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Portfolio Asset Allocation Based on Maximum Sharpe Ratio

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Abstract:
With the digital transformation of society, the diversity of portfolios is increasingly improving. As a result, the methods of achieving optimum portfolio asset allocation attract more and more investors. Therefore, research on portfolio asset allocation is imperative. This research is aimed at a portfolio construction strategy based on the maximum Sharpe ratio. Eight A-share market stocks and three Exchange-Traded Fund (ETF) are selected as research objects. Sharpe ratio is regarded as a key indicator that balances the performance between portfolio returns and volatility. As the research showcases, a diversified portfolio among different asset categories is capable of reducing unsystematic risk and improving the stability of an asset allocation, thus increasing the Sharpe ratio. The result of the research proves the effectiveness of the asset diversification theory, whose potential for reducing unsystematic risk and improving portfolio returns is indicated. This research provides practical strategic recommendations with their practical significance and application value. However, the assumption of a normal distribution in portfolio returns, as implied by the Sharpe ratio, may not always hold, which can be further addressed by a copula-based approach.

Keywords: asset allocation; diversity; Sharpe ratio.

1. Introduction

With the transformation of society towards Society 5.0, portfolio asset allocation is no longer limited to traditional assets, but also expands to digital assets such as virtual currency, among which cryptocurrency stands out from the crowd with its mature and novel methods to invest [1, 2]. How to make a great balance between risk and portfolio returns by a diversified portfolio in order to achieve stable long-term growth of wealth has become a critical issue for many investors and researchers to cope with.

As it comes to existing research results, many people are believed to recall the traditional asset allocation theory based on Markowitz's mean-variance model, highlighting the balance between risk and returns. Follow-up studies include the Black-Litterman model, factor investment, and risk parity strategy, and so on. As studies continuously explore and innovate, researchers have made investment strategies under the joint effect of ambiguity and business cycle with the assistance of dynamic investment models, revealing that the risk effect plays a leading role in the ambiguity effect [3]. In volatile financial markets, Multi-Objective Model Predictive Control was also adapted to make an optimal balance between return maximization and risk minimization [4]. Simultaneously, it was pointed out to researchers that portfolio returns may change by anywhere between 0.5 to 2% per year owing to fixed cost and variable cost [5]. However, the methods above are limited when dealing with high-dimensional, nonlinear, and dynamic financial data. Nowadays, with the emergence of big data and artificial intelligence, quantitative investment and intelligent investment are becoming popular in asset allocation. Nonlinear variation relationships can be captured by a machine learning algorithm, which is of great significance when considering how to optimize an asset allocation to increase risk-adjusted returns under limited risk tolerance. Tommi Huotari et al used a convolutional neural network model to manage asset allocation, gaining a 328.9% return during the five-year test period [6]. However, research like this has not yet formed a systematic framework.

As the awareness of wealth management is rising, investors pay more attention to the entirety of the portfolio, especially a diversified portfolio [7, 8]. Though recent research has tried numerous portfolios, the degree of diversity is not enough, implying that it is worth conducting further research on diversified portfolio asset allocation. The purpose of this study is to maximize the excess return of the portfolio under unit risk, managing to optimize the portfolio.

2. Methods

The data used in this study are secondary data taken from Investing and Eastmoney [9, 10]. Investing is a financial data aggregation platform whose data set is indicative prices, reflecting the market trend, and is of certain reliability. The data set of Eastmoney is public, which is reliable as well. The major data is weekly closing data of eleven different assets from 2022.8.14 to 2025.8.9. To make the portfolio much more universal and sporadic, eight A-share market stocks from seven industries, such as petroleum, banking, information technology, electrical equipment, electronic equipment, basic chemical industry, textile and clothing, and Qualified Domestic Institutional Investor type, commodity type, stock type, three types of ETFs are included in the portfolio.

The assets above are weighed to form a Portfolio P. The Sharpe ratio of Portfolio P from 2022.8.14 to 2025.8.9 is given by

$$SR = \frac{R_p - R_f}{\sigma_p}, \tag{1}$$

$$R_p = [\prod_{i=1}^{149}(R_i + 1)]^{\frac{1}{3}} - 1, \tag{2}$$

$$\sigma_p = \sqrt{\frac{52 \times \sum_{i=1}^{149}(R_i - E(R))^2}{149 - 1}}, \tag{3}$$

$$R_i = \sum_{j=1}^{11} \omega_j r_{ij}, \tag{4}$$

Where SR is the Sharpe ratio, R_p is the 3-year annual cumulative rate of return, R_f is annual risk-free interest rate of China's 3-year treasury bonds, R_i is the rate of return of the portfolio at week i, σ_p is unbiased standard deviation of weekly returns which reflects the volatility of R_i, $E(R)$ is the average weekly rate of return of the portfolio, ω_j is the proportion of asset j in total assets and r_{ij} is the rate of return of asset j at week i.

The Sharpe ratio values the excess return of the portfolio over unit risk. Besides, the rate of return has considered the dividends, which simulates the reality effectively.

3. Results

3.1 The analysis of the Sharpe Ratio

The weight of each asset is distributed with the aim of maximizing the Sharpe ratio. The optimal weight distribution can be seen in Table 1:

Table 1. Weight Distribution of Portfolio P

Asset	600028	002281	513030	601288	003041	300274
Weight	0.023121	0.025057	0.070814	0.377597	0.030358	0.061149
Asset	300641	518880	516160	688183	300750	
Weight	0.009859	0.364751	0.019609	0.004026	0.013659	

Table 1 describes the details of the mixed portfolio, including stocks and ETFs. Portfolio P contains eleven dif-

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ferent assets. The codes of each asset are given in the first and third rows, while the second and fourth rows give the weights of each asset. The asset codes start at 60, 00, 51, 30, and 688, which symbolize listed sectors of different securities exchanges. For more details, see Table 2:

Table 2. The Meanings of the Codes

60/688	Shanghai A-share or Science and Technology Innovation Board of the Shanghai Stock Exchange
00/30	Shenzhen A-share or Growth Enterprise Market of Shenzhen Stock Exchange
51	Funds or ETF products of the Shanghai Stock Exchange

The performance of Portfolio P can be seen in Table 3 below:

Table 3. The Performance of Portfolio P

Sharpe Ratio	3.84784
Gross Return	1.45006
Volatility	0.01203
Maximum Backrest	0.05116

Table 3 showcases four important targets of Portfolio P, comprehensively depicting the risk-adjusted return performance. The Sharpe ratio of equal-weight Portfolio Q is 2.02003 while the Sharpe ratio of Portfolio P is 3.84784, about 90.5 % higher than Portfolio Q ((3.84784−2.02003)/2.02003). This means that the optimization model has significant advantages in the performance of risk-adjusted returns. Generally, a Sharpe ratio greater than 1 is considered good, greater than 2 is considered very good, and 3.85 indicates that the portfolio performs extremely well in the balance of risk and return, and the investment efficiency is very high. The Sharpe ratio of Portfolio P indicates that its historical risk-adjusted return performance is better and has significant advantages. Low volatility (0.01203) proves a stable trend of Portfolio P, which means that the investor's asset experience is relatively smooth and the risk is low. The combination of low volatility and high Sharpe ratio becomes strong evidence to illustrate that high returns do not come from high risk but effective investment strategies. The maximum backrest is nearly 5%, suggesting that the anti-fall ability of Portfolio P is significantly better than the market.

Fig. 1 depicts the detailed performance of each asset:

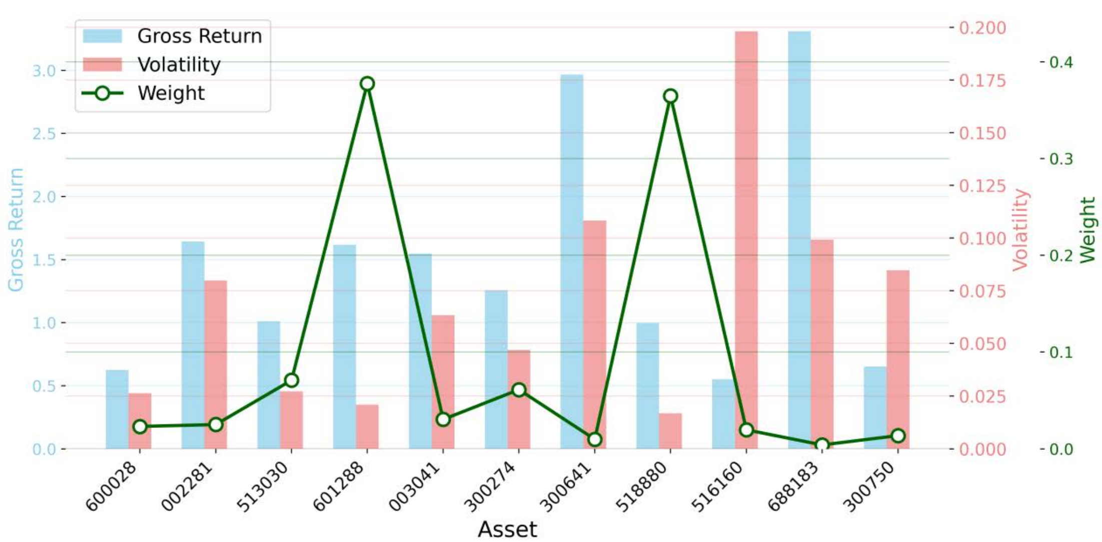

Fig. 1 The Performance of each Asset r (Photo/Picture credit: Original).

Fig. 1 combines the weights, gross returns, and volatilities of each asset. The abscissa represents the asset class, while three ordinates represent gross return, volatility, and weight, respectively, among which the blue represents gross return, the red represents volatility, and the green represents weight.

In Fig. 1, the weights of 601288 and 518880 hold a safe lead due to their low volatility, reflecting that stocks of large state-owned commercial banks and gold ETFs play an important role in the portfolio. The weights of 300641 and 688183 are the least. It is worth noting that Portfolio P is conforming to the process of de-dollarization because it has a large amount of assets in the Asia Pacific region [11].

3.2 Model Verification

When the risk-free return becomes the return of other treasury bonds, the change of Portfolio P is small. Portfolio R uses the return of China's 30-year treasury bonds. Weight distribution is as Table 4.

Table 4. Weight Distribution of Portfolio R

Asset	600028	002281	513030	601288	003041	300274
Weight	0.02097	0.02522	0.07042	0.38014	0.03056	0.06144
Asset	300641	518880	516160	688183	300750	
Weight	0.01023	0.36331	0.01981	0.00435	0.01356	

The Weight Distribution of Portfolio P and Portfolio R can be seen as two 11-dimensional column vectors. The Euclidean distance (d) of the two vectors is 0.00001. Any Euclidean distance of two vectors is less than $\sqrt{2}$ (d_{max}) if the sum of the elements of each vector is 1.

$$\frac{d}{d_{max}} = 0.000007, \tag{5}$$

Therefore, the change of weight distribution is small, showcasing certain robustness of Portfolio P.

4. Discussion

The rate of return measures the quality of the income; the risk-free interest rate is the baseline, and the volatility represents the uncertainty of the income. Therefore, the Sharpe ratio reflects the excess return of the portfolio over unit risk. For investors pursuing stable income, the diversity of the portfolio is worth investors' attention. In the face of geopolitical instability, the allocation of gold and alternative assets is crucial for yield-seeking investors, as gold has a greater opportunity to add value than cash can [11]. Portfolio P indicates that gold ETFs and stocks of large state-owned commercial banks play a necessary part in the portfolio, which are too essential to ignore.

This study has certain limitations. The data set is a retrospective index, without the promise of a future Sharpe ratio. The calculation of optimal weight distribution is seriously dependent on the input parameters based on historical data. This makes the result sensitive to the estimation error, which may lead to significant deviation in weight distribution and affect the practical application. Besides, the assumption that the market environment is certainly stable does not put constructive change of the financial market into consideration, which may undermine the optimal portfolio strategy and then weaken the robustness and applicability of the results. Another assumption is that income distribution is normal. However, the return distribution of investment strategies such as option strategies and hedge funds is often skewed or fat-tailed. Samane Al-sadat Mousavi et al suggested a copula-based approach to solve estimation problems, obtaining a small Copula-based Sharpe ratio [12]. The study can further make use of this approach to make up for the lack of the Sharpe ratio.

5. Conclusion

The study uses data from eleven assets, discovering Portfolio P with a high Sharpe ratio. This strongly proves the advantages of diversified investment methods, which deserve the attention of investors. A high Sharpe ratio indicates that an excellent return after risk adjustment is achieved, and the impact of non-systematic fluctuations is minimized through diversifying capital investment in different assets. Therefore, it is a reasonable choice for investors who pursue long-term stable returns.

The results of the research are of great significance for further research on portfolio optimization. They provide future study with a substantial evidence foundation. In the long run, it is necessary to continue exploring the practical application of the Sharpe ratio so as to analyze its effectiveness in different market stages, different asset categories, and considering macroeconomic factors. On this basis, the development of more complex models will assist in improving the investment decision-making process so that asset management achieves a higher level of accuracy and scientific basis.

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