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Portfolio Optimization under the Background of Continued Interest Rate Hikes

Yuxuan Shi[1,a,*]

[1] *Wuhan University, Wuhan 430072, China*
a. 2021301052073@whu.edu.cn
**corresponding author*

Abstract: In the process of investment, the primary investment objectives for investors are undoubtedly risk minimization and return maximization. This paper fo-cuses on the US investment market and, in the context of the Federal Re-serve's continuous interest rate hikes, avoids the currently popular artificial intelligence sectors, and focuses on the analysis of representative stocks in the manufacturing, pharmaceutical, technology, and financial industries. This paper selects 10 stocks from the above-mentioned industries for analy-sis. This paper collects stock prices, financial data (including P/E ratio, BPS, etc.), risk-free rates, market indices, and other data, and uses multiple linear regression models to predict the return data from January 1st, 2023, to March 10th, 2023. Next, the mean-variance framework is employed for the purpose of selecting both the portfolio with the highest Sharpe ratio and the one with the lowest volatility. Once the weights for both groups are ob-tained, this study tests the portfolio's performance using actual stock price data spanning from January 1st, 2023, to March 10th, 2023. After obtaining the performance data of the two groups, this paper further compares the per-formance of the portfolio with the 1/N portfolio and the market performance. The results show that the market performance is the best, followed by the 1/N portfolio and the minimum volatility portfolio, and the maximum Sharpe ratio model is the worst. This result may provide some guidance for portfolio management for some investors in this special period.

Keywords: multiple linear regression model, mean-variance model, portfolio man-agement

1. Introduction

Based on factors such as the pandemic and the Russian-Ukrainian War, the Federal Reserve implemented an open monetary policy in the early stages. This policy led to the inflation rate that has been maintained at the 2% level consistently going up in recent years. At the same time, after reaching a peak of 9.1% in June 2022, CPI has remained at a high level of over 7%. To cope with persistent high inflation, since March 2022, the Federal Reserve has continued to raise interest rates and launched a plan to reduce balance sheet size in June of the same year. The Federal Reserve has implemented a total of 450 basis points increase in interest rates as of March 10, 2023. This is the first sustained increase since 2015 [1]. The US stock market has been hit hard. Therefore, how to optimize portfolios and balance returns and risks against the backdrop of a sluggish stock market has become the most concerned issue for investors.

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The Mean-variance Model (MV), introduced by Markowitz, who is considered the pioneer of modern portfolio theory, serves as a standard for addressing portfolio management issues [2]. Due to differences in endowments, investors have different expectations for risk and return, but most investors are generally risk-averse [3]. In the Mean-variance Model, minimizing risk, that is, minimizing variance, is a typical characterization of consumer risk aversion [4]. Therefore, by plotting all possible asset combinations together according to their risk-expected return characteristics, a clustering area with a positively sloping boundary called the "efficient frontier" is constructed. Based on different investment strategies, the optimal investment portfo-lio can be selected from the efficient frontier. In this paper, 1/N investment portfoli-os, investment market indices and two risk-based strategies, i.e., maximum Sharpe ratio strategy and minimum variance strategy, will be applied.

It can be found that there are currently a large number of studies on portfolio op-timization. Some of these studies are about global and large-scale investments, such as the typical Black-Litterman model that studies the global allocation of investment portfolios [5]; Kenig Eyal analyzed portfolio selection in non-stationary markets [6]. Others are about specific industries, such as Hans, Sahamkhadam and Stephan who studied the best portfolio performance of the global timber and forestry industry and compared it with the global S&P index [7]; Sharafi, Nourollahzadeh and Sarraf stud-ied the issue of investment portfolio selection with 76 pharmaceutical and steel companies active in the stock market [8]. However, few studies have focused on cross-industry portfolio optimization. Therefore, the purpose of this paper is to study the optimal allocation of portfolios composed of stocks of companies across indus-tries.

The empirical analysis process of this paper is as follows: First, this paper selects ten typical companies' stocks from the pharmaceutical and healthcare industry, fi-nance industry, manufacturing industry and technology industry. At the same time, this paper obtained stock closing prices, financial data, risk-free interest rates and market indices from January 1, 2021, to March 10, 2023. Second, this paper prepro-cessed and standardized the data, divided it into training sets and prediction sets for training and prediction of multivariate regression models. Third, this paper applied Multiple Linear Regression Models to the selected time series data and predicted returns for the forecast period based on the trained models. Fourth, this paper used the Mean-variance Model to calculate the optimal weights of the predicted returns and obtained the optimal weights under maximum Sharpe ratio. Fifth, based on actu-al stock price data and comparing with 1/N portfolio and market returns, this paper analyzed the performance of the model and concluded that market performance is better than that of the model. This conclusion holds true in the context of a reces-sionary stock market and Fed rate hikes.

2. Data

The data in this article is derived from Yahoo Finance (https://finance.yahoo.com/), CSMAR database (https://csmar.com/) and iFind Data-base(https://ft.10jqka.com.cn/) . This paper selects the 10 representative companies, the tickers of which are JPM, MET, FR, MSFT, BAC, ACI, ADBE, UBS, SLM, CB (See Table 1). This article chooses closing prices of these stocks and collects PE ratio, market cap, market indices (S&P 500) and risk-free interest rate (Five-year Treasury bonds rates) from January 1st, 2021, to March 10th, 2023. Subsequently, the regression data (from January 1st, 2021, to September 31st, 2022) is partitioned into a training set and a test set. The training set is utilized to construct a multiple linear regression model, whereas the test set is reserved for forecasting the future return rate of each stock. All data collected is used for Mean-Variance Model and evaluating the performance of the selected assets allocations by comparing the per-formance of this portfolio with the equal weight model and the market.

Table 2 is the descriptive statistics of the daily return of the 10 stocks. All return data of each stock has been standardized to compare with each other. In this table, it is easy to find that ACI has the max

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daily return while CB has the least. And ACI has highest mean return rate, while UBS has the least. Also, for standard deviation data, it is clear that ACI's volatility is the highest among all stocks and FR is the most stable one. For kurtosis, ADBE has the highest kurtosis, which means most data is closely distributed around mean return rate. And for skewness data less than zero, it is not difficult to find that ADBE has the largest skewness data, indicating that its distribution has an obvious left-skewed shape. At the same time, for skewness data greater than zero, it can be seen that the distribution of BAC has an obvious right-skewed shape.

Table 1: Selected stocks.

	Company
ACI.N	Albertsons Companies, Inc.
ADBE.O	Adobe Inc.
BAC.N	Bank of America Corporation
CB.N	Chubb Limited
FR.N	First Industrial Realty Trust, Inc.
JPM.N	JPMorgan Chase & Co.
MET.N	MetLife, Inc.
MSFT.O	Microsoft Corporation
SLM.O	SLM Corporation
UBS.N	UBS Group AG

Table 2: Descriptive statistics of the daily return of the 10 stocks.

	Max	Min	Mean	Std Dev	Kurtosis	Skewness
ACI	0.159	-0.150	0.0008	0.026	7.507	0.015
ADBE	0.099	-0.184	-0.0006	0.024	7.678	-1.216
BAC	0.068	-0.066	0.0001	0.018	1.092	0.160
CB	0.047	-0.064	0.0006	0.015	1.382	-0.150
FR	0.073	-0.093	0.0005	0.014	4.398	-0.307
JPM	0.060	-0.063	0.0002	0.016	1.039	0.007
MET	0.059	-0.056	0.0007	0.016	0.788	-0.018
MSFT	0.079	-0.080	0.0003	0.018	1.431	-0.056
SLM	0.131	-0.184	0.0003	0.025	8.533	-0.933
UBS	0.089	-0.119	-0.0008	0.020	4.587	-0.170

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3. Methods

3.1. Compounded Return

Compounded return is widely used in portfolio management to calculate return rate of each stock [9]. It is more robust than simple return, by being able to reduce the impact of extreme values. Also, the additivity of compounded return makes it convenient to calculate multi-period and cumulative returns. And compounded return standardizes the returns of different assets, making it possible to compare returns of different assets. The calculation is as follows.

$$Compounded\ Returns = ln\ (\frac{r_{i+1}}{r_i}) \quad (1)$$

Where, r_i is the return of one asset in period i, r_(i+1) is the return of one asset in the next period of i.

3.2. Multiple Linear Regression Model

In the realm of finance and investment, multiple linear regression models are extensively employed to examine the correlations between a dependent variable and multiple independent variables, such as financials, stock market indices, risk-free rates, etc. [10]. These models are useful for predicting short-term results based on historical data. In addition, multiple linear regression models can capture both random fluctuations and systematic patterns in the data. The general form of a multiple linear regression model can be expressed as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \varepsilon \quad (2)$$

where Y is the dependent variable, $X_1, X_2, \ldots, X_n$ n are the independent variables, $\beta_0, \beta_1, \beta_2, \ldots, \beta_n$ are the coefficients of the independent variables, and ε is the error term. With mature theoretical foundations, multiple linear regression models can accurately estimate the relationships between the independent and dependent variables and can be used to make predictions about future trends. Therefore, multiple linear regression models are an important tool for return prediction of each stock in the portfolio in this paper.

3.3. Mean-Variance

During the investment process, investors usually have two main objectives: maximizing returns and minimizing risk. However, in practice and quantitative analysis, researchers find that these two objectives actually have a certain degree of conflict [11]. Therefore, balancing returns and risk becomes an important issue. Markowitz used mathematical and statistical methods to quantify the risks in investment portfolios and based on this, conducted simulations of the risk side of investment portfolios.

The Mean-variance Model, also referred to as Modern Portfolio Theory (MPT), provides a mathematical framework for constructing a portfolio. At the heart of the model is the fundamental principle of either maximizing the anticipated return for a specified level of risk or minimizing the risk for a given return. In this paper, the Mean-variance Model is founded on the following assumptions: 1. Investors exhibit risk aversion and aim to optimize their expected utility. 2. Investors are rational and base their decisions on anticipated returns and risks. 3. Investors can borrow and lend at a risk-free rate. 4. Investors possess homogeneous expectations concerning asset returns. 5. Investors have equivalent access to information. The fundamental steps of the mean-variance model are outlined below:

Firstly, calculate the expected returns of one portfolio:

$$Return\ Rate\ Vector:\ R = (r_1, r_2, \ldots, r_i)^T \quad (3)$$

$$Weight\ Vector:\ W = (w_1, w_2, \ldots, w_i)^T \quad (4)$$

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Where return rates r_i (i =1, 2, …, n) are predicted by multiple linear regression model.

Secondly, use return rate and weight to calculate the expected return of portfolio:

$$Expected\ Return\ of\ Portfolio: \mathrm{E}(R_P) = W^T R = \sum_i w_i r_i \quad (5)$$

While:

$$\sum_i w_i = 1 \quad (6)$$

Where, r_i is the return of each asset in the portfolio. w_i is weight of each asset in the portfolio. $E(R_P)$ is the expected return of the portfolio.

After determining the expected return, this paper began to measure the risk, which can be expressed as variance in statistics.

$$Variance: \sigma_P^2 = \mathrm{var}(\sum_i w_i r_i) = \sum_{ij} w_i w_j \mathrm{cov}(r_i r_j) \quad (7)$$

Where, σ_P^2 is the variance of the portfolio.

Furthermore, this paper can use Sharpe Ratio to express the relationship betthis paperen portfolio's risk and return.

$$Sharp\ Ratio = \frac{E(R_P) - R_f}{\sigma_P} \quad (8)$$

Where, R_f is the return of risk-free asset [12].

4. Results

Based on the multiple regression model, the author uses return rate, stock price, risk-free rate, market index and financials (PE ratio, BPS, etc.) data of each stock to train a linear model of each stock by importing data from 2021 to 2022. Then, the author uses the trained regression model to predict the return rate data from January to March 2023 and compared it with the actual return rate. The results are shown in Table 3 and Figure 1 below. Basically, the predicted return rate data will be smoother than the actual data.

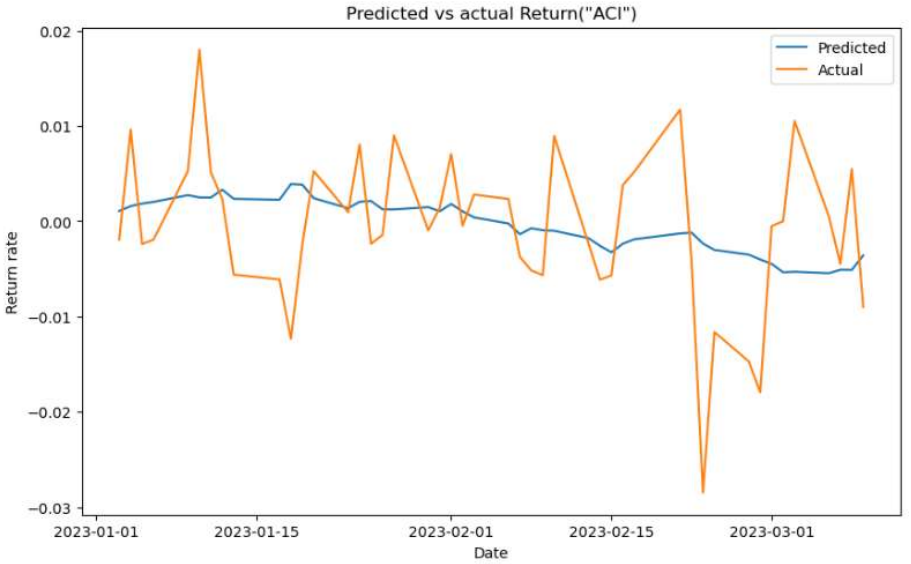

Figure 1: Predicted returns vs actual returns

Notes: The author only shows 'ACI' as an example to show the result of multiple linear regression model. Then, data predicted is used in Mean-variance model to get the best weight. The author

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construct certain portfolios, i.e., maximize Sharpe Ratio portfolio and minimize variance portfolio. And the results are shown in the following Table 3.

Table 3: Results for maximize Sharpe ratio and the minimum variance portfolios.

	ACI	ADBE	BAC	CB	FR	JPM	MET	MSFT	SLM	UBS
Max Sharpe ratio	1.6%	9.76%	17.84 %	5.56 %	25.62 %	2.76 %	1.23 %	0.62 %	22.22 %	12.79 %
Min volatility	11.8 %	14.7%	12.5%	0	12.3%	0	13.5 %	11.7 %	11.8%	11.8%

As the table indicates, 'BAC' has comparatively large weight in both maximum Sharpe ratio and minimum volatility portfolio, accounts for 17.84% and 12.5%, respectively. 'ACI', 'MET' and 'MSFT' account very little in max Sharpe ratio portfolio, however, large in min volatility portfolio.

Obtaining the two asset allocations leads to the next step: the calculation of the portfolio return. Using the actual return from 1st of January 2023 to 10th of March 2023 together with the stock weights, the daily return and annualized returns can be gained. For comparison, the S&P 500 Index return data is collected over the same period.

By comparison in Figure 2 and Table 4, it is easy to find that market performs best during this period, with comparatively high returns and a stable performance. Max Sharpe ratio portfolio, though, have a high return performance, is not stable and have a large volatility, even some big jumps.

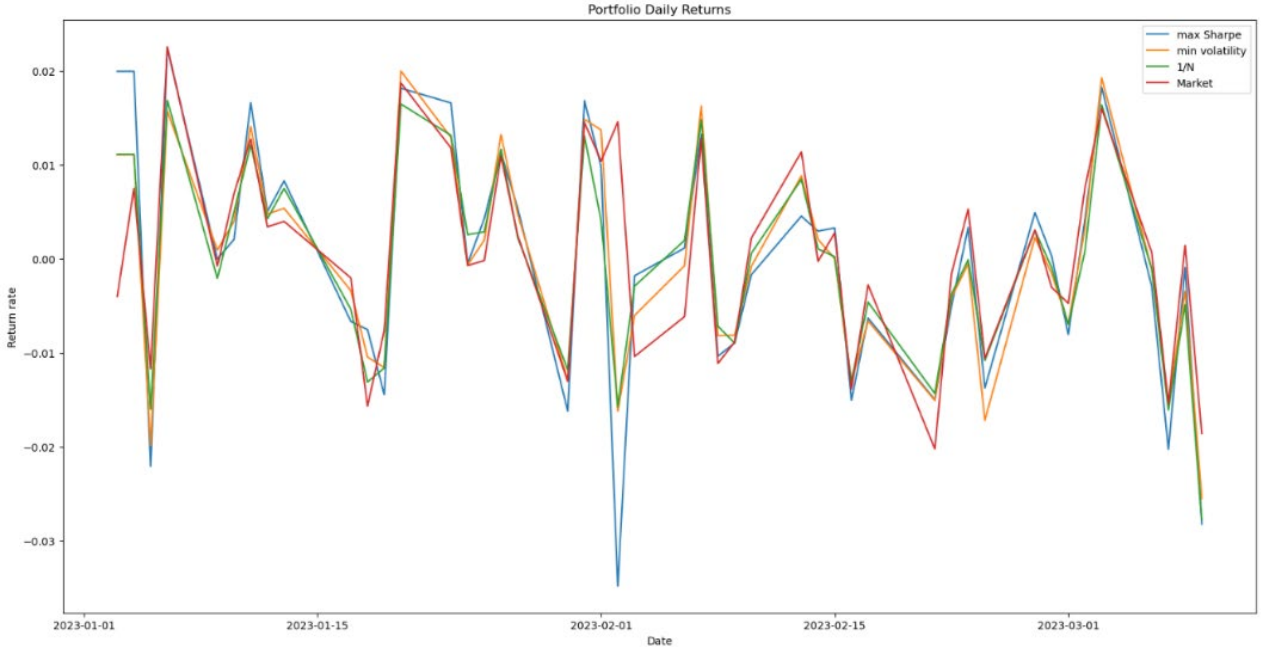

Figure 2: Daily return comparison

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Table 4: Annualized return comparison

	Annualized Return	Volatility
Max Sharpe Ratio	-10.07%	4.14%
Min Volatility	-6.8%	3.11%
1/N portfolio	-1.02%	2.73%
S&P 500 index	0.86%	1.06%

From Table 4 one can observe that the study result underperforms the broad market. The annualized return of the maximum Sharpe ratio portfolio is -10.07%, that of the minimum volatility portfolio is -6.8% and for 1/N portfolio it is -1.02%, comparing with the S&P 500 index return of 0.86%. Furthermore, the risk of the market is much lower than any study portfolio.

5. Conclusion

Currently, most of the portfolio research is focused on global investment portfolios and single-industry portfolios, and there is insufficient research on cross-industry portfolios. In fact, the greater the difference between industries, the less similar the sources of risk are, and the greater the role of diversified risk that an investment portfolio can achieve. Based on this premise, this paper selects stocks from the healthcare industry, manufacturing industry, financial industry, and technology industry for portfolio analysis to provide reference for investors.

Intuitively, the three investment portfolios (1/N, minimum variance, and maximum Sharpe ratio) and the stock index involved in this paper have little difference in daily return performance from the beginning of 2023 to March 10th. However, the annualized performance is as follows: market index performs the best, followed by 1/N model and minimum variance model, and maximum Sharpe ratio performs the worst. It can be seen that the model's performance is not as good as the actual market index performance, and this conclusion is consistent with the actual situation. When investors make investments, they should base their investments on macro situations and dynamic thinking methods, and flexibly use models based on their own risk-return expectations for investment.

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