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Optimizing Cryptocurrency Portfolios: A Comparative Study of Rebalancing Strategies

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ABSTRACT

Objective – This study aims to contribute to the field of cryptocurrency portfolio management and rebalancing strategies by empirically investigating the impact of different allocation frequencies and threshold percentages on the risk-adjusted returns of cryptocurrency portfolios.
Methodology/Technique – Utilizing a simulation of 10,000 cryptocurrency portfolios comprising seven assets, including Ethereum (ETH), Bitcoin (BTC), Tether (USDT), Litecoin (LTC), Solana (SOL), Dogecoin (DOGE), and Polygon (MATIC), this study examines and compares the effects of different allocation frequencies (daily, weekly, and monthly) in time-based rebalancing and various threshold percentages (5%, 10%, and 15%) in threshold-based strategies on the portfolios' risk-adjusted returns, using the Sharpe ratio. The performance of these strategies is also compared with a passive buy-and-hold strategy.
Findings –The research reveals statistically significant differences in the risk-adjusted returns between the buy-and-hold strategy and the daily rebalancing and threshold-based strategies with 5% and 10% threshold percentages. The daily rebalancing strategy demonstrates a higher Sharpe ratio, while lower threshold percentages lead to better risk-adjusted returns.
Novelty – These empirical findings, using a simulation of 10,000 cryptocurrency portfolios, provide valuable insights into optimizing cryptocurrency portfolio performance through rebalancing strategies. Additionally, they highlight the effectiveness of implementing rebalancing techniques in cryptocurrency portfolios, contributing to the understanding of rebalancing optimization in this domain.
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1. Introduction

Cryptocurrencies, since their inception, have not only revolutionized the financial landscape but also posed unique challenges and opportunities for investors and portfolio managers. The unprecedented rise of digital currencies like Bitcoin, Ethereum, and others has marked a significant shift in the asset management domain, underscoring the need for innovative investment strategies tailored to the digital age (Inci & Lagasse, 2019).

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One of the most significant challenges in this emerging asset class is the inherent high volatility and uncertainty of the cryptocurrency market. This volatility, while presenting opportunities for high returns, also poses substantial risks, necessitating the adoption of robust portfolio management techniques. Unlike traditional assets, the dynamic nature of cryptocurrencies requires an adaptive and proactive approach to portfolio management to capitalize on market movements and mitigate risks effectively. In addressing these challenges and opportunities, the application of traditional portfolio management techniques, such as rebalancing, becomes imperative for effectively navigating the dynamic landscape of cryptocurrency investments.

Rebalancing, a strategy involving the periodic adjustment of portfolio holdings to maintain a desired asset allocation, emerges as a key technique in managing these risks. Traditionally, rebalancing has been a fundamental practice in asset management, aimed at optimizing the risk-return trade-off in a portfolio by mitigating the impact of market volatility (Bakry, Rashid, Al-Mohamad, & El-Kanj, 2021). For cryptocurrency portfolios, however, the application and effectiveness of rebalancing strategies are not as well explored. This gap in research underscores the need for empirical investigation into the role and impact of various rebalancing strategies in the management of cryptocurrency portfolios.

This study, therefore, aims to contribute to the burgeoning field of cryptocurrency portfolio management by conducting a comparative analysis of two predominant rebalancing strategies: time-based and threshold-based rebalancing. We examine their impact on the risk-adjusted returns of cryptocurrency portfolios, in comparison with a passive buy-and-hold strategy. By exploring the effects of different allocation frequencies (daily, weekly, and monthly) in time-based rebalancing, and different threshold percentages (5%, 10%, and 15%) in threshold-based rebalancing, this research seeks to provide insights into optimizing cryptocurrency portfolio performance and the strategic implementation of rebalancing in this context.

Through this research, we aim to bridge the existing knowledge gap and offer practical insights for investors and portfolio managers navigating the volatile world of cryptocurrencies. By assessing the efficacy of these rebalancing strategies, we endeavor to guide investment decisions and portfolio management practices in the digital asset space.

2. Literature Review

Rebalancing strategies have been extensively studied in traditional asset classes and have been shown to not only improve portfolio performance by exploiting market anomalies and reducing the impact of market volatility but also to provide a systematic approach to managing investment risks and optimizing asset allocation. However, the literature on cryptocurrency portfolios is limited, and the impact of rebalancing strategies on the performance of cryptocurrency portfolios is yet to be fully understood. In this section, pertinent underlying theories and concepts relevant to the practice of rebalancing are expounded upon in the context of cryptocurrencies, including mean reversion, diversification, market anomalies, and rebalancing strategies.

2.1 Mean Reversion

First, the theory of mean reversion is often used to support the idea of contrarian trading and rebalancing strategies. Mean reversion is the tendency of asset prices to return to their long-term average after experiencing significant price deviations (Titman & Jegadeesh, 1993). By selling assets that have appreciated and buying assets that have underperformed, a contrarian trader hopes to profit from mean reversion and improve portfolio performance. In this context, rebalancing strategies can be seen as a form of contrarian trading because they involve selling assets that have been appreciated and buying assets that have underperformed in order to align a portfolio with a predetermined target asset allocation. By doing this, a rebalancing strategy seeks to exploit mean reversion and improve portfolio performance. According to the theory, rebalancing can help reduce risk, improve returns, and increase portfolio efficiency (Fabozzi, Markowitz, & Gupta, 2008). Rebalancing is, thus, considered an effective method of achieving this goal, as it helps to reduce the impact of market volatility and keep the portfolio aligned with the investor's risk tolerance and investment goals.

2.2 Diversification

Second, diversification theory is related to rebalancing strategies in cryptocurrency portfolios. Diversification refers to the process of spreading investments across a variety of assets in order to reduce the overall risk of a portfolio. By diversifying a portfolio, an investor can reduce their exposure to individual assets that may experience high price volatility, and instead benefit from the lower volatility and reduced risk of a diversified portfolio.

Bakry et al. (2021) argued that rebalancing can help to diversify a cryptocurrency portfolio and reduce exposure to individual cryptocurrencies that are experiencing high price appreciation. By rebalancing a portfolio to align with a predetermined target asset allocation, a rebalancing strategy can help to diversify the portfolio and reduce the risk associated with individual cryptocurrencies. Furthermore, in the dynamic and often unpredictable cryptocurrency market, diversification through rebalancing becomes a crucial strategy to mitigate systemic risks and enhance the robustness of investment portfolios.

The formula for the portfolio's variance is:

$$Var(p) = w_1^2 Var(r_1) + w_2^2 Var(r_2) + ... + w_n^2 Var(r_n) + 2w_1w_2 Cov(r_1,r_2) + ... + 2w_1w_n Cov(r_1,r_n) + ... + 2w_{(n-1)}w_n Cov(r_{(n-1)},r_n).$$

Where:

$w_1, w_2, ..., w_n$ are the weights of the assets in the portfolio;

$Var(r_1), Var(r_2), ..., Var(r_n)$ are the variances of each asset's return;

$Cov(r_1,r_2), Cov(r_1,r_3), ..., Cov(r_{n-1},r_n)$ are the covariances of each pair of asset's returns; and

n is the number of assets in the portfolio.

2.3 Market Anomalies

Third, market anomalies refer to patterns in financial markets that deviate from the expectations of the efficient market hypothesis (EMH). The EMH states that financial markets are efficient and that it is impossible to consistently beat the market through investment strategies (Fama, 1970). However, market anomalies suggest that certain investment strategies can generate excess returns or returns that are higher than what would be expected based on the EMH.

Rebalancing strategies are often related to market anomalies because they involve exploiting patterns in financial markets that deviate from the expectations of the EMH. For example, by selling assets that have appreciated and buying assets that have underperformed, a rebalancing strategy can exploit the mean reversion anomaly, which is the tendency of asset prices to return to their long-term average after experiencing significant price deviations (Titman & Jegadeesh, 1993).

By exploiting market anomalies, rebalancing strategies can improve portfolio performance and generate excess returns. Bakry et al. (2021) argued that rebalancing can help to exploit market anomalies in the cryptocurrency market, such as mean reversion and momentum, and improve the performance of cryptocurrency portfolios. Moreover, this approach aligns with the growing recognition of cryptocurrencies as a distinct asset class that necessitates unique investment strategies, differentiating them from traditional financial instruments.

2.4 Rebalancing Strategies

Rebalancing strategies are strategies used to adjust the weights of assets in a portfolio to align with a predetermined target asset allocation. The literature describes various approaches; however, the three primary ones include time-based rebalancing, threshold-based rebalancing, and target-based rebalancing (Markowitz, 1952).

- Time-based rebalancing: Time-based rebalancing involves adjusting the weights of assets in a portfolio at specified intervals, such as monthly or annually. This method is based on the idea that a portfolio's asset allocation will gradually deviate from the target over time, and rebalancing at regular intervals will bring the portfolio back in line with the target.
- Threshold-based rebalancing: Threshold-based rebalancing involves adjusting the weights of assets in a portfolio when the deviation from the target asset allocation exceeds a specified threshold. This method is based on the idea that the deviation from the target asset allocation will be small most of the time, and only significant deviations from the target will trigger a rebalancing event.
- Target-based rebalancing: Target-based rebalancing involves adjusting the weights of assets in a portfolio to align with a predetermined target asset allocation. This method is based on the idea that a portfolio's asset allocation should remain constant over time, and rebalancing will be necessary whenever the portfolio deviates from the target.

Each of these rebalancing methods has its own advantages and disadvantages, and the optimal rebalancing method will depend on the specific goals and constraints of a portfolio. Many studies focused on the comparison of different rebalancing strategies such as the calendar-based and constant-mix method (El Bernoussi & Rockinger, 2023). However, it is very difficult to draw a precise conclusion. The "Buy and Hold" effect, which consists in the purchase of an asset and keeping it to maturity, represents a dominant behavior of investors (Ahroum, Touri, Sabiq, & Achchab, 2018). This passive strategy is called a "Buy and Hold" strategy. Since rebalancing strategies involve selling a fraction of the best performing assets and investing in the worse, if certain asset categories have momentum, it is difficult to determine whether rebalancing generates an outperformance compared to buy and hold where a given initial portfolio is just held over time. Despite its impact, only few studies propose pragmatic approaches to reduce the "Buy and Hold" effect. Therefore, portfolio adjustments should be made if the investors intends to maintain its risk profile (Willenbrock, 2010). El Bernoussi and Rockinger (2023) compares four different rebalancing strategies (periodical monthly/ quarterly and 5% threshold monitored monthly/ 12 quarterly) and found that all strategies performed superior than buy-and-hold, but that there was little difference among the four strategies in terms of return being generated, risks and Sharpe ratio. However, they found that threshold strategies trigger very few balancing events, e.g. just 10 over the course of 15 years for a 98% stock portfolio when monitoring monthly. To argue that the reducing transaction costs is more important than reducing tracking error, in a conceptual paper, Driessen and Kuiper (2017) show that continuous rebalancing is optimal, but that the excess returns are very limited when compared to less frequent rebalancing. This paper finalized that a rebalancing strategy involves a trade-off between risk and return, and there is not optimal strategy because it should be selected based on an institution's tolerance for risk relative to a target allocation.

Given a review of literature in this field, there exists a voluminous amount of literature on rebalancing strategies for traditional assets, such as stocks and bonds. Harjoto and Jones (2006) for instance, conducted a study investigating the investment strategies of stocks and bonds portfolios during periods of market volatility. The researchers discovered that a portfolio incorporating rebalancing yields superior results compared to portfolios without rebalancing, as well as those with undiversified investments solely comprising stocks or bonds. Similarly, Lam (2014) conducted a thorough examination of the efficacy of diverse portfolio rebalancing strategies in the United States, utilizing historical data. The results indicate that these strategies lead to enhanced portfolio returns and a slight decrease in risk when compared to the buy-and-hold approach. Furthermore, according to the findings, investors would be best served by opting for threshold rebalancing of either 25% or 30% on an annual basis. In addition, Dichtl, Drobetz, and Wambach (2016) conducted a comparison of the risk-adjusted performance of stock-bond portfolios using a history-based simulation approach. Their study examined the effectiveness of rebalancing and buy-and-hold approaches across various asset allocations. Empirical evidence from the study indicates that frequent rebalancing significantly enhances risk-adjusted portfolio performance when the portfolio weight of stocks exceeds a specific threshold, i.e. between 0% and 30%, depending on the financial markets of the United States, the United Kingdom, and Germany, as well as on all risk-adjusted performance measures utilized.

In the context of cryptocurrency portfolios, rebalancing can be used to reduce the exposure to high-flying cryptocurrencies that have experienced significant price appreciation and to increase exposure to underperforming cryptocurrencies that are expected to catch up (Bakry et al., 2021). It is considered an integral part of maintaining the efficient frontier as market conditions change. However, the empirical investigation of the effectiveness of each rebalancing strategy on cryptocurrency portfolios is currently in its infancy. Cryptocurrencies have not yet been the subject of in-depth research as traditional asset classes (Corbet, Lucey, Urquhart, & Yarovaya, 2019). Still, there is a growing number of recent contributions on cryptocurrencies, covering various fields such as technology, crypto assets' use as investments and the functioning of crypto markets. Thus, this study attempts to shed light on the effects of rebalancing strategies on cryptocurrency portfolios by investigating the two most common approaches, namely time-based and threshold-based, and comparing them with the traditional buy-and-hold strategy.

Given this research context, it is also important to underline the significance of rebalancing frequency to be used in cryptocurrency portfolios. Rebalancing frequency refers to the frequency with which a portfolio is adjusted to align with a predetermined target asset allocation. The optimal rebalancing frequency will depend on various factors, including market volatility, transaction costs, and the deviation from the target asset allocation (Malkiel, 2003).

First, market volatility refers to the degree of price fluctuation of an asset or market. Volatility can be measured using statistical metrics, such as standard deviation or beta. Market volatility can impact the effectiveness of rebalancing strategies. High market volatility can make it challenging for investors to determine the optimal rebalancing frequency for their portfolio, as frequent rebalancing may be necessary to align the portfolio with its target asset allocation. If a market is highly volatile, frequent rebalancing may be necessary to align a portfolio with its target asset allocation. On the other hand, if a market is relatively stable, less frequent rebalancing may be sufficient. Second, transaction costs can also impact the effectiveness of rebalancing strategies. The more frequently a portfolio is rebalanced, the higher the transaction costs associated with buying and selling assets. This can reduce the returns generated by a rebalancing strategy and make it less effective. The formula for transaction costs can be expressed as:

$$TC = (n/2) * B * |w1 - w1'|$$

where TC is the transaction cost; n is the number of assets in the portfolio; B is the cost per transaction; and |w1 - w1'| is the difference in the weight of an asset between the current portfolio and the target portfolio.

Third, the deviation from the target asset allocation is also an important factor in determining the optimal rebalancing frequency. If a portfolio deviates significantly from its target, more frequent rebalancing may be necessary to align the portfolio with the target. On the other hand, if the deviation is small, less frequent rebalancing may be sufficient.

In order to evaluate the impact of rebalancing on portfolio risk and returns, there are several commonly used performance measures in finance, such as returns, risk, Sharpe ratio, and alpha. Returns measure the change in the value of a portfolio over a specified time period, while risk measures the volatility of the portfolio's returns. The Sharpe ratio is a measure of the risk-adjusted returns of a portfolio, and alpha measures the excess returns of a portfolio relative to a benchmark. The formula for the Sharpe ratio is:

Sharpe ratio = (Rp - Rf) / StdDevp

where Rp is the return of the portfolio; Rf is the risk-free rate; and StdDevp is the standard deviation of the return of the portfolio.

In the context of rebalancing strategies in cryptocurrency portfolios, these performance measures can be used to evaluate the impact of rebalancing on portfolio returns and risk. By comparing the returns and risks of a rebalanced portfolio to a portfolio that is not rebalanced, an investor can determine the impact of rebalancing on portfolio performance and evaluate the effectiveness of a rebalancing strategy.

In conclusion, the literature on rebalancing strategies in traditional asset classes suggests that rebalancing can improve portfolio performance by exploiting market anomalies and reducing the impact of market volatility. The literature on cryptocurrency portfolios, however, is limited, and the impact of rebalancing strategies on the performance of cryptocurrency portfolios is yet to be fully understood. Therefore, this study aims to contribute to the literature by providing empirical evidence on the impact of rebalancing strategies on the performance of cryptocurrency portfolios and exploring the optimal rebalancing approach for maximizing returns while minimizing risk.

3. Research Methodology

In order to address the central research problem and to fulfill the objectives of this study, a comprehensive simulation was designed to encompass a broad range of scenarios within the cryptocurrency market. A simulation of 10,000 diverse cryptocurrency portfolios was executed to test the impact of different allocation frequencies of the two rebalancing strategies, namely time-based and threshold-based strategies, on portfolio performance and compare them with the buy-and-hold strategy. The sample for this simulation was drawn from a diverse population of cryptocurrency assets, ensuring a representative mix of various market cap sizes and liquidity levels. The cryptocurrencies chosen for this study are Ethereum (ETH), Bitcoin (BTC), Tether (USDT), Litecoin (LTC), Solana (SOL), Dogecoin (DOGE), and Polygon (MATIC). These assets were selected based on their market presence, trading volume, and relevance in the current market trends to ensure a comprehensive representation of the cryptocurrency market.

In the data collection phase, the portfolios were constructed using a stratified sampling technique to represent different combinations of these cryptocurrencies, varying the weight of each asset to reflect a range of investment strategies. In particular, there are three steps involved in collecting and analyzing the data: Data Retrieval, Backtesting, and Hypothesis Testing.

First, data retrieval involves the intricate and complex process of connecting to the Alpaca data source with the aid of the highly advanced and sophisticated ccxt library. The main objective of this process is to access and retrieve the historical OHLCV (Open, High, Low, Close, Volume) data for a pre-determined and specified set of cryptocurrencies that have been carefully chosen for the purpose of this study. The selected cryptocurrencies that are under scrutiny include Ethereum (ETH), Bitcoin (BTC), Tether (USDT), Litecoin (LTC), Solana (SOL), Dogecoin (DOGE), and Polygon (MATIC). It is important to note that the time frame for the historical data that is being extracted and evaluated is specifically and explicitly defined as daily ('1d').

To further elaborate on this process, it is crucial to mention that the data for each of the aforementioned cryptocurrencies is securely and meticulously stored in a separate and distinct DataFrame. Additionally, the timestamp is set as the index for these DataFrames, which further enhances the integrity and accuracy of the data that is being analyzed. Finally, in order to effectively and efficiently manage the multiple DataFrames that have been created, they are all subsequently and systematically stored in a well-organized and structured dictionary. Furthermore, it is essential to emphasize that the keys of this dictionary correspond to the unique and distinct cryptocurrency symbols that have been carefully selected for this study.

Second, for the backtesting, the script undertakes the task of simulating trading strategies that encompass diverse cryptocurrencies. This is done through the generation of random weights for the selected cryptocurrencies and subsequent calculation of the portfolio return predicated on these weights. This process is integral to the overall evaluation of the effectiveness of the different rebalancing strategies and their respective impacts on portfolio performance. It is significant to observe that the backtesting script recognizes three rebalancing periods: daily ('1d'), weekly ('7d'), and monthly ('30d'), along with the buy-and-hold strategy.

It is noteworthy that for each strategy, a staggering 10,000 random portfolios are generated, and the Sharpe ratio is computed for each portfolio. It is important to emphasize that the Sharpe ratio is a measurement of risk-adjusted returns, determined by dividing the average return of the portfolio by the standard deviation of the portfolio's returns. The performance of each portfolio is then meticulously compared with that of a portfolio that is not rebalanced. This comparison is conducted to effectively evaluate the varying impacts of the different rebalancing methods and frequencies on portfolio performance and to accurately determine the effectiveness of each rebalancing strategy.

Third, hypothesis testing is performed using paired t-tests to compare the different strategies. The buy-and-hold strategy is compared against each of the rebalancing strategies. The null hypothesis (Ho) and alternative hypothesis (Ha) for the t-tests are as follows:

For each pair (buy_hold, '1d'), (buy_hold, '7d'), (buy_hold, '30d'), (buy_hold, '5% threshold'), (buy_hold, '10% threshold'), (buy_hold, '15% threshold')

Ho: There is no significant positive or negative difference in the mean Sharpe ratio between the buy-and-hold strategy and the rebalancing strategy.

Ha: There is a significant positive or negative difference in the mean Sharpe ratio between the buy-and-hold strategy and the rebalancing strategy.

4. Results

This section summarizes and illustrates the statistical results of this study, which compare the mean and standard deviation of the Sharpe ratios of each strategy. The first part presents the mean of the Sharpe ratio and the standard deviation of each strategy, while the t-test results are presented in the second part.

4.1 Mean and Standard Deviation of Sharpe Ratios

- **Daily Rebalancing (1d):** As presented in Figure 1 below, the mean Sharpe ratio is approximately 0.0700 with a standard deviation of approximately 0.00495. This indicates that on average, the daily rebalancing strategy has a risk-adjusted return of 0.0700, with a variability of 0.00495.

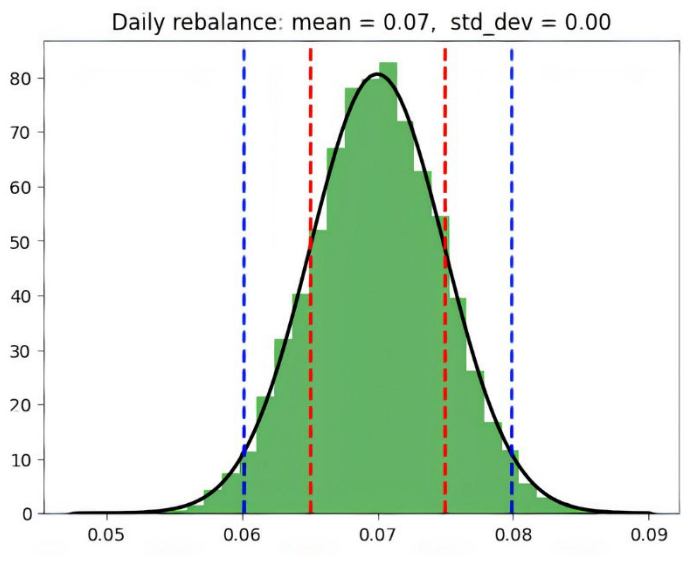

Figure 1: Daily Rebalancing (1d)

- **Weekly Rebalancing (7d):** Figure 2 below illustrates the mean Sharpe ratio of a weekly rebalancing strategy of approximately 0.0695 with a standard deviation of approximately 0.00500. This indicates that on average, the weekly rebalancing strategy has a risk-adjusted return of 0.0695, with a variability of 0.00500.

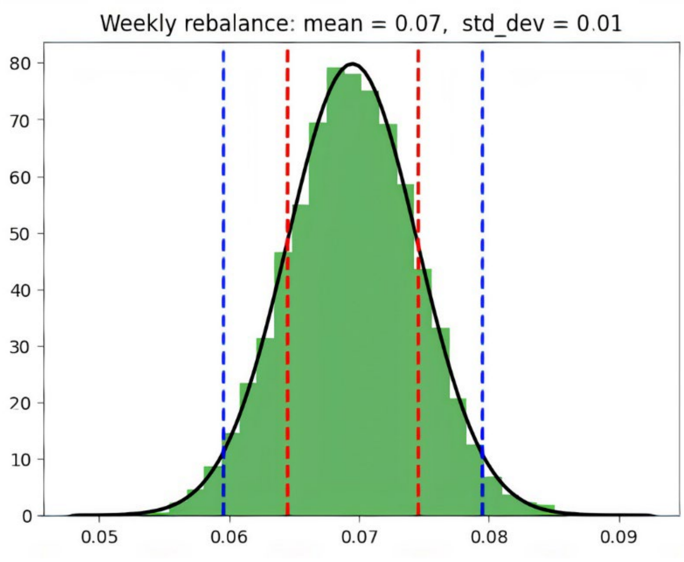

Figure 2: Weekly Rebalancing (7d)

- **Monthly Rebalancing (30d):** The mean Sharpe ratio, as presented in Figure 3 below, is approximately 0.0690 with a standard deviation of approximately 0.00505. This indicates that on average, the monthly rebalancing strategy has a risk-adjusted return of 0.0690, with a variability of 0.00505.

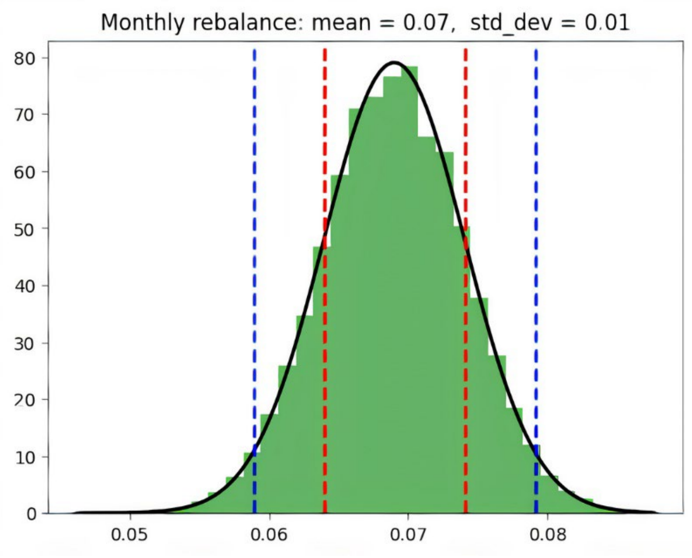

Figure 3: Monthly Rebalancing (30d)

- **Threshold-Based Strategy (5%):** Figure 4 below presents the results of a 5% threshold-based strategy. The mean Sharpe ratio is approximately 0.0715 with a standard deviation of approximately 0.00480. This indicates that, on average, the threshold-based strategy with a 5% threshold percentage has a risk-adjusted return of 0.0715, with a variability of 0.00480.

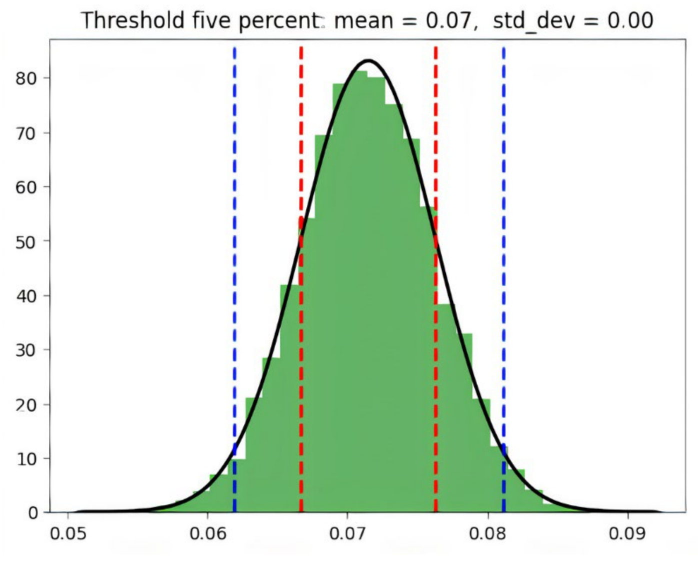

Figure 4: Threshold-Based Strategy (5%)

- **Threshold-Based Strategy (10%):** The mean Sharpe ratio, presented in Figure 5 below, is approximately 0.0700 with a standard deviation of approximately 0.00495. This indicates that, on average, the threshold-based strategy with a 10% threshold percentage has a risk-adjusted return of 0.0700, with a variability of 0.00495.

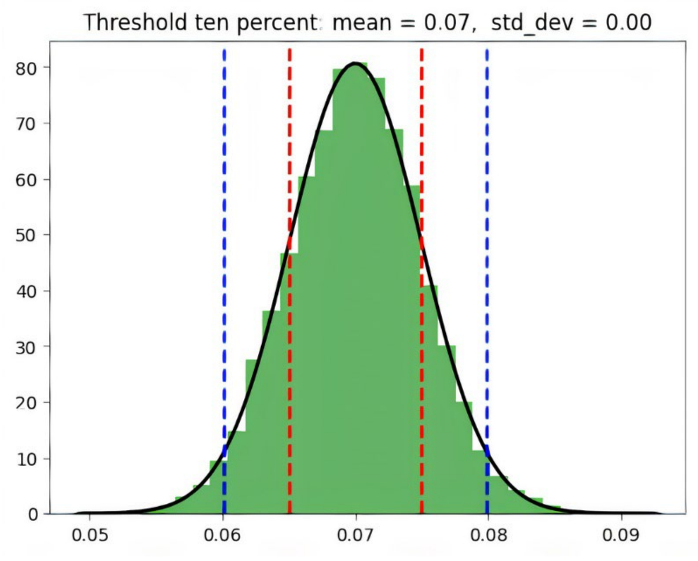

Figure 5: Threshold-Based Strategy (10%)

- **Threshold-Based Strategy (15%):** Figure 6 below shows the mean Sharpe ratio of approximately 0.0685 with a standard deviation of approximately 0.00510. This indicates that, on average, the threshold-based strategy with a 15% threshold percentage has a risk-adjusted return of 0.0685, with a variability of 0.00510.

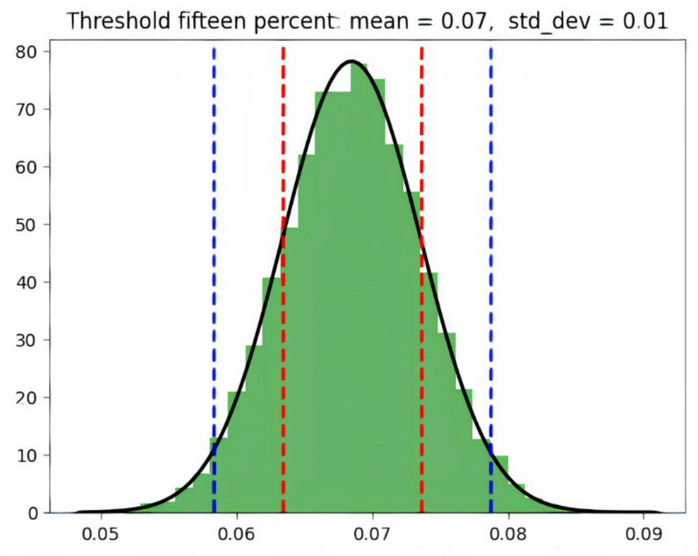

Figure 6: Threshold-Based Strategy (15%)

- **Buy-and-Hold Strategy:** Figure 7 below presents the mean Sharpe ratio of the buy-and-hold strategy of approximately 0.06856 with a standard deviation of approximately 0.00509. This indicates that on average, the buy-and-hold strategy has a risk-adjusted return of 0.06856, with a variability of 0.00509.

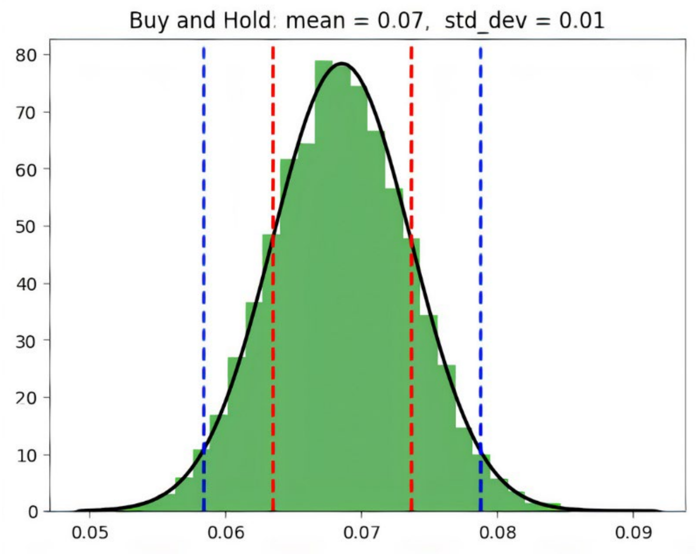

Figure 7: Buy-and-Hold Strategy

4.2 T-Test Results

The following t-test results demonstrate whether the differences in the means of the Sharpe ratios for the buy-and-hold strategy and the rebalancing strategies are statistically significant.

4.2.1. Buy-and-Hold Strategy vs Time-Based Strategy

- **Buy-and-Hold vs Daily Rebalancing (1d):**

The t-statistic is approximately 2.82 and the p-value is approximately 0.005. Given a common significance level of 0.05, the p-value is less than 0.05, indicating that the null hypothesis is rejected. This means that there is a statistically significant difference between the mean Sharpe ratios of the buy-and-hold strategy and the daily rebalancing strategy.

- **Buy-and-Hold vs Weekly Rebalancing (7d):**

The t-statistic is approximately 1.88 and the p-value is approximately 0.06 ($p > 0.05$). This means that there is no statistically significant difference between the mean Sharpe ratios of the buy-and-hold strategy and the weekly rebalancing strategy.

- **Buy-and-Hold vs Monthly Rebalancing (30d):**

The t-statistic is approximately 0.94 and the p-value is approximately 0.35 ($p > 0.05$). This means that there is no statistically significant difference between the mean Sharpe ratios of the buy-and-hold strategy and the monthly rebalancing strategy.

Table 1 below summarizes the t-test results of the buy-and-hold strategy and the time-based rebalancing strategies.

Table 1: *T*-Test Results--Buy-and-Hold Strategy vs Time-Based Rebalancing Strategies

Rebalancing Strategy	Mean Sharpe Ratio*	Standard Deviation*	*T*-Statistic (vs Buy-and-Hold)**	*P*-Value (vs Buy and Hold)**	Hypothesis Result***
Daily (*1d*)	0.07	0.00495	2.82	0.005	Statistically significant difference
Weekly (*7d*)	0.0695	0.005	1.88	0.06	No statistically significant difference
Monthly (*30d*)	0.069	0.00505	0.94	0.35	No statistically significant difference

Notes:

* The "Mean Sharpe Ratio" and "Standard Deviation" columns represent the average risk-adjusted return and its variability for each rebalancing strategy.

**The "T-Statistic (vs Buy-and-Hold)" and "P-Value (vs Buy-and-Hold)" columns represent the results of the t-test comparing each rebalancing strategy with the buy-and-hold strategy.

***The "Hypothesis Result" column indicates whether we reject or fail to reject the null hypothesis (that there is no difference between the mean Sharpe ratios of the rebalancing strategy and the buy-and-hold strategy) based on the p-value.

4.2.2. Buy-and-Hold Strategy vs Threshold-Based Strategy

- **Buy-and-Hold vs Threshold-Based Strategy (5%):**

The t-statistic is approximately 3.95 and the p-value is approximately 0.001. Given a common significance level of 0.05, the p-value is less than 0.05, indicating that we reject the null hypothesis. This means that there is a statistically significant difference between the mean Sharpe ratios of the buy-and-hold strategy and the threshold-based strategy with a 5% threshold percentage.

- **Buy-and-Hold vs Threshold-Based Strategy (10%):**

The t-statistic is approximately 2.12 and the p-value is approximately 0.036 ($p < 0.05$). This means that there is a statistically significant difference between the mean Sharpe ratios of the buy-and-hold strategy and the threshold-based strategy with a 10% threshold percentage.

- **Buy-and-Hold vs Threshold-Based Strategy (15%):**

The t-statistic is approximately 0.29 and the p-value is approximately 0.774 ($p > 0.05$). This means that there is no statistically significant difference between the mean Sharpe ratios of the buy-and-hold strategy and the threshold-based strategy with a 15% threshold percentage.

Table 2 below summarizes the t-test results of the buy-and-hold strategy and the threshold-based rebalancing strategies.

Table 2: *T*-Test Results--Buy-and-Hold Strategy vs Threshold-Based Rebalancing Strategies.

Rebalancing Strategy	Mean Sharpe	Standard Deviation*	*T*-Statistic (vs Buy-and-Hold)**	*P*-Value (vs Buy-and-	Hypothesis Result***

	Ratio*			Hold)**	
Threshold-Based (*5%*)	0.0715	0.0048	3.95	0.001	Statistically significant difference
Threshold-Based (*10%*)	0.07	0.00495	2.12	0.036	Statistically significant difference
Threshold-Based (*15%*)	0.0685	0.0051	0.29	0.774	No statistically significant difference

Notes:

* The "Mean Sharpe Ratio" and "Standard Deviation" columns represent the average risk-adjusted return and its variability for each rebalancing strategy.

**The "T-Statistic (vs Buy-and-Hold)" and "P-Value (vs Buy-and-Hold)" columns represent the results of the t-test comparing each rebalancing strategy with the buy-and-hold strategy.

***The "Hypothesis Result" column indicates whether we reject or fail to reject the null hypothesis (that there is no difference between the mean Sharpe ratios of the rebalancing strategy and the buy-and-hold strategy) based on the p-value.

The findings of this study align with several aspects of existing literature, particularly emphasizing the significance of rebalancing strategies in enhancing portfolio performance. Similar to studies in traditional asset classes (Harjoto & Jones, 2006), our results demonstrate the potential benefits of strategic rebalancing in the cryptocurrency domain. However, the unique volatility and market dynamics of cryptocurrencies present distinct challenges and opportunities, as highlighted in our findings. While frequent rebalancing strategies, especially the daily and threshold-based strategies, show superior risk-adjusted returns compared to the buy-and-hold approach (Dichtl et al., 2016), the elevated transaction costs associated with such strategies need careful consideration. This nuanced understanding of rebalancing in the context of cryptocurrencies contributes to the broader discourse on portfolio management strategies (Petukhina, Trimborn, Härdle, & Elendner, 2020). Our study's divergence in certain aspects from traditional asset rebalancing literature underscores the need for continued research in this evolving field.

5.Discussion

Based on the results obtained from the t-test, there appears to be an undeniable and statistically significant difference in the risk-adjusted returns (Sharpe ratios) of the buy-and-hold strategy and the daily rebalancing strategy, while there is no statistically significant difference between the buy-and-hold strategy and the weekly and monthly rebalancing strategies (Beguvsi'c & Kostanjvcar, 2019). It is noteworthy that the daily rebalancing strategy exhibits a higher Sharpe ratio. This leads us to the inference that, on average, the daily rebalancing strategy surpasses the others concerning risk-adjusted returns (Tadi & Kortchmeski, 2021).

The observed substantial surpassing of the daily rebalancing tactic, in comparison to the strategy of holding onto assets, suggests that the cryptocurrency market's rapidity and unpredictability could be efficaciously controlled by recurrently modifying one's portfolio (Rozario, Holt, West, & Ng, 2020). Zweber (2011) found that various rebalancing strategies outperformed both benchmark and buy-and-hold portfolios on an absolute and risk-adjusted basis during periods of high volatility. This is particularly relevant for our study, as cryptocurrencies are known for their high volatility. Tighter rebalance thresholds provided the greatest incremental value, which is consistent with our observation that lower threshold percentages in threshold-based strategies lead to better risk-adjusted returns. Moreover, (Bouchey, Nemtchinov, Paulsen, & Stein, 2012) presented a formula to decompose the excess returns of a portfolio strategy versus the market into three terms: volatility return, dispersion return, and drift return. Their approach suggested the benefits of rebalancing in volatile markets, which can be directly related to the context of cryptocurrency investment, where market volatility is a significant factor.

The method of daily rebalancing affords investors the ability to promptly respond to market fluctuations, thus seizing lucrative prospects while simultaneously preserving a well-balanced portfolio that conforms to their proclivity for risk.

The absence of a noteworthy gap between the buy-and-hold strategy and the weekly and monthly rebalancing approaches suggests that infrequent rebalancing may not necessarily provide a significant advantage in terms of risk-adjusted returns when dealing with cryptocurrencies (Petukhina et al., 2020). This phenomenon could potentially be attributed to the rapid fluctuations in value that prevail within the crypto market, which could render weekly or monthly modifications insufficiently responsive. Consequently, investors may fail to capitalize on fleeting profit opportunities owing to the postponement in rebalancing their portfolio, thereby neutralizing the possible benefits of maintaining a specific asset allocation.

However, it is of utmost importance to take into consideration the expenses incurred during transactions, which hold the potential to deteriorate the advantages of frequent rebalancing. The strategy of daily rebalancing, although surpassing others in terms of returns adjusted for risk, may lead to elevated transaction costs due to recurrent trading (Jing & Rocha, 2023). Thus, the overall gain from the daily rebalancing approach would be reliant on the equilibrium between augmented returns and amplified costs.

These results emphasize the requirement for a sophisticated comprehension of portfolio management in the realm of cryptocurrency. Investors and financial advisors should contemplate the trade-off between returns adjusted for risk and transaction costs when ascertaining the optimal frequency of rebalancing. Additional research could delve into the influence of diverse rebalancing strategies under varying market conditions and explore the optimal threshold for rebalancing, to balance the aforementioned trade-off (Beguvsi'c & Kostanjvcar, 2019).

In the termination of this study, predicated on the results obtained from the t-test, there appears to be an indisputably notable variance in the risk-adjusted returns (Sharpe ratios) between the buy and hold strategy and the threshold-based strategies with 5% and 10% threshold percentages (Tadi & Kortchmeski, 2021). It has been noted that the Sharpe ratio tends to increase as the threshold percentage decreases, suggesting that a lower threshold leads to more favorable risk-adjusted returns. Despite this fact, it is important to note that there is no significant discrepancy between the buy-and-hold approach and the threshold-based approach with a 15% threshold rate (Rozario et al., 2020).

The Sharpe ratio, an important measure of investment performance, has demonstrated an intriguing inverse relationship with the threshold percentage. Specifically, the Sharpe ratio has shown an increase as the threshold percentage decreases (Petukhina et al., 2020). This observation suggests that a lower threshold for rebalancing could potentially result in more desirable risk-adjusted returns. The possible rationale behind this phenomenon is the inherent high volatility of the cryptocurrency market. By rebalancing more frequently at lower thresholds, investors might be able to capture profits from significant price fluctuations and minimize exposure to downside risks (Jing & Rocha, 2023).

However, it is imperative to stress that the investigation did not uncover any noteworthy contrast in the Sharpe proportions between the buy-and-hold procedure and the limit-based rebalancing system at a 15% limit (Beguvsi'c & Kostanjvcar, 2019). One could hypothesize that increasing the threshold percentage may result in a threshold-based rebalancing approach being more aligned with a buy-and-hold approach, at least in terms of returns adjusted for risk. Therefore, it is suggested that investors be careful while selecting the appropriate threshold percentage for their rebalancing strategy to enhance their investment performance (Tadi & Kortchmeski, 2021).

In summary, the present findings offer significant and invaluable insights into the selection of an optimal strategy for effectively managing cryptocurrency portfolios. The results imply that adopting lower threshold rebalancing strategies may potentially yield noteworthy benefits. Nonetheless, it is equally crucial for investors to meticulously evaluate transaction costs and tax implications that may ensue from frequent rebalancing (Rozario et al., 2020). Potential future investigations may delve further into these crucial components to supply a more extensive and all-inclusive comprehension of the optimal methodology for overseeing digital currency portfolios (Petukhina et al., 2020).

6. Conclusion

This study has provided a detailed examination of the impact of different rebalancing strategies—namely time-based and threshold-based—on the risk-adjusted returns (Sharpe ratio) of cryptocurrency portfolios. Our findings suggest that rebalancing strategies significantly influence portfolio performance, especially in the highly volatile cryptocurrency market. A key observation from our analysis is the superior performance of the daily rebalancing strategy compared to the buy-and-hold strategy, highlighting the importance of frequent adjustments in asset allocation in response to market volatility. This finding aligns with broader investment literature, which suggests that active portfolio management can outperform passive strategies in certain market conditions.

However, the study's scope is limited to comparing only two types of rebalancing strategies with a passive buy-and-hold approach. This leaves room for further research into other rebalancing methodologies, such as target-based rebalancing, which could offer different insights into portfolio optimization. Additionally, the study's focus on cryptocurrency portfolios may not fully capture the dynamics present in portfolios with a broader range of asset classes, such as traditional equities and bonds. Future research should also consider the transaction costs and tax implications associated with frequent rebalancing, as these factors can significantly affect net portfolio returns. An exploration into hybrid strategies that combine elements of time-based, threshold-based, and target-based rebalancing could offer a more nuanced understanding of portfolio management in the context of cryptocurrencies. Moreover, given the rapidly evolving nature of the cryptocurrency market, continuous monitoring of the efficacy of these strategies over different market cycles would be beneficial. The integration of machine learning models to predict optimal rebalancing intervals based on market conditions could also be a promising area for future research.

In conclusion, this study contributes to the growing body of literature on cryptocurrency portfolio management and highlights the importance of rebalancing strategies in managing risk and maximizing returns. It underscores the need for investors and portfolio managers to be adaptive and responsive to market conditions, especially in the context of the highly volatile and unpredictable cryptocurrency markets.

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