitcoin's return distribution is negatively skewed, which is -0.64 annually, meaning its mean return is lower than its median return. In contrast, gold's returns are positively skewed, with a 0.93 annual value, indicating that its mean return is higher than the median. In kurtosis columns, both assets also exhibit negative annual kurtosis, -0.43 and -2.00 for GLD and BTC respectively, suggesting a platykurtic distribution (flatterer than a normal distribution). However, Bitcoin's kurtosis is lower, and combined with its negative skewness, it implies that although there are outliers on both sides of the distribution, the average return is still less than the median return. Gold, with its positive skewness and fewer outliers, generally provides more stable returns compared to Bitcoin. Bitcoin also has a much higher maximum drawdown than gold, comparing 78.43% and 12.67%, which indicates that its price fluctuates more significantly, reinforcing its reputation for volatility and instability. Despite this, Bitcoin has a higher Sharpe ratio than gold (0.52 to 0.50), suggesting that while both assets have negative

annual returns, Bitcoin offers higher returns relative to its risk. However, the higher returns are accompanied by greater risk, making Bitcoin a more speculative investment compared to gold.

Bitcoin is based on blockchain technology, which creates a decentralized and tamper-proof system for recording transactions. This technology is not only used in Bitcoin mining but also in various other industries such as energy, retail, and media. For instance, companies in the media sector use blockchain to track the movement of goods between suppliers and buyers. Gold, on the other hand, is essential in the technology sector due to its stability, malleability, resistance to oxidation, and conductivity, making it indispensable in electronic devices, albeit in small amounts.

The SPDR S&P 500 ETF Trust (SPY) is designed to track the S&P 500 Index, representing the performance of 500 large companies across various industries in the United States. In Table 3, SPY offers moderate annual returns, 7.81%, with lower volatility compared to Bitcoin, and its annual Sharpe ratio, 0.44, while higher than gold's, is still much lower than Bitcoin's 0.52. The negative skewness and kurtosis of SPY, like Bitcoin, indicate that it has fewer outliers and a return distribution closer to normal. This stability makes SPY a safer investment with more predictable returns. In general, SPY is a solid long-term investment, providing steady, moderate returns. Bitcoin, on the other hand, is often used as a speculative investment, particularly in times of inflation or financial instability. Unlike SPY, which represents the broader U.S. economy, Bitcoin operates outside traditional financial systems and can be traded globally in any currency, making it less tied to U.S. economic conditions solely.

The U.S. Dollar Index (DXY) measures the value of the U.S. dollar against a basket of six major currencies: the Euro, Japanese Yen, British Pound, Canadian Dollar, Swedish Krona, and Swiss Franc. Notably, it does not include other significant currencies like the Chinese Yuan or Australian Dollar. A higher DXY indicates stronger U.S. dollar purchasing power, which can affect the global trade of Bitcoin. When the DXY is high, more Bitcoin might be traded in U.S. dollars, and when it declines, Bitcoin may be traded more in other currencies. Some countries, like China, Australia, and New Zealand, may have stronger currencies that are not reflected in the DXY. In such cases, Bitcoin might be more actively traded to avoid unnecessary spending in those currencies. Based on Table 2, DXY has remained relatively stable since its inception, with an annual return of 1.06%, the lowest Sharpe ratio, 0.20, and the lowest volatility among the five assets discussed, which is 5.36%. Although its 13.08% annual maximum drawdown is slightly higher than gold's, it is significantly lower than Bitcoin's 78.43%, underscoring the DXY's low return and stability. The DXY's negatively skewed, platykurtic return distribution shows fewer outliers, and its skewness, -0.20, is closest to zero among the assets, making its return distribution the most normal. A higher DXY might also reduce demand for Bitcoin by increasing the opportunity cost of holding assets like Bitcoin instead of spending or investing in more liquid assets.

The Invesco QQQ ETF tracks the Nasdaq-100 Index, focusing primarily on technology companies. With 58.94% allocated to information technology, 17.90% to consumer discretionary, and 6.29% to healthcare, QQQ tends to outperform SPY during bull markets, reflecting the strong performance of the tech sector. The annual return of QQQ is 12.80%, higher than SPY's 7.81%. However, QQQ is also more volatile, offering higher returns but with greater risk. Bitcoin outperforms QQQ in terms of return but is riskier, with a significantly higher maximum drawdown (78.43% compared to 34.80%). Both QQQ and Bitcoin are closely tied to technology—QQQ's value is influenced by tech companies' performance, while Bitcoin's value is driven by blockchain technology. Both assets are highly volatile and tend to perform well during periods of technological growth but can be negatively impacted during downturns (26.92% for QQQ and 52.43% for BTC). QQQ is popular among investors looking for exposure to high-growth technology companies, while Bitcoin attracts those interested in the potential for high returns from the adoption of digital currencies. During speculative market phases, both QQQ and Bitcoin can see significant price appreciation, but they are also prone to sharp corrections.

The reason why the return of DXY and GLD is relatively lower than the other 3 stocks is because QQQ and GLD is more about stocks to store their value instead of investment. Buying gold is a way to secure the money since gold price doesn't fluctuate given its MaxDD. Similarly, no can could expect the US dollar to depreciate and appreciate erratically. As a result, the intention to invest in DXY and GLD would be different from investing in SPY, QQQ, or BTC, which are more related to technology, innovation, and long-term investment. Because of the higher return derived from QQQ, SPY, and Bitcoin, their MaxDD and volatility are conspicuously higher than that of DXY and SPY.

3.2. The Correlation between Bitcoin and All Other 4 Assets During the COVID Period

In Figure 2, looking of the horizontal time axis, Bitcoin, which was at its highest point $10,500 in the mid of February, slipped below $8,000 since Covid compounded. On March 12, Bitcoin price hit a low of $3,850, which plunged 39% in a single day. As CARES was passed and the change in federal fund rate, Bitcoin price went back to about $8600 in April. Because of the huge volatile and unexpected performance Bitcoin made during the early period of COVID-19, many institutions have started to endorse Bitcoin. Bank of America published a survey of fund managers and found that "long bitcoin" was one of the most "crowded trades" in global markets, along with "long tech" and "short dollar."

Gold, as a traditional asset, also experienced a decline in March 2020. However, it was less affected by the stock market crash compared to equities such as SPY, QQQ, or Bitcoin. Initially, gold prices rose as the market turmoil began. In Figure 1, Although gold saw a noticeable drop from $156 to $140 between March 12 and March 16, 2020, its price rebounded to $153 by March 26, even before the CARES Act was enacted. This stability suggests that gold remained a reliable asset during the period of upheaval. Investors likely turned to gold as a haven amid the uncertainty, which helped it maintain relatively stable value despite the broader market disruptions caused by COVID-19.

The stock market crash of 2020 occurred between February 20 and April 7. On March 8, 2020, Saudi Arabia initiated an oil price war with Russia, leading to a 65% drop in oil prices for the quarter. This collapse in oil prices, combined with the broader financial turmoil, prompted significant market disruptions. On March 9, 12, and 16, the S&P 500 triggered Level 1 market-wide circuit breakers—automatically halting trading for 15 minutes—due to a 7% drop from the previous close. The index also experienced a circuit breaker trigger later in the day on March 18.

The oil price war resulted in substantial financial strain on oil-producing nations. Saudi Arabia increased its debt ceiling from 30% to 50% of GDP in response to the crisis. Concurrently, the Russian ruble fell over 30% between the start of the year and March 18. In reaction to the economic downturn, countries around the world introduced new fiscal policies. For example, the Mexican federal government permitted banks to defer loan repayments, the Swiss federal government launched a $20.4 billion business credit-line program, and the Bank of Korea committed to financing half of South Korea's stimulus program.

Because of the upheaval, the price of SPY, an ETF that tracks the S&P 500, began to decline in late February 2020. In Figure 1, it reached a low point between March 12 and March 26, 2020, coinciding with two market-wide circuit breakers in the United States. SPY's price fell from around $366 on February 11, 2020, to $241 on March 12, and further down to $212 by March 26. Similarly, QQQ, which tracks the Nasdaq-100 index, peaked at $236 on February 20, 2020, the day the stock market crash began. It then dropped to $174 on March 16 and $171 on March 23. Following the enactment of the CARES Act on March 27, 2020, both SPY and QQQ began to rise gradually and stabilize.

On an annual basis, by analyzing Table 6, Bitcoin (BTC) shows a moderate to strong correlation with both QQQ and the U.S. Dollar Index (DXY), with correlations of 0.60 and 0.74, respectively. Interestingly, despite both SPY and QQQ representing broad stock indices that include top-performing global companies, the correlation between BTC and SPY is relatively low at around 0.31. This is even lower than the correlation between BTC and GLD (gold), which stands at 0.53. Over shorter time frames, such as monthly, weekly, and daily intervals, Bitcoin's correlation with these indices is quite weak, with all values below 0.20. Specifically, the daily correlations between BTC and QQQ, DXY, and GLD are negative, at -0.07, -0.08, and -0.02, respectively. During the period from February 2020 to June 2020, according to Table 7, the monthly correlation between Bitcoin (BTC) and QQQ, DXY, and SPY was relatively high. This observation is not surprising given that both QQQ and DXY include numerous high-tech companies, which experienced significant impacts from the COVID-19 pandemic. Consequently, their correlations with BTC were expected to be similar due to the widespread effects of the pandemic on these sectors.

What is particularly intriguing is the moderate correlation observed between BTC and SPY, especially since SPY, which tracks the broader S&P 500 index, appeared to be less affected by the pandemic during February and March 2020. Despite this relative resilience, the moderate correlation between BTC and SPY suggests that Bitcoin's performance was influenced by broader market trends or investor sentiment during this period, reflecting a degree of interconnectedness with the overall equity market.

3.3. Optimal Diversified Portfolio

To find the optimal portfolio diversification, I decide to calculate the Sharpe ratio within a portfolio, given the Sharpe ratio's consideration of both volatility and return. Firstly, to estimate a possible range of optimal Sharpe ratio, I manually set the percentage of each stock, which creates 24 categories in total. All the data performs in Table 8. The reason why the BTC percentage varies only between 3% to 5% is because Bitcoin improves the efficient frontier of that portfolio, from the 4 percent level of return onwards [13]. Overall, portfolio no. 4 and no.12 have the highest Sharpe ratio with 1.18, where the Bitcoin percentage is 4% and 5%, and the investment in DXY is around 40%. Based on the calculated data, it is evident that portfolios with higher allocations in QQQ, SPY, and BTC tend to exhibit increased volatility, higher average monthly returns, and greater cumulative monthly returns. However, when considering the monthly weighted Sharpe Ratio, the portfolio with the highest return is not necessarily the most optimal, as its Sharpe Ratio is not the highest. Among the 24 portfolios analyzed, portfolios 4 and 12 have the highest Sharpe Ratios, making them potential optimal choices. When examining Kurtosis and Skewness, additional insights emerge. Since all the weighted Kurtosis values are between 0 and 3, and all the weighted Skewness values are negative, the weighted monthly returns for these portfolios follow a Platykurtic distribution and are negatively skewed. Given this, portfolio 8 emerges as the best combination. A higher Kurtosis indicates fewer outliers and a distribution where the median and mode-weighted returns are higher than the mean. Consequently, portfolio 8 carries less risk compared to portfolio 4, as its weighted Kurtosis is lower, and its weighted Skewness is more negative than that of portfolio 4. In other words, the optimal portfolio has a Sharpe ratio of at least 1.18.

Using the solver method discussed earlier, after specifying the correct decision variable cells, objective cells, and solving method, I identified the portfolio with the highest Sharpe ratio, which is 1.25. The portfolio allocation shows that Bitcoin maintains a weight of 3.92%, aligning with the findings of Apolónia and Abreu. Stable assets like GLD account for approximately one-quarter of the portfolio, while SPY is reduced to 15%. Both QQQ and DXY are maintained at roughly 28%.

When comparing this portfolio to the manually calculated optimal portfolio (Portfolio 4) from Table 8, the allocations differ significantly for all assets except Bitcoin. Specifically, the percentage allocations for QQQ and SPY are not identical; QQQ has a higher allocation in the optimized portfolio, which is 28.11% compared with 20.00%, while SPY is lower: 15.10% in the solver model calculated portfolio and 20.00% in the manually calculated model. Additionally, GLD's allocation is 10% higher, and DXY is lower.

Although QQQ and DXY exhibit very similar price patterns from 2017 to 2023 (as shown in Figure 3), with a consistent price gap between them, their MaxDD and Sharpe ratios are also quite similar. Furthermore, they are strongly positively correlated both

over the entire period and during the COVID-19 period (from February 2020 to June 2020). Despite these similarities, their portfolio allocations should not necessarily be the same. Their similarity suggests that their allocations should differ to a meaningful extent.

When the market is booming, higher allocations to QQQ and SPY can generate higher returns. However, this also increases portfolio risk. By adjusting the allocations to lower-risk assets, such as GLD and DXY, overall portfolio volatility can be reduced. For instance, when one asset declines in value, the other might rise or remain stable, providing a stabilizing effect on the portfolio.

The reason for lowering SPY's allocation likely stems from its higher Kurtosis and Skewness, as indicated in Table 3. For example, SPY's monthly kurtosis is ten times higher than QQQ's, suggesting more outliers in its return distribution. Additionally, SPY exhibits more negative skewness monthly. Therefore, QQQ is considered more stable than SPY, which justifies its higher allocation in the portfolio.

Bitcoin is known for its high volatility and instability, which undermines its effectiveness as a hedge against equity market risks. When added to a portfolio, BTC primarily increases the potential return due to its significant price swings, rather than providing effective risk reduction. In Table 9, even when Bitcoin is included in my portfolio, it takes less than 5% of the portfolio -3.92%- which testifies its risk again. What's more, Bitcoin's extreme volatility limits its ability to serve as a reliable hedge (*D.G. Baur et al*). Bitcoin's risk-reducing properties are weak and marginal, largely due to its high volatility [14]. Additionally, the correlation analysis between BTC and other major assets (QQQ, DXY, SPY, GLD) shows consistently low correlations across various time frames. In Table 11, where correlation is on a monthly time basis from 2017 to 2023, the correlation between BTC and QQQ, DXY, SPY, and GLD is 0.13, 0.12, 0.20, and -0.236, respectively. In Table 12, the daily correlation is much lower: the correlation between BTC and QQQ, SPY, and GLD are all negative, and BTC's correlation with DXY is only around 0.07. These low values further suggests that Bitcoin does not provide a robust hedge against equity market risks. While cryptocurrencies like Bitcoin and Ether showed some hedging effectiveness (20%-40%) for the S&P 500 in 2022, they also demonstrated a volatile hedge ratio [15]. This volatility necessitates frequent rebalancing to maintain an optimal hedge, which increases the cost and complexity of hedging. Therefore, Bitcoin has only a marginal impact on mitigating equity market risks, making it an unreliable hedge instrument due to its high volatility and unstable performance.

Since Bitcoin is not a hedge asset in the portfolio, and QQQ and SPY are expected to provide higher returns, the allocation to assets like GLD and DXY must be increased to stabilize the portfolio's weighted volatility. As a result, GLD and DXY together comprise more than 50% of the portfolio allocation. In Table 10, if Bitcoin is excluded from the portfolio, it would result in a higher allocation to other assets, particularly the DXY, which increases to 37%. The Sharpe ratio also improves significantly, exceeding the maximum Sharpe ratio achieved when Bitcoin is included. Interestingly, the allocations to other equities, such as GLD, SPY, QQQ, and others, remain relatively unchanged. One possible explanation for this shift is the higher liquidity of DXY compared to GLD. The U.S. dollar, which underpins the DXY, is constantly interacting with other major currencies such as the British Pound, Canadian Dollar, and others. As Bitcoin is removed from the portfolio, the need for the buffer provided by GLD to mitigate the risks and volatility associated with BTC diminishes. Instead, to compensate for the lost liquidity and returns from Bitcoin, the portfolio reallocates more into DXY, which offers a more stable balance in terms of liquidity and return. In summary, to optimize the Sharpe ratio of a portfolio, it is often more effective to invest in stable equities with predictable returns and lower volatility, rather than relying on high-risk, high-reward assets like Bitcoin, especially when a certain level of liquidity and return has already been secured.

4. Conclusion

In my study, I investigate Bitcoin's role within a diversified portfolio. First, I analyze the characteristics of the five equities included in my portfolio over an approximately five-year period, calculating variables that assess their performance and investment potential. Specifically, I focus on their behavior during the early stages of the COVID-19 pandemic, particularly the first half of 2020. This period provides insight into each equity's resilience under economic stress and the impact of government stimulus on their recovery. I also examine correlations among the equities during this period, which are notably stronger than in the overall five-year dataset. Second, I construct a portfolio to maximize the Sharpe ratio, testing the optimal allocation step-by-step. Once the optimal ratio is found, I recalculate it after excluding Bitcoin, noting that the Sharpe ratio remains relatively stable retaining around 80% of its value even without Bitcoin. Finally, I assess Bitcoin's potential as an instrument to increase the Sharpe ratio in a portfolio, especially given the prevalence of cryptocurrency fraud.

My findings suggest that it is unnecessary to include Bitcoin in a portfolio, given the Sharpe ratio is not higher than when Bitcoin is excluded in the same portfolio. Just as the Interactive Brokers Chairman Thomas Peterffy says, "I think it can go to zero, and I think it can go to a million dollars. I have no idea." Investing in Bitcoin wisely will give investors a wealth of return, due to this high volatility and return, but it does mean people will not earn money when Bitcoin is excluded from their portfolio. They are still able to earn the amount of it, given the high Sharpe ratio of the portfolio when bitcoin is excluded.

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Appendix A: Variable Definitions

Variables	Description	Formula
Main variables		
Average monthly return	Consider daily return as an example: I find the percentage change in the closing value from one day to the next. In the case of monthly returns, I calculate the percentage change from the start of the month to the last day of the month. To determine the average return over a period, I sum the individual monthly returns and divide by the total number of months under consideration.	$\frac{\text{closingPrice}_{\text{EN}}}{\text{closingP}_{\text{SN}}} - 1$ $closingPrice_{SN}$: closing price of the stock on the start day of month N $closingPrice_{EN}$: closing price of the stock on the end day of month N
Average monthly volatility	the degree of variation in an asset's price over a given period. It is commonly measured by calculating the standard deviation of returns during that period, which provides an indication of how much the price fluctuates. In my study, I use the STDEV equation in Excel to calculate volatility	$\sigma * \sqrt{\text{T}}$ σ: standard deviation of monthly return T: number of periods in the time horizon In the study, I used the formula $STDEV.S(monthly\ return)$ in Excel to calculate monthly volatility
Average monthly maximum drawdown	a metric that measures the largest percentage decline in the value of an investment from its peak to its lowest point over a specific period. It is calculated by identifying the highest and lowest values of the asset during the time frame and then determining the percentage decrease from the peak to the trough.	$\frac{\text{L}_{\text{N}}}{\text{MAXH}_{\text{N}}} - 1$ L_N: the low price of stock on the last day of month N $MAXH_N$: the maximum high price of a stock in the month N
Monthly skewness	Skewness measures the asymmetry of a data distribution. A skewed distribution indicates that the data points tend to be concentrated on one side of the mean. If the majority of values are concentrated on the left with a long right tail, the distribution is positively skewed. Conversely, if the majority of values are on the right with a long left tail, the distribution is negatively skewed. A skewness of 0 indicates a symmetric distribution. Skewness is calculated using the following formula:	$\text{N} * \frac{\sum(\text{x}_\text{i} - \bar{\text{x}})^3}{(\text{N}-1)(\text{N}-2) * \sigma^3}$ N: numbers of monthly samples x_i:i^{th} monthly sample $\bar{x}$: monthly sample mean σ: monthly sample standard deviation In the study, I used the formula SKEW(monthly return samples) in Excel to calculate monthly skewness

Monthly kurtosis	Kurtosis measures the "tailedness" of a distribution, indicating the presence of outliers by comparing the shape of the tails to that of a normal distribution. If the kurtosis is greater than 3, the distribution is leptokurtic, meaning it has a higher peak and heavier tails than a normal distribution, suggesting more extreme values (outliers). If the kurtosis is less than 3, the distribution is platykurtic, meaning it has a flatter peak and lighter tails, indicating fewer outliers. A mesokurtic distribution has a kurtosis close to 3, resembling a normal distribution in terms of its peak and tail shapes. Kurtosis is calculated using the following formula:	$\frac{N(N+1)}{(N-1)(N-2)(N-3)} * \sum(\frac{x_i - \bar{x}}{\sigma})^4 - \frac{3(N-1)^2}{(N-2)(N-3)}$ N: numbers of monthly samples x_i:i^{th} monthly sample $\bar{x}$: monthly sample mean σ: monthly sample standard deviation In the study, I used the formula KURT(monthly return samples) in Excel to calculate monthly kurtosis.
Annualized monthly Sharpe ratio	a widely used method for measuring risk-adjusted returns. By taking both return and volatility into account, it provides a more balanced metric than analyzing volatility or return in isolation, helping to reduce potential biases. This formula scales the monthly data to an annual timeframe. Similarly, when calculating a weighted daily Sharpe Ratio, I use the power of 365 for the adjusted daily return, while for a weighted weekly Sharpe Ratio, I use the power of 52 for the adjusted weekly return.	$\frac{R}{V} * \sqrt{52}$ R: average monthly return V: average monthly volatility $\sqrt{52}$: annualizing factor

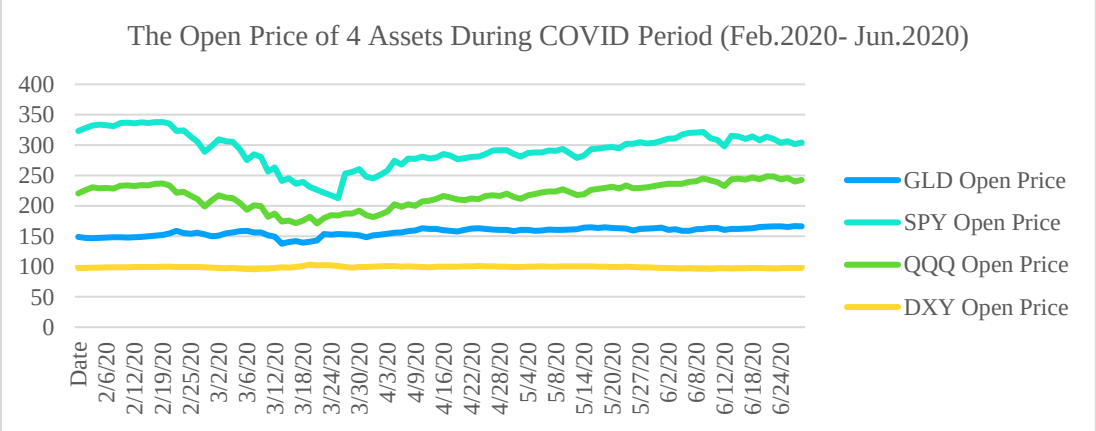

Figure 1. The Open Price of 4 Assets During COVID Period (Feb.2020-Jun.2020)

This figure represents the variation of the open price of the assets from a specific period in 2020. The data are collected from Yahoo Finance.

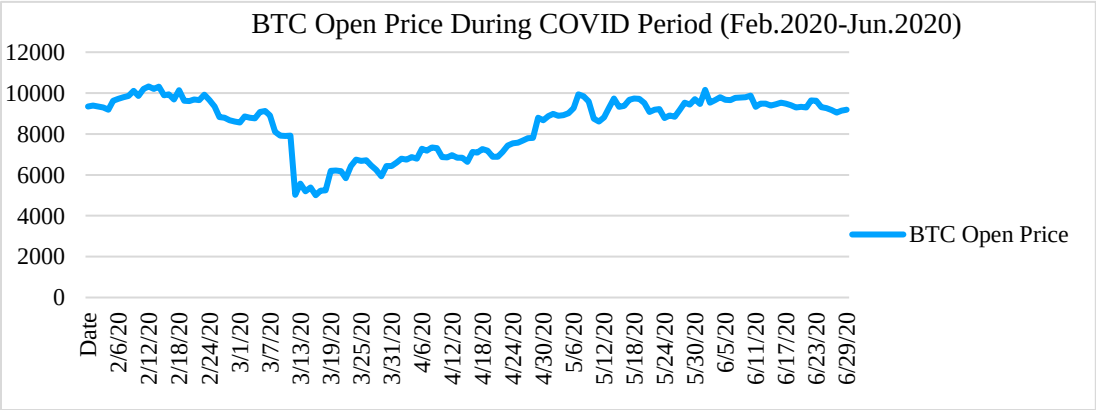

Figure 2. BTC Open Price During COVID Period (Feb.2020-Jun.2020)

This figure shows the variation of the open price of Bitcoin during the same period as mentioned in Figure 1. Data are also collected from Yahoo Finance.

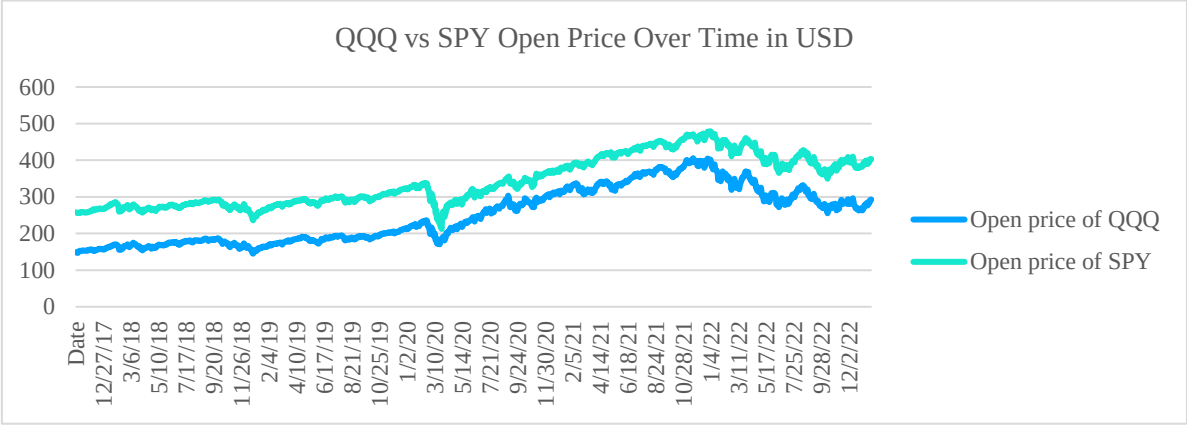

Figure 3. QQQ vs SPY Over Time

This figure represents the Open Price of QQQ and SPY from October 2017 to January 2023. I collect the open prices of these two assets and create this line chart. The price is in USD.

Table 1. Descriptive Statistics of QQQ

QQQ						
	Return	Volatility	MaxDD	Skewness	Kurtosis	Sharpe Ratio
Daily	%	%	%	-0.36		
Weekly	%	%	%	-0.33		
Monthly	%	%	%	-0.11		
Annually	%	2%	%	-0.63		

This table presents summary statistics of QQQ for the six variables used in this study, covering the period from October 2017 to January 2023. Variable definitions can be found in Appendix A. For each variable, values are calculated based on various time intervals, as listed in the column headings.

Table 2. The value of the main variables for DXY from 11/2017-1/2023

DX-Y.NYB						
	Return	Volatility	MaxDD	Skewness	Kurtosis	Sharpe Ratio
Daily	%	%	%	-0.08		
Weekly	%	%	%			
Monthly	%	%	%	-0.32		
Annually	%	%	%	-0.20	-1.15	

This table presents summary statistics of DXY for the six variables used in this study, covering the period from October 2017 to January 2023. Variable definitions can be found in Appendix A. For each variable, values are calculated based on various time intervals, as listed in the column headings.

Table 3. The value of the main variables for SPY from 11/2017-1/2023

SPY						
	Return	Volatility	MaxDD	Skewness	Kurtosis	Sharpe Ratio
Daily	%	%	%	-0.54		
Weekly	%	%	%	-0.72		
Monthly	%	%	%	-0.34		
Annually	%	%	%	-0.26	-0.79	

This table presents summary statistics of SPY for the six variables used in this study, covering the period from October 2017 to January 2023. Variable definitions can be found in Appendix A. For each variable, values are calculated based on various time intervals, as listed in the column headings.

Table 4. The value of the main variables for GLD from 11/2017-1/2023

GLD						
	Return	Volatility	MaxDD	Skewness	Kurtosis	Sharpe Ratio
Daily	%	%	%	-0.27		
Weekly	%	%	%	-0.22		
Monthly	%	%	%			
Annually	%	%	%		-0.43	

This table presents summary statistics of GLD for the six variables used in this study, covering the period from October 2017 to January 2023. Variable definitions can be found in Appendix A. For each variable, values are calculated based on various time intervals, as listed in the column headings.

Table 5. The value of the main variables for BTC from 11/2017-1/2023

BTC						
	Return	Volatility	MaxDD	Skewness	Kurtosis	Sharpe Ratio
Minutely	0.00%	0.12%	27.40%	0.78	253.01	0.00
Hourly	0.00%	0.89%	12.56%	0.10	21.62	0.00
Daily	0.07%	4.20%	16.86%	0.30	6.09	0.26
Weekly	0.53%	11.74%	33.40%	0.39	1.18	0.33
Monthly	1.28%	24.49%	50.45%	1.32	1.57	0.18
Annually	27.40%	52.43%	78.43%	-0.64	-2.00	0.52

This table presents summary statistics of BTC for the six variables used in this study, covering the period from October 2017 to January 2023. Variable definitions can be found in Appendix A. For each variable, values are calculated based on various time intervals, as listed in the column headings.

Table 6. Correlation between Bitcoin and all 4 other assets

Correlation	BTC to QQQ	BTC to DXY	BTC to SPY	BTC to GLD
Daily	-0.07	-0.08		-0.02
Weekly				-0.04
Monthly				-0.24
Annually				

This table presents summary statistics of the correlation between Bitcoin and all 4 other assets from October 2017 to January 2023. Correlation coefficients are calculated based on various time intervals, as listed in the column headings,

Table 7. Correlation between Bitcoin and all 4 other assets from February 2020 to June 2020

Correlation	BTC to QQQ	BTC to DXY	BTC to SPY	BTC to GLD
Daily	-0.13	-0.17		-0.08
Weekly				
Monthly				

This table shows summary statistics for the correlation between Bitcoin and each of the other four assets during the period from February 2020 to June 2020—a time when COVID-19 was significantly impacting global markets. The analysis aims to determine if the correlation between Bitcoin and these assets experienced substantial shifts during this period of heightened uncertainty, compared to a long-term perspective.

Table 8. Portfolio Management: weight statistics

BTC weight	GLD weight	QQQ weight	SPY weight	DXY weight	monthly volatility	monthly averaged return	monthly cumulative return	weighted annualized Sharpe ratio	weighted kurtosis	weighted skewness
%	%	%	%	%	%	%	%			-0.19
%	%	%	%	%	%	%	%			-0.19
%	%	%	%	%	%	%	%			-0.18
%	%	%	%	%	%	%	%			-0.14
%	%	%	%	%	%	%	%			-0.28
%	%	%	%	%	%	%	%			-0.28
%	%	%	%	%	%	%	%			-0.26
%	%	%	%	%	%	%	%			-0.19
%	%	%	%	%	%	%	%			-0.16
%	%	%	%	%	%	%	%			-0.17
%	%	%	%	%	%	%	%			-0.18
%	%	%	%	%	%	%	%			-0.18
%	%	%	%	%	%	%	%			-0.26
%	%	%	%	%	%	%	%			-0.27
%	%	%	%	%	%	%	%			-0.28
%	%	%	%	%	%	%	%			-0.25
%	%	%	%	%	%	%	%			-0.11
%	%	%	%	%	%	%	%			-0.11
%	%	%	%	%	%	%	%			-0.12
%	%	%	%	%	%	%	%			-0.15
%	%	%	%	%	%	%	%			-0.22
%	%	%	%	%	%	%	%			-0.23
%	%	%	%	%	%	%	%			-0.24
%	%	%	%	%	%	%	%			-0.25

This table presents summary statistics for the weighted values of the six variables based on different portfolio compositions. To specify each asset's weight, I varied the Bitcoin allocation between 3% and 5%. For each Bitcoin allocation, Gold's weight was set at either 10% or 15%. Since QQQ and SPY are high-return assets, I assigned them the same weight, making it the highest in the portfolio, ranging from 20% to 35% in 5% increments across portfolios. Finally, DXY filled the remaining allocation, varying between 10% and 45%. In total, 24 unique portfolio combinations were created.

Table 9. Portfolio Management: Sharpe ratio is maximized with Bitcoin included

Asset name	Asset Weight
GLD	24.76%
QQQ	28.11%
SPY	15.10%
DXY	28.11%
BTC	3.92%
average monthly weighted return	0.45%
weighted volatility	0.01
maximized weighted Sharpe ratio	1.25

This table represents the portfolio configuration that maximizes the Sharpe ratio when Bitcoin is included, determined using the solver model described in section 3.2. The asset weights are displayed below, with the corresponding weighted return, volatility, and Sharpe ratio listed at the bottom of the table.

Table 10. Portfolio Management: Sharpe ratio is maximized with Bitcoin excluded

Asset name	Asset Weight
GLD	21.79%
QQQ	26.93%
SPY	14.34%
DXY	36.93%
average monthly weighted return	0.25%
weighted volatility	0.01
maximized weighted Sharpe ratio	1.60

This table represents the portfolio configuration that maximizes the Sharpe ratio when Bitcoin is excluded, determined using the solver model described in section 3.2. The asset weights are displayed below, with the corresponding weighted return, volatility, and Sharpe ratio listed at the bottom of the table.

Table 11. Correlation between assets over time (monthly)

	DXY	SPY	GLD	BTC
QQQ	-0.05	0.94	0.29	0.13
DXY		0.003	-0.08	0.12
SPY			0.28	0.20
GLD				-0.24

This table represents the correlation between each asset from October 2017 to January 2023. I calculated these correlations using the CORREL formula in Excel. First, I determined the daily returns for each asset over this period and then calculated the monthly correlations between assets based on these returns, as monthly data is sufficient for this analysis.

Table 12. Correlation between assets during COVID (daily)

	DXY	SPY	GLD	BTC
QQQ	-0.32	0.84	0.30	-0.13
DXY		-0.38	-0.65	0.07
SPY			0.35	-0.17
GLD				-0.08

The second table shows the correlations between assets during the Covid period, specifically from February 2020 to June 2020. Again, I used the CORREL formula, but since this period covers only five months, I calculated daily correlations instead of monthly to include more return data and improve accuracy.