Novel Portfolio Construction Based on Stocks, Traditional Stock Indices, Futures and Cryptocurrencies

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Abstract: As emerging assets continue to develop, they are increasingly integrated into traditional portfolio construction. Given that these new asset classes often exhibit low correlation with traditional assets, their inclusion can enhance overall portfolio performance. This study, based on Markowitz's mean-variance theory, utilizes five years of historical data to construct a portfolio consisting of six assets, including stocks, traditional stock indices, futures, and cryptocurrencies. Two objective functions are applied: maximum the Sharpee ratio and minimum variance. According to the analysis, the results demonstrate that the portfolio optimized for the maximum Sharpee ratio achieves the highest returns, while the portfolio optimized for minimum variance shows better stability. By comparing asset weights and cumulative net value chart, the effectiveness of these objective functions in portfolio optimization is validated. This research contributes to the literature by illustrating how Modern Portfolio Theory (MPT) can be used to combine traditional and new asset classes to meet diverse investment objectives.

1 INTRODUCTION

Since its introduction in the mid-20th century, portfolio theory has undergone significant development. In 1952, Harry Markowitz introduced the mean-variance optimization framework, which laid the foundation for modern portfolio theory (Markowitz, 1952). Markowitz's theory emphasized reducing risk and optimizing returns through the construction of diversified portfolios with assets that are not perfectly correlated.

Following Markowitz, William Sharpee's Capital Asset Pricing Model (CAPM), proposed in 1964, extended this theory by introducing the concept of the Security Market Line, which establishes the relationship between risk and expected return, assisting investors in evaluating asset performance under market equilibrium (Sharpee, 1964). Eugene Fama's Efficient Market Hypothesis (EMH), proposed in 1970, challenged the traditional assumptions of market rationality and impacted portfolio management (Fama, 1970). Behavioral finance and risk factor models further enriched portfolio theory. Others' prospect theory revealed common irrational behaviors in investor decision-making (Kahneman & Tversky's, 1979), while Fama and French's three-factor and five-factor models advanced the understanding of risk premiums and returns (Fama & French, 1993).

With technological advancements, the integration of big data and machine learning has provided new tools for portfolio optimization. Others found that deep learning and reinforcement learning algorithms can enhance the accuracy and efficiency of investment decisions (He & Liao, 2021). Additionally, the rise of high-return cryptocurrencies offers new perspectives for portfolio development (Chen & Liu, 2022). In recent years, research on portfolio construction has increasingly incorporated emerging asset classes and advanced technologies to improve traditional optimization methods.

When integrating futures into traditional portfolios, scholars analysed the role of commodity futures (Gorton & Rouwenhorst, 2021). Their study indicates that commodity futures, due to their low correlation with traditional assets, can effectively hedge against inflation and market volatility (Gorton & Rouwenhorst, 2021). Similarly, Szymanowski (2021) explored the role of commodities in portfolios, finding that they offer distinct risk-return characteristics compared to traditional financial assets, thereby enhancing overall portfolio performance (Szymanowski, 2021). Cryptocurrencies, as a new asset class, are

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increasingly being added to traditional portfolios. Some researchers discovered that cryptocurrencies, with their low correlation and high return potential, effectively diversify traditional portfolio risks and improve risk-adjusted returns (Chen & Liu, 2022).

Some advanced technologies also promote the development of portfolio research. The introduction of machine learning techniques has provided new methods for portfolio optimization. He and Liao explored the application of deep learning and reinforcement learning in portfolio management, showing that these algorithms can identify market patterns, refine investment strategies, and enhance prediction accuracy (He & Liao, 2021). The role of big data analysis has also been widely studied. Guo and Lin found that sentiment analysis and market data can enhance market trend forecasting and improve risk management (Guo & Lin, 2022). Blockchain technology further improves transparency and efficiency in portfolio management. Zhang and Liu noted that blockchain technology, through smart contracts, automates transactions, reduces intermediary costs, and enhances data security (Zhang & Liu, 2023). Additionally, ESG (Environmental, Social, and Governance) factors have become a significant aspect of portfolio management. Sullivan and Mackenzie found that incorporating ESG standards not only improves social responsibility performance but also generates long-term financial returns (Sullivan & Mackenzie, 2021). These studies emphasize that integrating emerging assets and technologies provides new perspectives and tools for portfolio construction.

Although traditional portfolio theory offers effective risk management tools, it encounters limitations when dealing with emerging assets such as cryptocurrencies. Introducing cryptocurrencies into the portfolio provides new development opportunities. The low correlation and high return of cryptocurrencies compared to traditional stock indices and futures give them unique value in asset allocation. This study selects six assets and uses five years of data to construct the portfolio based on Markowitz's mean-variance theory, applying two objective functions: maximizing the Sharpee ratio and minimizing variance. Subsequently, by comparing the asset weights and cumulative net value charts of portfolios optimized with these two objective functions, it is found that the portfolio optimized for maximizing the Sharpee ratio achieves the highest returns, while the minimum variance portfolio maintains better stability, thus validating the effectiveness of the model.

2 DATA AND METHOD

The data for six assets of the portfolio in the paper comes from Yahoo Finance (Yahoo Finance, n.d.). As shown in Figure. 1, these assets are JPMorgan Chase & Co., NASDAQ, Crude Oil Futures, Wheat Futures, Bitcoin Cash to US Dollar and Ethereum to US Dollar. To ensure the validity of the portfolio, this paper uses weekly data for five years from August 2019 to August 2024. The six asset types selected are stocks, traditional stock indices, futures and cryptocurrencies. As a financial instrument, stocks are an indispensable part of every portfolio. The traditional stock index has low volatility, which provides the basic risk protection for this portfolio. In addition, commodity futures often move differently from stock prices, which can hedge portfolio risk. Cryptocurrencies as a new asset can add overall returns to the portfolio with their high risk and high returns. Therefore, these four different types of assets were chosen.

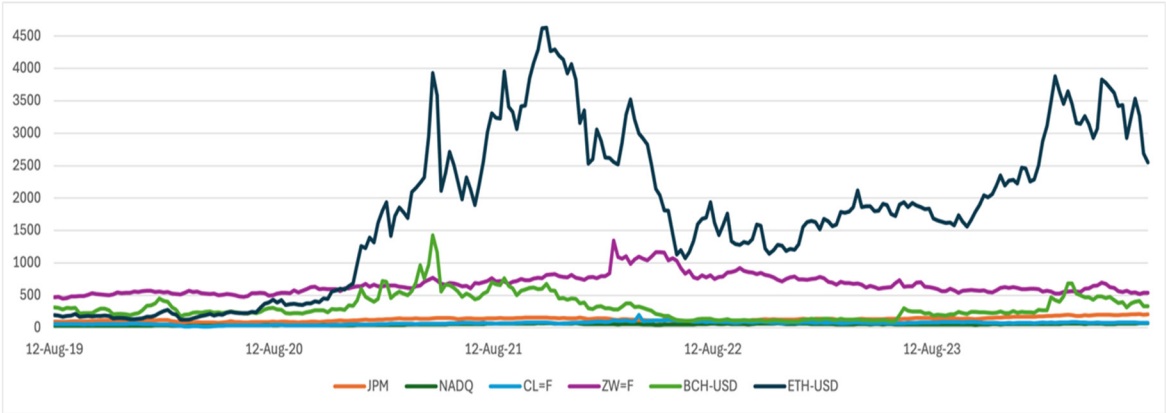

Figure 1: price change curves for six assets (Photo/Picture credit: Original).

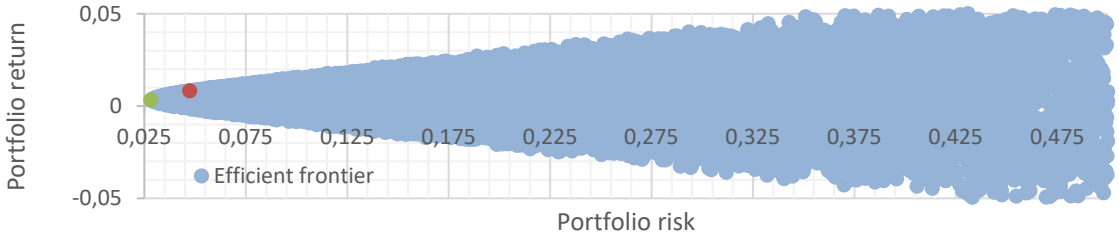

Figure 2: Efficient frontier retrieved by Excel (Photo/Picture credit: Original).

This paper use Excel to construct the portfolio. Mean-variance model proposed by Markowitz is the basis of portfolio construction in this paper. The mean-variance model indicates that investors define the standard deviation as the risk of the portfolio, and the expected return is defined as the return of the portfolio. This theory helps investors maximize returns or minimize risks under different portfolio risks. Based on the hypothesis that investors are rational economic people, investors will adjust their portfolios according to the behavior of the mean-variance. When the expected return rate is the same, the low-risk portfolio will be chosen. Additionally, when the risks are the same, they will choose the high return portfolio. According to Mean-variance model, Using the Eq. (1) to achieve theExpected return of portfolio:

$$R_p = W^T * \mu \quad (1)$$

Here, R_p is expected return of portfolio return, and W is the weight of the selected asset. μ is expected return of selected asset. Eq. (2) is used to calculate the risk of the portfolio return:

$$\sigma_p = \sqrt{W^T * \Sigma * W} \quad (2)$$

where σ_p is the standard deviation of the portfolio and Σ is the covariance matrix of selected asset return

This paper utilizes two objective functions to optimize the portfolio return and illustrates in the Figure. 2. The first objective is to minimize the standard deviation of portfolio. This approach focuses on reducing portfolio risk by minimizing standard deviation. Investors are risk averse, therefore undoubtfully they choose the portfolio with lower risk under the same expected return. The Eq. (3) of this objective function is shown as:

$$min\sigma_p = min\ \sqrt{W^T * \Sigma * W} \quad (3)$$

It is limited by the following constraints.

$$\sum_{i=1}^{n} \omega_i = 1 \quad (4)$$

$$\omega_i \geq 0 \quad for\ all\ i \quad (5)$$

The second objective is to maximum the Sharpee ratio of the portfolio. The Sharpe ratio is used to measure the excess return of each unit of risk. A higher Sharpe ratio means that the investment portfolio can obtain higher excess returns after taking certain risks. Thus, investors can use the Sharpee ratio to select the portfolio that receives the highest excess return for the same level of risk. The objective function is illustrated following:

$$Max\ Sharpe\ ratio = Max\ \frac{E(R_p)-R_f}{\sigma_p} \quad (6)$$

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

3 RESULTS AND DISCUSSION

3.1 Effective Frontier

The paper is based on these six assets using Excel to simulate 50000 times of portfolio with different weights. As illustrated in the Figure. 2, the shadow formed by the blue scatter is the feasible set of this portfolio. The upper boundary of the feasible set is the efficient frontier. Under the certain risk, the points on the efficient frontier are the portfolios that bring the highest returns to investors, so these portfolios can attract more investors to invest. The investment portfolio studies in this paper are the minimum risk portfolio and the maximum Sharpe ratio portfolio. Both are portfolios that ultimately achieve the best returns through asset allocation.

3.2 Model Performance

In the maximum Sharpe ratio portfolio (as shown in Table 1), Ethereum has the largest weight, which is 41.24%. The asset with the smallest weight is Bitcoin Cash at -10.58%, which indicates that Bitcoin Cash is short. Maximizing the Sharpe ratio indicates the highest excess return per unit risk. This portfolio buys and holds the most Ethereum, illustrating that investors are optimistic about the development prospects of cryptocurrencies. In this portfolio, cryptocurrencies can bring high return (Corbet et al., 2018). Ethereum is a more flexible decentralized application app. Compared with the digital currency

Bitcoin, it has a wider range of uses, such as providing infrastructure for decentralized finance, non-fungible tokens, and other blockchain application (VanEck, n.d.). Therefore, Ethereum is more innovative and has great room for development, which bring more return to the portfolio. Shorting Bitcoin is to hedge the risks of the cryptocurrency market. When the price of Ethereum falls, part of the loss will be offset by shorting Bitcoin Cash, thereby reducing the volatility of the portfolio.

In the minimum risk portfolio, the Nasdaq index has the largest weight, 48.05%, and Ethereum has the smallest weight, -2.52%, indicating shorting Ethereum. Since the portfolio seeks to minimize the risk of the portfolio, the largest asset weight is placed on the Nasdaq index. The index represents many technology stocks that have strong profitability and low volatility. Shorting high-yield and high-risk Ethereum helps reduce the volatility of the entire portfolio.

Comparing the two portfolios, JPMorgan Chase is a large financial institution, which leads to more stable stocks, so it accounts for a small proportion in the maximum Sharpe ratio portfolio, and the risk is higher in the portfolio that pursues the lowest risk, but the difference in the proportion of JPMorgan Chase in the two portfolios is not large, indicating that JPMorgan Chase can play a stable market performance in both asset portfolios. Crude oil futures and wheat futures are commodities with high volatility and are affected by various economic factors such as exchange rates and supply and demand. Therefore, the proportion of futures in the two portfolios is quite different. The maximum Sharpe ratio portfolio uses two futures to increase the return of the portfolio, while another portfolio uses less asset weight allocation to reduce risk.

Table 1: Asset weights of selected portfolio.

Weights	Maximum Sharpe ratio	Minimum risk
JPM	0.2171687	0.257923747
NADQ	0.2632056	0.48055297
CL=F	0.1022184	0.029643431
ZW=F	0.1108830	0.029643431
BCH_USD	-0.1058841	0.010999937
ETH_USD	0.4124083	-0.025222376

Table 2: Performance of two selected portfolio.

	Portfolio risk	Portfolio return	Sharpe ratio
Maximum Sharpe ratio	0.047	0.008	0.163
Minimum risk	0.028	0.003	0.097

As shown in Table 2, the portfolio risk, portfolio return, and Sharpe ratio of the minimum risk portfolio and the maximum Sharpe ratio portfolio are calculated. As can be seen from the table, the maximum Sharpe ratio portfolio has a higher return and a higher risk. On the contrary, the minimum risk portfolio has a lower return and a lower risk.

Figure. 3 is the cumulative net value chart of portfolio, showing the performance of three different investment portfolios from August 2019 to August 2024. The three investment portfolios are the maximum Sharpe ratio portfolio, the minimum risk portfolio and the equal asset weight portfolio. In Figure. 3, the maximum Sharpe ratio portfolio has the largest volatility in five years, but its growth rate is also the highest, and the final cumulative net asset value is 6.25. The cumulative net asset value of the equal weight investment portfolio is less than that of the maximum Sharpe ratio investment portfolio, which is 4.35. Although the return performance of this strategy is relatively good, this portfolio does not have special measures to avoid market risks, which means that if the market goes down or fluctuates violently, the entire investment portfolio may suffer a comprehensive loss. The minimum risk investment portfolio has the lowest cumulative net asset value, which is 1.90. All in all, this graph shows that the maximum Sharpe ratio investment portfolio has the best return, and the minimum risk investment portfolio has a lower return, even lower than the equal weight portfolio.

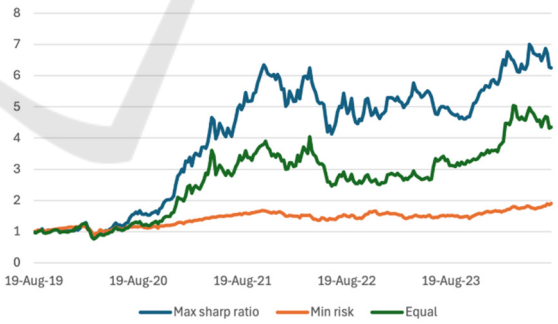

Figure 3: Cumulative net value chart of portfolio (Photo/Picture credit: Original).

In summary, the investment portfolio constructed by maximum Sharpe ratio selects assets with higher returns to pursue a higher Sharpe ratio, even if it is accompanied by greater market risks. Therefore, this portfolio will perform better in a bull market and is suitable for investors who pursue high returns and are able to bear risks. The minimum risk investment portfolio will perform better when the market

volatility is high, and the uncertainty is large. Therefore, this portfolio is more suitable for risk-averse investors, with lower investment risks and stable returns.

3.3 Limitations and Prospects

The five-year data period used in this paper includes the COVID-19 epidemic period. During this period, there is a significant increase in the volatility of different financial assets, and even anomalies such as plummeting. The cryptocurrencies and futures in this portfolio are less liquid, especially during times of high market volatility or even liquidity depletion (Liu & Tsyvinski, 2021). Therefore, extreme changes in asset prices during an epidemic may affect the market performance of the assets, while model results that include this period may not be applicable to other periods. The construction of portfolio in this paper is based on the underlying mean-variance model, which assumes that the expected returns of the assets follow a normal distribution. However, new asset cryptocurrencies are highly volatile in price, and the distribution of returns does not always show a normal distribution, but may be skewed and thick tailed, so that a normal distribution tends to underestimate the risks associated with extreme variations. (Klein et al., 2018). Plus, the mean-variance model assumes that the covariance matrix between assets is stable. In the real market, covariances always change constantly, especially during the epidemic period, so using a simple covariance matrix to construct the portfolio is not an accurate assessment of market performance. In addition, the model building tool used in this paper is Excel, not Python. large-scale data models are more accurately and efficiently constructed in Python. And the effective frontier graph which is showed does not show in detail the changes in the Sharpe ratio of the weights of the various assets, which is the limit of Excel. As for the future research, it is a good attempt to expand the data range to improve model accuracy and explore the use of machine learning, artificial intelligence, or tail risk management algorithms for optimizing portfolios with new assets to address market volatility.

4 CONCLUSIONS

To sum up, this study evaluates portfolio construction using Markowitz's mean-variance theory, applying two optimization objectives: maximizing the Sharpee ratio and minimizing variance. The results indicate that the portfolio optimized for maximizing the Sharpee ratio can achieve the highest returns, demonstrating its effectiveness in enhancing return potential. In contrast, the minimum variance portfolio provided greater stability, highlighting its advantage in risk management. However, the study's limitations include reliance on historical data and the omission of new asset market impact, which may affect real-world applicability. This research not only demonstrates optimization methods for traditional assets but also provides empirical support for including new asset cryptocurrency in the portfolio. It reveals how mean-variance theory can be applied to diverse asset allocations to achieve higher risk-adjusted returns, offering valuable insights for investors navigating complex financial markets.

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