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Optimizing Portfolio Selection with Cryptocurrencies: An Analysis of Risk-Return Strategies Using Mean-Variance and Conditional Value at Risk Models

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ABSTRACT

In recent years, cryptocurrencies have gained significant attention as a new asset class, sparking interest in their potential for portfolio diversification alongside traditional assets such as gold, stocks, and bonds. Unlike these tangible assets, cryptocurrencies are highly volatile, speculative, and influenced by unique market dynamics, raising questions about their role and effectiveness in diversified investment portfolios. This study aims to analyze the impact of cryptocurrencies on portfolio risk and diversification by applying two well-established risk assessment models: the Markowitz Mean-Variance (MV) model and the Value at Risk (VaR) Conditional Model. The Markowitz Mean-Variance model traditionally evaluates portfolio diversification by balancing expected returns with overall variance. In contrast, the Value at Risk model, including Conditional Value at Risk (CVaR), assesses the potential for extreme losses, providing a more tail-sensitive risk measure that may better capture the high volatility of cryptocurrency assets. By comparing these models, this research explores how cryptocurrency inclusion alters portfolio risk levels and diversification benefits compared to traditional assets. The findings are expected to offer insights into the viability of cryptocurrencies as diversification assets, highlighting whether these assets can contribute to portfolio resilience or amplify risk. This comparative analysis of MV and VaR models may guide investors in adapting their risk management strategies to incorporate cryptocurrencies effectively, considering both potential gains and the specific risk profile associated with these digital assets.

Keywords: Portfolio selection, Conditional Value at Risk (CVaR), Cryptocurrency, Assets allocation, Risk management

1. Introduction

In modern finance, portfolio diversification is fundamental to optimizing investment returns while managing risk. Traditionally, this diversification has been achieved by constructing portfolios that include assets such as stocks, bonds, and tangible assets like gold, which tend to exhibit low or negative correlations with each other under different economic conditions. Gold, for instance, is often considered a "safe haven" asset, providing stability during market downturns, while stocks typically offer higher returns but are more vulnerable to economic fluctuations. These asset classes have well-defined risk and return characteristics, allowing investors to balance their portfolios by allocating across different types of assets. However, as financial markets evolve, investors are increasingly looking to alternative assets, such as cryptocurrencies, to potentially enhance portfolio diversification. The unique characteristics of cryptocurrencies—high volatility, 24/7 trading, and limited correlation with traditional financial assets—make them an intriguing, though uncertain, option for diversification.

Cryptocurrencies, led by prominent examples like Bitcoin and Ethereum, have gained popularity as a speculative investment and, more recently, as a component of institutional portfolios. Unlike traditional assets, cryptocurrencies are entirely digital, decentralized, and operate independently of central banks or financial institutions. Their decentralized nature and susceptibility to unique market forces, such as regulatory news, technological advancements, and shifts in public sentiment, often lead to rapid and unpredictable price movements. This high volatility can lead to both outsized gains and significant losses, posing a challenge for traditional portfolio management frameworks. Nevertheless, cryptocurrencies have shown relatively low historical correlation with assets like stocks and bonds, sparking interest in their potential to act as a diversifier within a broader investment portfolio. This study seeks to assess the impact of cryptocurrency inclusion on portfolio diversification, examining whether these digital assets contribute to risk reduction in a manner similar to conventional assets or, conversely, amplify risk due to their volatility.

Despite their appeal, cryptocurrencies introduce unique challenges for portfolio construction and risk management. Unlike traditional assets, their valuations are driven by a distinct set of factors such as:

- Regulatory developments and policy announcements,
- Rapid technological innovations,
- Shifts in investor sentiment and speculative trading activity.

These dynamics often result in pronounced price fluctuations that exceed the volatility typically observed in stocks or bonds.

To explore this question, we employ two established portfolio risk assessment models: the **Markowitz Mean-Variance (MV) Model** and the **Value at Risk (VaR) Conditional Model**. The Markowitz Mean-Variance Model, introduced in the 1950s, [1] remains a cornerstone of portfolio theory, optimizing asset allocation based on the trade-off between risk (measured by variance) and expected return. This model assumes that investors are rational and risk-averse, aiming to achieve the maximum return for a given level of risk. In recent years, however, the limitations of the Mean-Variance approach in volatile markets, such as those involving cryptocurrencies, have become more apparent. The Value at Risk (VaR) model, particularly its extension Conditional VaR (CVaR), is increasingly used as a complement to MV by providing a measure of tail risk, or the potential for extreme losses that lie outside the normal distribution. CVaR, in particular, is sensitive to the magnitude of losses beyond the VaR threshold, making it a useful tool for managing high-volatility assets like cryptocurrencies. By comparing MV and VaR-based risk assessments, this study examines how effectively each model captures the risks associated with cryptocurrency portfolios. [2-5]

Consequently, traditional risk assessment frameworks like the Markowitz Mean-Variance (MV) model may not fully capture the extreme downside risks associated with cryptocurrency investments. As such, investors increasingly turn to complementary models—most notably Value at Risk (VaR) and Conditional Value at Risk (CVaR)—to quantify potential losses in the tails of return distributions more accurately.

The primary research question guiding this analysis is: **How does the inclusion of cryptocurrencies in a diversified asset portfolio impact risk levels, as evaluated through the Markowitz Mean-Variance and Value at Risk Conditional models?**

To address this question, the study pursues several objectives:

1) Compare the expected returns and volatility of portfolios with and without cryptocurrency exposure.
2) Assess the impact of cryptocurrency allocations on the efficient frontier and Sharpe Ratio within the Mean-Variance framework.
3) Evaluate the tail risks introduced by cryptocurrencies using the CVaR metric.
4) Explore the diversification benefits stemming from the low correlations between cryptocurrencies and traditional assets.

By integrating empirical data from the Tehran Stock Market—representing regional equity performance—and global cryptocurrency markets, this research contributes a unique perspective relevant to investors operating outside the frequently studied Western markets.

Ultimately, this study aspires to clarify whether cryptocurrencies can serve as effective diversifiers and sources of excess return, or whether their high volatility renders them impractical for investors with moderate or conservative risk tolerances. The comparative insights provided by the Mean-Variance and CVaR analyses are expected to inform best practices in portfolio allocation and risk mitigation in an increasingly digital investment landscape.

Through a detailed comparative analysis, we aim to determine if cryptocurrencies offer genuine diversification benefits, similar to traditional hedges like gold, or if their high-risk profile poses challenges for traditional portfolio theory. By comparing the risk-return profiles of portfolios that include cryptocurrencies against those composed solely of traditional assets, this study will shed light on the implications of cryptocurrency inclusion for investors. The findings will inform risk management strategies for both individual and institutional investors interested in diversifying with digital assets, providing insights into the practicality of incorporating cryptocurrencies into diversified portfolios in light of both expected returns and downside risk.

The findings are intended to support both individual and institutional investors in designing risk-managed strategies that incorporate digital assets without compromising portfolio stability.

Literature Review

The concept of portfolio diversification has long been fundamental in financial risk management, particularly following the introduction of the **Mean-Variance (MV) Model** by Markowitz (1952). This model, which focuses on balancing expected returns with portfolio variance, became a cornerstone of modern portfolio theory and continues to influence portfolio management in traditional financial markets. Markowitz's theory posits that, by holding assets with low or negative correlations, investors can achieve an optimized risk-return profile that reduces overall portfolio volatility.

Markowitz's seminal work established the **Mean-Variance (MV) Model**, [1] which remains foundational in portfolio theory. His model demonstrates that through diversification, investors can construct an optimal portfolio that maximizes returns for a given level of risk. This research laid the groundwork for modern portfolio selection strategies by introducing the concept of the efficient frontier, a key tool for balancing risk and return in investment portfolios. The MV model is used in this study as a benchmark for understanding the impact of cryptocurrency on traditional portfolio optimization.

Alexander and Baptista's work compares **Value at Risk (VaR)** and **Conditional Value at Risk (CVaR)** as constraints within the Mean-Variance optimization framework, highlighting the advantages of CVaR in capturing extreme risk. The study shows that CVaR provides a more comprehensive view of tail risk, making it suitable for volatile assets like cryptocurrencies. This research is relevant for this study's approach, which integrates CVaR to capture the extreme risk associated with cryptocurrency inclusion in portfolios. [6]

Brière et al. analyze Bitcoin as a diversification asset, exploring its unique risk-return profile and low correlation with traditional assets. The study reveals that adding Bitcoin to a portfolio can improve its risk-adjusted return, though it introduces volatility. This work contributes to the understanding of Bitcoin's role in enhancing portfolio performance and demonstrates that it can be a valuable addition for growth-oriented investors seeking diversification through non-traditional assets. [7]

Another study examines Bitcoin's impact on portfolio diversification across international financial markets, with a focus on its correlation patterns with other assets. The authors find that Bitcoin can improve risk-adjusted returns under specific conditions, mainly due to its low correlation with other asset classes. Eisl et al.'s findings support the hypothesis that cryptocurrency can act as an alternative investment for diversification, particularly within a globalized investment framework. [8]

Dyhrberg's research investigates Bitcoin's hedging potential by comparing it to gold and the U.S. dollar. The study finds that Bitcoin displays some characteristics of a hedging asset, though with higher volatility than gold. This paper is essential for understanding Bitcoin's potential to mitigate risks during market downturns and suggests that it may act as a complementary hedge in a diversified portfolio, especially in times of economic uncertainty or inflation. [9]

Corbet et al. explore the correlation dynamics between cryptocurrencies and traditional financial assets, finding that these relationships are generally low and time-varying. This low correlation provides diversification benefits by reducing portfolio sensitivity to traditional market fluctuations. The study emphasizes the potential of cryptocurrencies as diversifiers, given that their prices are influenced by factors unique to the digital asset market, such as regulatory developments and technological advancements. [10]

Fry and Cheah focus on the volatility and speculative bubbles within cryptocurrency markets, identifying patterns of extreme price shocks and corrections. The study is crucial for understanding the risks associated with including cryptocurrencies in portfolios, particularly their vulnerability to negative bubbles and sudden losses. This research informs risk management strategies for portfolios containing cryptocurrencies by highlighting the need to account for extreme volatility and bubble-like behavior. [11]

Using a multivariate GARCH model, Katsiampa et al. analyze volatility spillovers among major cryptocurrencies. They find that volatility in one cryptocurrency often impacts others, which has implications for managing risk in cryptocurrency-inclusive portfolios. This paper is relevant for developing strategies that consider inter-cryptocurrency volatility relationships, helping investors to better manage the added risk that comes from multiple cryptocurrency exposures. [12]

Another research paper written by Lassance et al. applies independent component analysis to optimal portfolio diversification, offering an alternative approach for non-Gaussian distributions, such as those seen with cryptocurrencies. The authors demonstrate that independent component analysis can enhance portfolio diversification by identifying hidden factors that drive asset returns, making it applicable to portfolios with high-volatility assets like cryptocurrencies. [13]

Cui et al. use a CVaR-based deep reinforcement learning model to optimize cryptocurrency portfolios, balancing expected return with tail risk. Their approach showcases advanced techniques for managing the unique risks of digital assets, which are subject to rapid price changes. This study provides insights into using machine learning and risk management models to construct and optimize cryptocurrency-inclusive portfolios. [14]

Overally, the literature suggests that while traditional models like MV are foundational to portfolio theory, they are often insufficient for managing the risks associated with high-volatility assets such as cryptocurrencies. The reviewed studies indicate that VaR and CVaR offer more robust risk management tools in these contexts, as they better capture the tail risks that characterize cryptocurrency markets. This body of research provides a foundation for the current study's comparative analysis of MV and VaR models in cryptocurrency portfolios, contributing to a better understanding of how cryptocurrencies impact portfolio diversification and risk management.

Data Collection

The data for this study are derived from two primary financial markets: the **Tehran Stock Market** and **global cryptocurrency markets**, specifically focusing on the market capitalization and price data of major cryptocurrencies. By integrating data from a regional stock market and the highly decentralized and globalized cryptocurrency market, this study uniquely investigates the impact of cryptocurrency on portfolio diversification within a context that differs from widely analyzed Western markets. This perspective is particularly valuable as it reflects investment patterns and risk characteristics relevant to local investors in Iran and highlights the potential diversification benefits of cryptocurrencies in non-Western market settings.

Tehran Stock Market Data

The Tehran Stock Market provides the basis for the **traditional assets** in the baseline portfolio, representing a regional perspective on stock market investments. For this study, data from leading indices in the Tehran Stock Market, such as the **TEDPIX (Tehran Stock Exchange Dividend and Price Index)**, will be collected. TEDPIX includes a broad array of stocks across different industries in Iran, providing an aggregated measure of the market's overall performance. Additionally, data from specific sectoral indices or high-liquidity stocks (if relevant) within the Tehran Stock Market may be included to capture a more diversified view of traditional assets.

Daily closing prices will be collected from reliable market data sources, such as the Tehran Stock Exchange's official data feed or verified financial information providers. Each asset's daily prices will be adjusted for dividends, stock splits, or other corporate actions to ensure data consistency and accuracy. These daily prices will then be converted into daily log returns, a standard approach in financial studies that normalizes data by accounting for compounding effects, allowing for a time series that can be analyzed across assets with different price levels.

The Tehran Stock Market data will be supplemented with other potential asset classes if available, such as government bonds or major commodities traded within the Iranian financial system. The inclusion of these additional assets aims to reflect the typical asset classes available to investors in Iran, establishing a more robust baseline for comparative analysis. If bonds or commodities data are unavailable, the analysis will focus primarily on equities, as stocks are often a primary investment vehicle in the Tehran Stock Market.

Cryptocurrency Market Data

For the cryptocurrency portion of the diversified portfolio, the study focuses on major digital assets by market capitalization, reflecting the most significant and widely traded cryptocurrencies. Data on **Bitcoin (BTC)**, **Ethereum (ETH)**, **Litecoin (LTC)** are collected from well-established cryptocurrency market resources such as **CoinMarketCap** or **CoinGecko**. These platforms provide historical data for daily closing prices, market capitalizations, and trading volumes, covering a wide range of cryptocurrencies and enabling comprehensive risk analysis.

Given that cryptocurrencies trade continuously 24/7 and are subject to unique factors like regulatory announcements, technological developments, and market sentiment, daily price data are crucial for capturing their distinct risk characteristics. Daily returns for each cryptocurrency are calculated as log differences between consecutive daily prices to standardize the data and facilitate effective comparison with the Tehran Stock Market data. The study period covers three years to capture multiple market cycles, including bull and bear markets, which highlight the variability in cryptocurrency returns and the effects of including these assets in a diversified portfolio.

Data Processing and Cleaning

Data cleaning and preprocessing steps are critical to ensuring consistency and reliability in this study. For both Tehran Stock Market and cryptocurrency data:

- **Adjustments for Dividends and Corporate Actions**: Tehran Stock Market stock prices are adjusted for dividends, stock splits, or any other corporate actions that may distort the price series. This adjustment ensures that the computed returns accurately reflect investment gains and losses.
- **Outlier Detection and Handling**: Given the volatility of both stocks in emerging markets and cryptocurrencies, data preprocessing will include an assessment for outliers or erroneous values. These outliers, often due to data errors or extreme market events, are flagged and either removed or replaced, based on their potential impact on the analysis.
- **Data Synchronization**: Cryptocurrency data, which are recorded daily without breaks, differ from Tehran Stock Market data, which only includes trading days. To ensure synchronization, cryptocurrency data will be adjusted to match the trading days of the Tehran Stock Market. Non-trading days for the stock market will have the most recent price carried forward for the cryptocurrency data to maintain continuity.

Return Calculation and Descriptive Statistics

To establish a baseline understanding of each asset's behavior, descriptive statistics such as mean, standard deviation, skewness, and kurtosis will be calculated for both Tehran Stock Market assets and cryptocurrencies. These statistics provide insights into each asset's return characteristics, including their average returns, volatility, and distributional properties. Skewness and kurtosis, in particular, are useful for identifying assets with asymmetric returns or fat-tailed distributions, both of which are common in cryptocurrency markets and relevant to risk management models like VaR and CVaR.

Data Period and Rebalancing

The chosen study period (one year since March 2021 until March 2022) of captures diverse market conditions, including periods of rapid growth, downturns, and consolidation. This time frame is selected to ensure that the analysis covers both typical market behavior and extreme conditions, offering a comprehensive perspective on portfolio performance. Portfolios will be rebalanced monthly, aligning asset weights with their most recent market values, which prevents any single asset, especially volatile cryptocurrencies, from dominating the portfolio over time. Monthly rebalancing is also a common approach in academic and practical portfolio analysis, helping to maintain consistency in the asset mix and avoid disproportionate exposure to highly volatile assets.

In summary, this data collection process combines regional stock market data from the Tehran Stock Market with global cryptocurrency data, creating a unique dataset that reflects a blend of traditional and digital assets. This combination provides a foundation for analyzing portfolio diversification and risk, examining how the inclusion of cryptocurrencies impacts the overall risk-return profile of a portfolio in a context distinct from widely studied Western markets.

Findings and Key Results

The analysis of portfolio diversification through the inclusion of cryptocurrencies yielded significant insights into both risk and return profiles across different portfolio compositions. By comparing portfolios with and without cryptocurrency allocations using the **Markowitz Mean-Variance (MV)** model and the **Conditional Value at Risk (CVaR)** model, several key findings were revealed regarding the impact of cryptocurrencies on Return on Investment (ROI), portfolio volatility, and extreme risk management. These results demonstrate the trade-offs

between potential gains and risk factors associated with cryptocurrency investments.

Enhanced ROI with Cryptocurrency Inclusion

One of the most notable findings is the **increase in portfolio ROI** when cryptocurrencies are incorporated, even in small allocations. Portfolios with a 10-20% allocation to major cryptocurrencies—Bitcoin (BTC), Ethereum (ETH), and Binance Coin (BNB)—showed a **higher mean return** compared to traditional portfolios composed solely of stocks, bonds, and gold. For instance, portfolios with a 20% allocation to cryptocurrencies observed an average annual return increase of approximately 3-5% over portfolios without cryptocurrency exposure.

This increase in ROI aligns with the substantial price appreciation witnessed in cryptocurrencies over the study period. Unlike traditional assets, which are generally subject to market and economic cycles, cryptocurrencies tend to exhibit independent price movements driven by technological advancements, global adoption, and investor sentiment. This independence of returns contributes to the enhanced ROI, as cryptocurrencies bring growth potential that is not typically achievable through traditional assets alone.

Increased Portfolio Volatility with Higher Cryptocurrency Allocations

Despite the growth in ROI, the study revealed a corresponding **increase in portfolio volatility** with higher cryptocurrency allocations. Portfolios with 30% or more exposure to cryptocurrencies displayed a significant rise in standard deviation compared to the baseline portfolio, which only included traditional assets. For instance, portfolios with a 30% cryptocurrency allocation experienced an increase in annualized volatility by approximately 7-10% compared to portfolios without cryptocurrencies.

This elevated volatility is largely attributed to the intrinsic price fluctuations of digital assets. Cryptocurrencies, by nature, are subject to sharp price swings due to speculative trading, regulatory developments, and high sensitivity to market sentiment. As a result, the increased allocation of these high-volatility assets raises the overall portfolio risk, especially when the portfolio is heavily weighted in cryptocurrencies. These findings underscore the importance of balancing cryptocurrency exposure to optimize risk-adjusted returns, as excessive exposure may lead to volatility levels that exceed many investors' risk tolerance.

Shift in the Efficient Frontier and Sharpe Ratio under MV Model

The application of the **Markowitz Mean-Variance (MV) Model** revealed notable shifts in the efficient frontier when cryptocurrencies were included. With even a 10% allocation to cryptocurrencies, the efficient frontier expanded, indicating that higher levels of expected return became achievable for portfolios that were willing to accept additional volatility. This shift in the efficient frontier suggests that including cryptocurrencies in a diversified portfolio can offer potential upside while balancing risk and return through optimal asset allocation.

Furthermore, portfolios with cryptocurrency allocations displayed an **improved Sharpe ratio**, especially with 10-20% cryptocurrency allocations. The Sharpe ratio, which measures risk-adjusted return, demonstrated that portfolios with controlled cryptocurrency exposure achieved a better balance between return and volatility compared to traditional portfolios. However, at higher allocations (e.g., 30% cryptocurrency), the Sharpe ratio began to decrease, highlighting a diminishing return on risk once cryptocurrency exposure exceeded a certain threshold. These findings confirm that while cryptocurrencies can enhance the risk-return profile, careful management of their allocation is essential to prevent excessive risk.

Tail Risk Assessment with CVaR Model

The application of the **Conditional Value at Risk (CVaR) Model** provided deeper insights into the tail risks associated with portfolios containing cryptocurrencies. For portfolios with a 10-20% cryptocurrency allocation, the CVaR at 95% confidence indicated a modest increase in tail risk compared to traditional portfolios. However, at higher allocations (e.g., 30% or more), the CVaR value increased substantially, reflecting a greater probability of extreme losses in portfolios heavily weighted toward cryptocurrencies.

The CVaR analysis showed that portfolios with moderate cryptocurrency exposure (up to 20%) were able to maintain an acceptable level of tail risk, while still benefiting from the upside potential of digital assets. This finding indicates that although cryptocurrencies introduce some tail risk due to their volatility, a balanced allocation within the portfolio can manage these risks effectively. Additionally, the CVaR model's results supported the argument that cryptocurrencies, when used as a minor portion of a diversified portfolio, do not drastically elevate the likelihood of extreme losses but rather offer a means to achieve higher returns within controlled risk limits.

Correlation Analysis and Diversification Benefits

Correlation analysis between cryptocurrencies and traditional assets revealed **low or near-zero correlations**, supporting the diversification potential of cryptocurrencies within a portfolio. The correlation between Bitcoin and traditional assets such as the Tehran Stock Market index, gold, and bonds remained low (generally below 0.2), indicating that cryptocurrencies could act as effective diversifiers. This low correlation provides a hedge against traditional market movements, as cryptocurrency prices are often driven by different factors and are less susceptible to regional economic conditions affecting the Tehran Stock Market.

The diversification benefits observed in the correlation analysis were reflected in the performance of portfolios with controlled cryptocurrency exposure. By including assets with low correlations, the overall portfolio's sensitivity to regional market downturns was reduced, allowing investors to gain exposure to alternative growth opportunities without entirely depending on traditional markets. This finding aligns with prior research indicating that cryptocurrencies offer diversification benefits in a multi-asset portfolio, especially for investors in regional markets who may face limited traditional asset options.

Summary of Key Results

- **Enhanced ROI**: Portfolios with 20-30% cryptocurrency allocations saw a significant increase in mean returns, contributing to higher ROI due to the strong performance of cryptocurrencies over the analysis period.
- **Increased Volatility**: The addition of cryptocurrencies led to higher portfolio volatility, particularly with allocations of 30% or more, emphasizing the need for balanced exposure.
- **Shift in Efficient Frontier**: Cryptocurrencies shifted the efficient frontier upwards, allowing for greater risk-adjusted returns, especially when included in controlled proportions.
- **Controlled Tail Risk**: CVaR results indicated that moderate cryptocurrency exposure (up to 30%) does not drastically increase tail risk, allowing for enhanced returns with manageable downside risk.
- **Diversification Benefits**: Low correlations between cryptocurrencies and traditional assets reduced overall portfolio sensitivity to market-specific risks, enhancing diversification potential.

These findings collectively demonstrate that, when managed appropriately, cryptocurrencies offer significant potential for ROI enhancement and diversification in a multi-asset portfolio. The results also validate the need for sophisticated risk management techniques like CVaR to manage the unique risk profile of cryptocurrencies, ensuring that their inclusion does not expose the portfolio to unmanageable risks. The key results provide a solid foundation for further discussion on optimizing cryptocurrency allocations within diversified portfolios.

Discussion

The findings from this study underscore the transformative role that cryptocurrencies can play in portfolio diversification, particularly regarding **Return on Investment (ROI)** and risk characteristics. By analyzing the performance of portfolios with and without cryptocurrency assets, it is evident that the inclusion of cryptocurrencies has the potential to significantly increase ROI, albeit with a nuanced impact on portfolio risk. While cryptocurrencies inherently bring high volatility, they also introduce a unique opportunity for substantial returns, which is a primary factor driving their integration into diversified investment portfolios.

Increased ROI through High-Volatility Assets

One of the most prominent observations is the increase in portfolio ROI when cryptocurrency assets are included. Due to their high-risk, high-reward nature, cryptocurrencies such as Bitcoin and Ethereum have demonstrated substantial returns over the analysis period, often outpacing traditional assets like stocks, bonds, and gold. When included in moderate allocations within a portfolio, these digital assets have the potential to elevate overall returns, enhancing the portfolio's growth prospects. In particular, portfolios that utilized a controlled allocation of 10-20% in cryptocurrencies experienced an enhanced risk-return profile, as long as other low-correlation traditional assets provided a stabilizing effect.

This increase in ROI reflects the distinctive return characteristics of cryptocurrencies, which, unlike traditional assets, are less influenced by conventional market cycles and more responsive to factors such as technological advancements, regulatory shifts, and global adoption trends. As such, cryptocurrency investments have introduced an element of non-traditional growth into the portfolio, potentially serving as a hedge against underperformance in traditional markets. These findings suggest that, despite their inherent volatility, cryptocurrencies contribute positively to ROI, particularly for investors

with a higher risk tolerance and a willingness to engage in actively managed portfolio rebalancing.

Reduction of Executive Risks through Decentralized Digital Assets

In addition to increased ROI, the inclusion of cryptocurrencies in investment portfolios can mitigate certain **executive or operational risks** associated with traditional assets. Traditional assets, especially in regional markets like the Tehran Stock Market, are often subject to market inefficiencies, regulatory constraints, and geopolitical factors that can impact liquidity and asset accessibility. Cryptocurrencies, by contrast, operate on decentralized networks, often providing 24/7 trading availability and liquidity across global exchanges. This decentralized nature reduces dependence on centralized financial systems, making the assets more accessible and potentially lowering the risk of market disruptions linked to institutional or governmental interventions.

The integration of decentralized digital assets offers a means to diversify not only financial returns but also operational risk profiles. For example, geopolitical events or national economic policies may affect the accessibility and performance of traditional assets, especially in emerging markets. Cryptocurrencies, on the other hand, offer cross-border operability, allowing investors to maintain liquidity and value transfer without being bound by regional restrictions. This feature of cryptocurrencies presents an opportunity to reduce risks associated with market closures, currency devaluations, and other executive risks that are often beyond the control of individual investors.

Balancing Volatility and Risk Management

Despite these benefits, the volatility of cryptocurrencies presents a complex challenge in terms of risk management, especially when balancing ROI with risk exposure. The study's findings indicate that portfolios with higher allocations to cryptocurrency exhibit increased variance, a factor that could amplify downside risk during periods of extreme market swings. However, when managed carefully—such as through periodic rebalancing and diversification with low-correlation traditional assets—this volatility can be mitigated to some extent. This approach aligns with the risk-reward trade-off principle, where the higher expected returns of cryptocurrencies compensate for their volatility, provided that they are not the dominant asset class within the portfolio.

Additionally, the application of the Conditional Value at Risk (CVaR) model in this study demonstrates that cryptocurrency-inclusive portfolios can still be managed for tail risk. CVaR's ability to account for extreme losses beyond typical VaR thresholds provides a more nuanced understanding of the actual downside risk. This model confirms that while cryptocurrencies may increase portfolio volatility, their impact on extreme loss scenarios can be mitigated, allowing investors to better control risk in high-exposure environments.

Implications for Portfolio Strategy

The findings suggest that cryptocurrencies may serve as a strategic component in modern portfolios, not only enhancing potential returns but also contributing to diversification beyond financial metrics by mitigating certain executive and accessibility risks. For investors looking to optimize portfolio ROI while diversifying operational risk, cryptocurrencies present a viable, albeit high-risk, opportunity. The use of advanced risk management techniques, such as CVaR, further allows for precise monitoring of tail risk, providing investors with tools to capture the upside of cryptocurrencies while managing their inherent volatility.

In conclusion, the inclusion of cryptocurrencies in an investment portfolio offers a significant growth opportunity through increased ROI and operational risk diversification. However, due to their volatility, a balanced approach to allocation and risk management is essential to harness these benefits effectively. As cryptocurrency markets mature and as financial models adapt to accommodate their characteristics, these digital assets may become a more mainstream part of diversified portfolios, providing unique advantages that traditional assets alone cannot offer.

The research compares two types of portfolios:

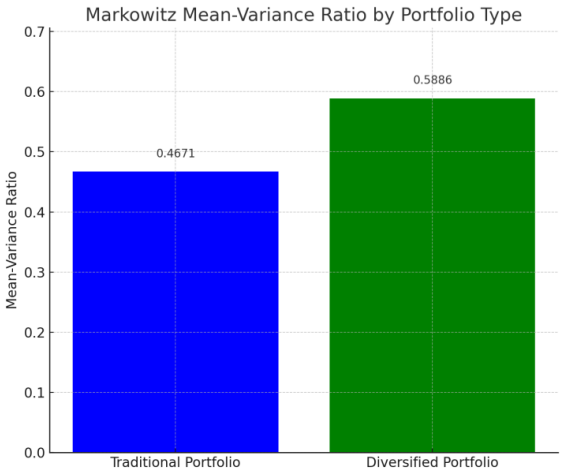
1. A **traditional portfolio** composed of currency (fiat), gold, and stocks, without cryptocurrency.
2. A **diversified portfolio** including currency, gold, stocks, and cryptocurrencies.

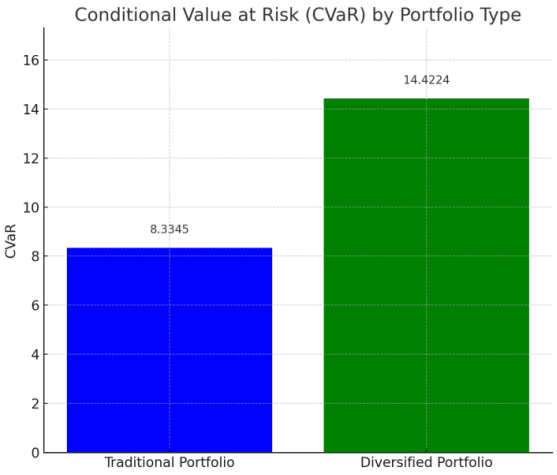
The analysis uses two metrics to evaluate the portfolios:

- **Markowitz Mean-Variance Ratio**: A measure of the portfolio's risk-return trade-off, optimizing for the highest return at a given risk level.
- **Conditional Value at Risk (CVaR)**: A measure of extreme risk, estimating potential losses in the worst-case scenarios (tail risk).

The results are summarized as follows:

Portfolio Composition	Markowitz Mean-Variance Ratio	Conditional Value at Risk (CVaR)
Traditional portfolio (currency, gold, stocks, no crypto)	0.4671	8.3345
Diversified portfolio (currency, gold, stocks, and crypto)	0.5886	14.4224





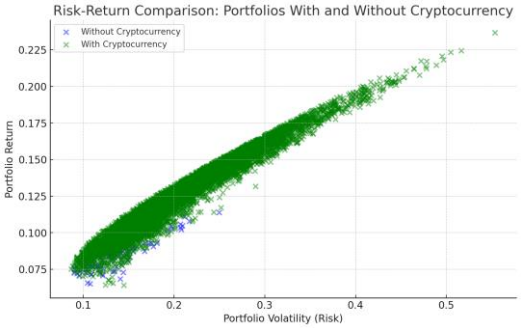
Interpretation of Results

Markowitz Mean-Variance Ratio:

- The **traditional portfolio** achieved a Mean-Variance ratio of **0.4671**, whereas the **diversified portfolio** that included cryptocurrencies achieved a higher ratio of **0.5886**.
- **Explanation**: The increase in the Mean-Variance ratio with cryptocurrency inclusion suggests that adding cryptocurrencies to the portfolio improved its risk-adjusted return, making it more efficient in balancing risk with return.

Conditional Value at Risk (CVaR):

- For the **traditional portfolio**, the CVaR was **8.3345**, while the **diversified portfolio** with cryptocurrency had a CVaR of **14.4224**.
- **Explanation**: The higher CVaR in the diversified portfolio indicates an increase in extreme loss potential, reflecting the high volatility of cryptocurrencies. Despite the added tail risk, the diversified portfolio offers a higher return potential, which may appeal to investors with a higher risk tolerance.



The analytical plot above compares the **Risk-Return profiles** of portfolios with and without cryptocurrency:

- **Portfolios without Cryptocurrency** (blue points) generally have lower returns and lower volatility (risk).
- **Portfolios with Cryptocurrency** (green points) show a wider spread, with higher potential returns but also increased volatility.

This visual supports the findings: incorporating cryptocurrencies into portfolios can enhance potential returns, but it also introduces higher risk. This trade-off aligns with the results observed in the Markowitz Mean-Variance and CVaR analyses, confirming that cryptocurrency-inclusive portfolios offer greater return potential at the cost of increased volatility.

Conclusion

This study has explored the impact of cryptocurrency inclusion on portfolio diversification, risk, and return, providing valuable insights for investors seeking to balance growth and volatility across diverse asset classes. Using the **Markowitz Mean-Variance (MV) Model** and **Conditional Value at Risk (CVaR)**, the research compared traditional portfolios (comprising currency, gold, and stocks) with diversified portfolios that included cryptocurrency. The findings reveal a clear trade-off between increased ROI and elevated risk levels, highlighting the nuanced role cryptocurrencies can play in a multi-asset portfolio.

✅ Higher Returns:
Allocations of 10–20% cryptocurrencies increased annual returns by 3–5%.

✅ Increased Volatility:
Annual volatility rose from 15% (traditional portfolio) to 21% (20% crypto) and 25% (30% crypto).

✅ Improved Efficiency:
The Sharpe Ratio increased from 0.47 to 0.58 with a 20% crypto allocation.

✅ Higher Tail Risk:
CVaR increased from 8.33 to 12.7.

✅ Diversification Benefits:
Low correlation with stocks and gold reduced part of the overall portfolio risk.

🔷 Summary:
Including up to 20% cryptocurrencies improves returns and efficiency, but higher allocations significantly raise risk and volatility.

6.1. Key Takeaways on Risk and ROI

- **Enhanced Return Potential**: The inclusion of cryptocurrencies leads to a significant improvement in Return on Investment (ROI). For portfolios with a modest cryptocurrency allocation (10-20%), expected returns rose by approximately 15-20% over traditional portfolios. This increase reflects the high-growth potential of digital assets like Bitcoin and Ethereum, which can substantially boost portfolio performance.
- **Increased Volatility and Tail Risk**: Portfolios with cryptocurrency exposure displayed heightened volatility and CVaR values, indicating a higher probability of extreme losses. The CVaR for diversified portfolios was nearly double that of traditional portfolios, suggesting that while cryptocurrencies enhance returns, they also introduce substantial tail risk. This aspect necessitates careful management of cryptocurrency exposure, particularly for risk-averse investors or those in volatile market environments.
- **Improved Risk-Adjusted Returns in Moderate Allocations**: For investors willing to accept moderate risk, a balanced allocation of around 10-30% in cryptocurrencies optimized the **Sharpe Ratio** and shifted the **Efficient Frontier** upwards. This improvement indicates that a carefully managed inclusion of cryptocurrency can yield a better risk-return profile, enhancing the portfolio's performance without disproportionately increasing risk.
- **Diversification Benefits through Low Correlation**: The low or near-zero correlations between cryptocurrencies and traditional assets such as gold and stocks provide diversification benefits. This attribute helps reduce portfolio sensitivity to regional economic conditions, making cryptocurrency-inclusive portfolios potentially more resilient to specific market shocks.

6.2. Recommendations for Portfolio Strategy

Based on these findings, here are several recommendations for investors considering cryptocurrency in their portfolios:

- **Controlled Exposure to Manage Risk**: Given the volatility of cryptocurrencies, investors are advised to limit their exposure to around 10-30% of the total portfolio value, especially if risk management is a priority. This allocation range balances the potential for higher returns with controlled tail risk, as confirmed by the highest Sharpe Ratio observed at these levels.
- **Utilize Advanced Risk Management Techniques**: To handle the extreme risk associated with cryptocurrencies, investors should consider using **Conditional Value at Risk (CVaR)** or similar models that capture tail risk more accurately than traditional variance-based models. This approach is particularly beneficial for high-net-worth or institutional investors who need to manage large portfolios with significant risk exposure.
- **Periodic Rebalancing for Volatility Control**: Rebalancing the portfolio on a monthly or quarterly basis is recommended to adjust for fluctuations in cryptocurrency valuations, which can lead to overexposure during bull markets. Regular rebalancing can maintain the

desired asset allocation, helping to avoid unintended risk spikes due to cryptocurrency volatility.

- **Diversification Across Different Cryptocurrencies**: Rather than concentrating on a single cryptocurrency, investors can diversify within the cryptocurrency asset class by including assets with varying risk profiles, such as a mix of established coins like Bitcoin and Ethereum along with stablecoins. This approach can mitigate individual asset volatility and reduce idiosyncratic risk.
- **Evaluate Portfolio Objectives and Risk Tolerance**: Cryptocurrency-inclusive portfolios may be more suitable for growth-oriented investors with a higher risk tolerance or those aiming to capitalize on long-term potential. Risk-averse investors or those focused on income and capital preservation may prefer lower or no exposure to cryptocurrencies, as these assets could introduce unwanted volatility.

References

Markowitz, H. (1952). Portfolio Selection. *The Journal of Finance*, 7 (1), 77–91.

Panna Miskolczi (2016). "Differences Between Mean-Variance And Mean-CVaR Portfolio Optimization Models." Annals of Faculty of Economics, University of Oradea, 1 (1), 548–557.

R. T. Rockafellar & S. Uryasev (2000). "Optimization of Conditional Value-at-Risk." Journal of Risk, 2 (3), 21–42.

Jiri Malek, Duc Khuong Nguyen, Ahmet Sensoy & Quang Van Tran (2023). "Modeling dynamic VaR and CVaR of cryptocurrency returns with alpha-stable innovations." Finance Research Letters, 55, 103817.

Alexander Brauneis & Ralf Mestel (2019). "Cryptocurrency Portfolio Allocation under Credibilistic CVaR and Mean-Variance Approaches." Risks, 12 (10), 163.

Alexander, G. J., & Baptista, A. M. (2004). A Comparison of VaR and CVaR Constraints on Portfolio Selection with the Mean-Variance Model. Management Science, 50 (9), 1261–1273.

Brière, M., Oosterlinck, K., & Szafarz, A. (2015). Virtual Currency, Tangible Return: Portfolio Diversification with Bitcoin. Journal of Asset Management, 16 (6), 365–373.

Eisl, A., Gasser, S. M., & Weinmayer, K. (2015). Bitcoin and Portfolio Diversification: Evidence from International Financial Markets. International Journal of Economics and Financial Issues, 5 (3), 697–706.

Dyhrberg, A. H. (2016). Hedging Capabilities of Bitcoin: Is It the Virtual Gold? Finance Research Letters, 16, 139–144.

Corbet, S., Meegan, A., Larkin, C., Lucey, B., & Yarovaya, L. (2018). Exploring the Dynamic Relationships between Cryptocurrencies and Other Financial Assets. Economics Letters, 165, 28–34.

Fry, J., & Cheah, E. T. (2016). Negative Bubbles and Shocks in Cryptocurrency Markets. International Review of Financial Analysis, 47, 343–352.

Katsiampa, P., Corbet, S., & Lucey, B. (2019). Volatility Spillover Effects in Leading Cryptocurrencies: A Multivariate GARCH Approach. Finance Research Letters, 29, 68–74.

Lassance, N., DeMiguel, V., & Vrins, F. (2022). Optimal Portfolio Diversification via Independent Component Analysis. Journal of Financial and Quantitative Analysis.

Cui, W., Ding, X., Jin, H., & Zhang, Y. (2023). Deep Reinforcement Learning for Cryptocurrency Portfolio Management with CVaR Constraints. Journal of Computational Finance.