The Optimal Analysis of the Markowitz Portfolio Model: A Case Study of the New Energy Vehicle and Automotive Industry

Kunyu Yang[1*]

[1]Mathematical Sciences, University of Southampton, Southampton, United Kingdom

Abstract. In the context of global environmental protection and the transition to a low-carbon economy, the new energy vehicle (NEV) industry has experienced rapid growth, with the Chinese market emerging as a key player. This paper selects five domestic NEV stock assets and applies the Markowitz portfolio model to optimize the portfolio weights. By analyzing historical data from August 2020 to August 2023, the optimal portfolio is calculated, and its effectiveness is validated using subsequent data from 257 trading days. The mean-variance model is employed for the calculations, and the optimal portfolio is selected based on the maximization of the Sharpe ratio. The results show that the proposed portfolio achieved a return of 41.1% during the backtesting period, significantly outperforming the equal-weighted portfolio, while also effectively controlling risk. Future research could enhance portfolio flexibility and return potential by incorporating multi-factor models or nonlinear optimization methods.

1 Introduction

In recent years, environmental pollution and the greenhouse effect have become increasingly severe, raising public awareness of environmental protection and low-carbon living. Against this backdrop, the new energy vehicle (NEV) industry has flourished, aligning with the global trend of transitioning to a green economy [1]. As one of the world's largest automotive markets and one of the first countries to strategically develop the NEV industry, China has made significant achievements in this sector. Between 2021 and 2025, the compound annual growth rate of the NEV market is expected to reach 38%, with the market size projected to reach nearly 13 million vehicles by 2025. In 2021, total financing in the industry exceeded 80 billion RMB, reflecting strong capital inflows [2]. Consequently, a growing number of investors and capital are seeking to invest in China's NEV and related automotive industries.

For investors, the challenge of diversifying investments within this industry has become an important issue. The Markowitz portfolio theory offers an excellent method for diversification, as its core principle is to optimize portfolio allocation by leveraging low correlations between assets, thereby balancing expected returns with risk to achieve optimal investment outcomes.

[*] Corresponding author: ky1u21@soton.ac.uk

This paper selects five NEV stock assets from the domestic market for experimental analysis, all of which have demonstrated strong performance during the rapid growth of the NEV sector and have significant future potential. Among them, BYD and Great Wall Motors are leaders in the Chinese NEV market, with substantial market share and extensive technological portfolios. Meanwhile, Seres, Yutong Bus, and JAC Motors offer diversified business models covering a wide range of segments, from passenger vehicles to commercial vehicles. However, this study does not include NIO, Xpeng, and Li Auto, despite their market presence in China, due to the high volatility of their stocks and the limited historical data available [3,4].

This paper will next introduce the Markowitz portfolio model and its evaluation criteria, provide a detailed explanation of data sources, and conduct descriptive statistics and correlation analysis. The optimal static-weight portfolio model will be constructed and its related data will be analyzed and evaluated. Finally, the model's feasibility will be validated through future results, leading to concrete conclusions and recommendations.

2 Model

2.1 The markowitz portfolio model

Investors typically allocate their funds across multiple securities, investing according to certain weights, and sell them at the end of the designated investment period. The key issue lies in selecting which stocks to invest in and determining the proportion (weight) of each stock to build an optimal portfolio. The goal of an optimal portfolio is to maximize returns while minimizing risk. In real markets, high-return securities often come with high risks, while low-risk securities generally offer lower returns. Therefore, finding the optimal balance between these two objectives is crucial. Against this backdrop, Harry M. Markowitz proposed the Modern Portfolio Theory (MPT) in 1952, providing investors with a systematic method for optimizing their portfolios. The core of this theory includes two key components: (1) the Mean-Variance Model, and (2) the Efficient Frontier Theory.

2.1.1 The Mean-Variance Model

The Mean-Variance Model defines risk as the volatility of returns and seeks to continuously optimize returns and risk to achieve the best balance. This model is based on several assumptions: 1. Investors make decisions based on the probability distribution of securities' returns over a specific holding period. 2. Investors assess portfolio risk by analyzing the variance or standard deviation of the expected returns of securities. 3. Investors' decisions are primarily based on the risk and returns of the securities. 4. Investors aim to maximize returns at a given risk level; correspondingly, at a specific return level, investors seek to minimize risk [5,6]. Based on these assumptions, Markowitz developed the Mean-Variance Model for asset optimization. The objective function of the model is the variance of the portfolio $\sum_i x_i r_i$

$$\sigma^2 = \mathrm{var}(\sum_i x_i r_i) = \sum_{ij} x_i x_j \,\mathrm{cov}(r_i, r_j) \tag{1}$$

The constraints are:

$$\sum_i x_i E(r_i) \geq \mu, \sum_i x_i \leq 1, x_i \geq 0 \tag{2}$$

If security i allows short selling, the corresponding constraint $x_i \geq 0$ can be removed. Here, $x_i$represents the proportion of funds invested in security i, and the total proportion of the entire investment $\sum_i x_i \leq 1$ does not exceed the budget. The expected return r_i of stock i is denoted as $E(r_i)$, and the covariance between the returns of stocks i and j is represented by $\text{cov}(r_i, r_j)$. The expected return of the portfolio to be achieved is $\sum_i x_i E(r_i) \geq \mu$. To achieve the target expected return μ, the proportion of funds x_i can be adjusted to minimize the risk σ^2 .

2.1.2 Efficient Frontier Theory

The Efficient Frontier Theory includes three key conditions: First, for a given expected return, it represents the portfolio with the lowest risk. Second, for a given level of risk, it represents the portfolio with the highest expected return. Finally, there is no other portfolio that simultaneously has a higher expected return and lower risk while satisfying both conditions.

2.2 Model evaluation criterion (sharpe ratio)

In the aforementioned models, the criterion for selecting the optimal model is the Sharpe ratio. A higher value of the Sharpe ratio indicates higher returns and lower risks associated with the corresponding portfolio. In this paper, the portfolio is denoted as P, with portfolio return R_p, portfolio volatility σp\sigma_pσp, and the risk-free rate R_f [7,8].

$$P = \sum_i x_i E(r_i) \tag{3}$$

$$\text{Sharpratio} = \frac{E(R_p) - R_f}{\sigma_p^2} \tag{4}$$

3 Data

3.1 Data sources

Firstly, regarding data selection, this paper chooses five stocks Y=(y1,y2,y3,y4,y5), namely BYD, SERES, YUTONG, Great Wall Motor, and Anhui Jianghuai Automobile Group Corp. Ltd., using their closing prices from the period of August 3, 2020, to August 2, 2023, as the basis for analysis and calculations. Additionally, data from August 3, 2023, to August 23, 2024, is used for validity verification. Furthermore, this paper selects the average interbank lending rate from August 3, 2020, to August 2, 2023, as the risk-free return rate. By calculation, the annualized return rate is 1.95%, and the daily risk-free return rate R_f is calculated as 1.95%/252=0.0077% (assuming 252 trading days in a year).

The specific return data for the five stocks (including mean, variance, standard deviation, maximum, minimum, and median) is shown in Table 1, along with the time-price curve in Figure 1.

Table 1. The specific return data.

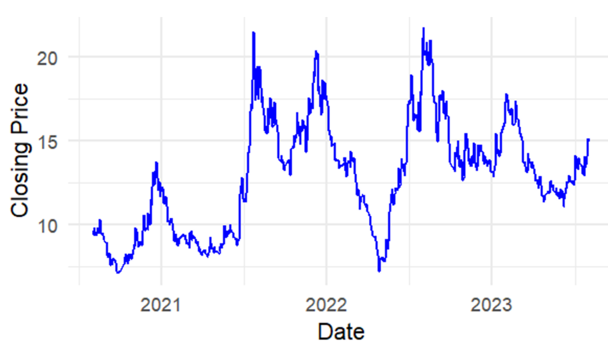
Category	BYD	SERES	YUTONG	Great.Wall .Motor	Anhui.Jianghuai.Automobile.Group.Corp.Ltd
mean	0.0020	0.0032	0.0003	0.0016	0.0013
Variance	0.0009	0.0021	0.0006	0.0012	0.0015
sd	0.0308	0.0455	0.0242	0.0347	0.0384
max	0.1000	0.1005	0.1004	0.1004	0.1005
min	-0.1000	-0.1002	-0.0884	-0.1	-0.1004
median	-0.0001	-0.0015	0.0	-0.0012	-0.0021

(a) BYD

(b) SERES

(c) YUTONG

(d) Great wall motor



(e) Anhui. Jianghuai. Automobile. Group. Corp. Ltd

Fig. 1. The time-price curve. (Picture credit: Original)

From the time-price curve in Figure 2, it is clear that from August 3, 2020, to August 2, 2023, the overall prices of the five stocks show an upward trend (except for YUTONG).

Among them, SERES experienced the highest increase of 373% over these three years, while YUTONG had the lowest increase at -1.2%.

3.2 Empirical rule

At the analytical level, based on the above closing price data, the daily returns of each stock can be calculated, and these returns are considered to follow an approximately normal distribution. First, the empirical rule is calculated, and a histogram and curve are plotted to verify whether the returns conform to a normal distribution, followed by the calculation of the mean and standard deviation of the daily returns. Additionally, the covariance between the stocks is calculated to observe the relationships among them.

The empirical rule in statistics states that for a normal distribution, 68% of the observed data points will fall within one standard deviation of the mean, 95% within two standard deviations, and 99.7% within three standard deviations.

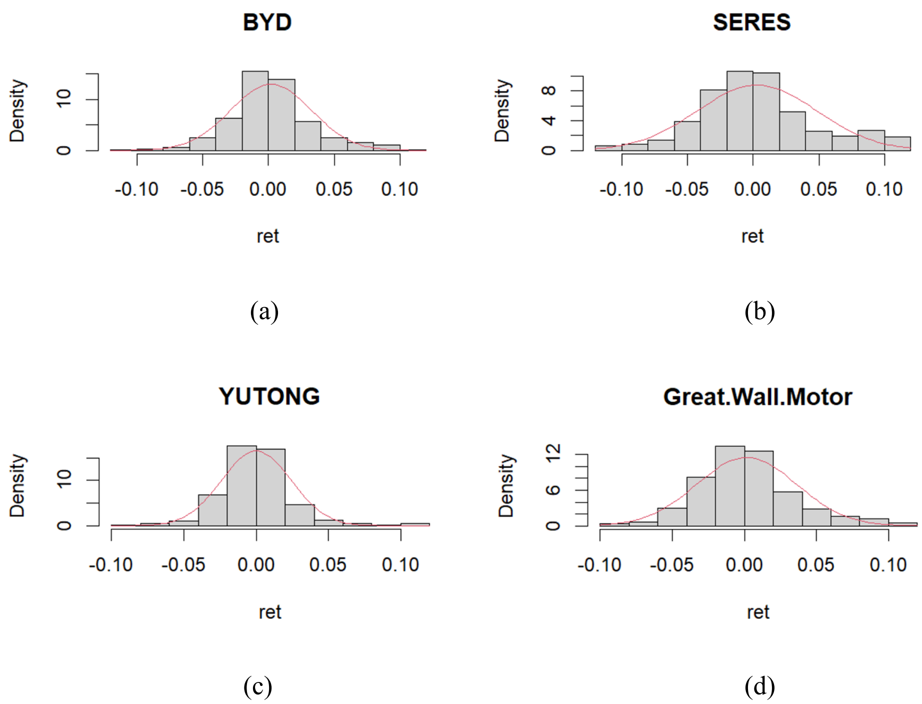
Table 2 shows the three standard deviation ranges calculated for the five stocks:

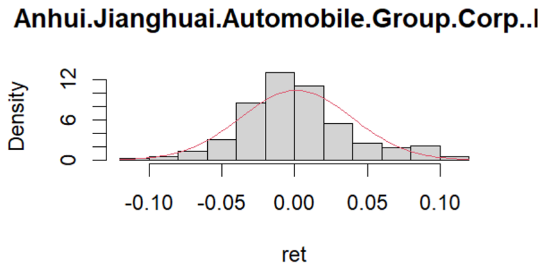
Table 2. The three standard deviation ranges

Stock	1 SDs	2 SDs	3 SDs
BYD	0.7294	0.9396	0.9849
SERES	0.7170	0.8929	1.0000
YUTONG	0.7706	0.9478	0.9821
Great.Wall.Motor	0.7239	0.9396	1.0000
Anhui.Jianghuai.Automobile.Group.Corp.Ltd	0.7404	0.9258	1.0000

Using the empirical rule, it was determined that all five selected stocks fall within the three standard deviation ranges, indicating that they follow a normal distribution.

The same conclusion was drawn using graphical methods: all stocks conform to a normal distribution, as shown in Figure 2.





(e)

Fig. 2. The normal distribution graph (Picture credit: Original)

Based on the above analysis, the daily returns of all five stocks follow a normal distribution. Among them, SERES has the highest average daily return of 3.15%, while YUTONG has the lowest at 0.27%. In terms of standard deviation, YUTONG has the lowest at 0.02, and SERES has the highest at 0.04. The covariance between the stocks is shown in Table 3:

Table 3. Covariance

	BYD	SERES	YUTONG	Great.Wall.Motor	Anhui.Jianghuai.Automobile.Group.Corp.Ltd
BYD	0.00095	0.00045	0.00021	0.00068	0.00053
SERES	0.00045	0.00207	0.00029	0.00054	0.00062
YUTONG	0.00021	0.00029	0.00058	0.00025	0.00030
Great.Wall.Motor	0.00068	0.00054	0.00025	0.00121	0.00066
Anhui.Jianghuai.Automobile.Group.Corp.Ltd	0.00053	0.00062	0.00030	0.00066	0.00148

As shown by the results, the covariance between each pair of stocks is less than 0.001, indicating a low correlation among the five stocks. This implies that the standard deviation of the portfolio composed of these stocks is relatively low. The correlation between the stocks is displayed in Table 4:

Table 4. Corelation

	BYD	SERES	YUTONG	Great.Wall.Motor	Anhui.Jianghuai.Automobile.Group.Corp.Ltd
BYD	1.0000	0.3197	0.2888	0.6397	0.4500
SERES	0.3197	1.00000	0.2642	0.3396	0.3539
YUTONG	0.2888	0.2642	1.0000	0.3036	0.3241
Great.Wall.Motor	0.6397	0.3396	0.3036	1.0000	0.4973
Anhui.Jianghuai.Automobile.Group.Corp.Ltd	0.4500	0.3539	0.3241	0.4973	1.0000

The results show that all correlation coefficients between the stocks are greater than 0, indicating a positive correlation. Among them, BYD and Great Wall Motor have the highest correlation coefficient at 0.64 [9].

4 Results

4.1 Optimal model results

By randomly generating 30^4 different weight combinations x_i, various portfolios P were obtained. A mean-sd plot was drawn for each portfolio, and the point corresponding to the highest Sharpe ratio was identified on this plot, as shown in Figure 3:

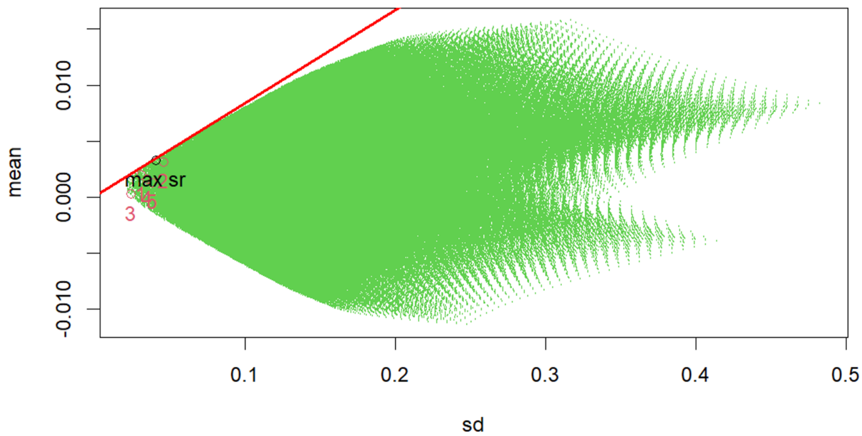


Fig. 3. The mean-sd plot (Short selling allowed) (Picture credit: Original)

The Sharpe ratio corresponding to the optimal portfolio is 0.08, and the corresponding weights X=(x1,x2,x3,x4,x5)are as follows:

x1 = 0.86, x2 = 0.62, x3 = -0.34, x4 = -0.34, and x5 = 0.20(negative weights indicate short selling).

For the case where short selling is not allowed, the optimal portfolio obtained is shown in Figure 4.

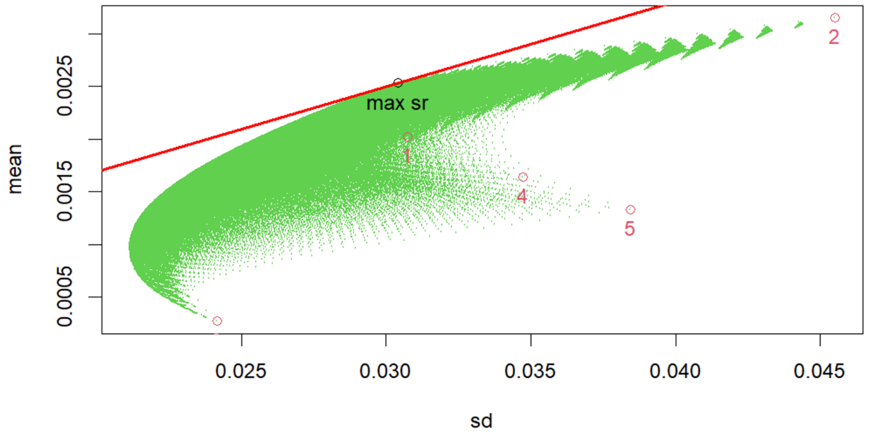


Fig. 4. The mean-sd plot (Short selling not allowed) (Picture credit: Original)

In the case where short selling is not allowed, the optimal portfolio corresponds to a Sharpe ratio of 0.08, with the corresponding weights K=(k1,k2,k3,k4,k5) as follows: k1=0.55, k2=0.45, k3=0, k4=0, and k5=0.

4.2 Model evaluation

The optimal model obtained in this paper (with short selling allowed) has an average daily return of 0.332% and a standard deviation of 0.04. Its return is higher than that of each individual stock, but its standard deviation is relatively high. For the optimal investment model where short selling is not allowed, the average daily return is 0.253% and the standard deviation is 0.03. Although its return is slightly lower than that of SERES, its standard deviation is better than that of four of the stocks.

In terms of the Sharpe ratio, both the short-selling and non-short-selling models have a Sharpe ratio of 0.08. The Sharpe ratios corresponding to the five stocks are shown in Table 5:

Table 5. Sharpe ratios

Stock	$Sharpratio$
BYD	0.0634
SERES	0.0677
YUTONG	0.0080
Great.Wall.Motor	0.0451
Anhui.Jianghuai.Automobile.Group.Corp.Ltd	0.0327

Thus, the Sharpe ratio of the optimal investment models is higher than that of the five individual stocks.

4.3 Prediction and validation

This paper compares the fixed investment weights X and K of the optimal portfolios, and the equally weighted investment W with the corresponding stocks Y. The stocks were purchased on August 3, 2023, and sold on August 23, 2024. The purchase price, selling price, and individual stock returns during this period, along with the three types of investment weights, are shown in Table 6.

Table 6. Stock return and three weights

time	BYD	SERES	YUTONG	Great.Wall.Motor	Anhui.Jianghuai.Automobile.Group.Corp.Ltd
2023/8/3	268.2300	43.1400	13.7100	29.8500	14.6300
2024/8/23	239.3400	80.3200	21.2900	22.4700	19.8500
stock profit margin	-0.1077	0.8618	0.5529	-0.2472	0.3568
weight X	0.8621	0.6207	-0.3448	-0.3448	0.2069
weight K	0.5517	0.4483	0.0000	0.0000	0.0000
weight W	0.2000	0.2000	0.2000	0.2000	0.2000

The expected returns of the three portfolios are presented in Table 7:

Table 7. Portfolio profit margin

total portfolio profit margin X	0.4105
total portfolio profit margin K	0.3269
total portfolio profit margin W	0.2833

The purchase price of each stock is PB_i, the selling price is PS_i, and the profit rate of each stock during this period is R_i:

$$R_i = {}^{(PS_i - PB_i)}/_{PB_i} \tag{5}$$

The total return for this period is R_t:

$$R_t = \sum_i x_i R_i \quad or \quad R_t = \sum_i k_i R_i \quad or \quad R_t = \sum_i w_i R_i \tag{6}$$

The results show that the optimal portfolio (with short selling allowed) achieved a return of 41.1% over the subsequent 257 trading days, significantly higher than the return of 32.7% for the portfolio without short selling and 28.3% for the equally weighted investment, while the annualized risk-free return (252 trading days) was only 1.95%. Although the return of the optimal portfolio is only slightly higher than that of the equally weighted investment, the calculated Sharpe ratio for the equally weighted investment is 0.06, which is lower than that of the optimal portfolio and even lower than that of the first three stocks. This indicates that while the returns are similar, the equally weighted investment carries greater risk. On the other hand, when comparing this portfolio with individual stocks, although its return is lower than that of SERES, YUTONG, and Anhui Jianghuai Automobile Group Corp. Ltd., it clearly avoids the risk of negative growth seen in BYD and Great Wall Motor. Therefore, overall, the optimal portfolio model derived from this model has an objective return and effectively avoids unsystematic risks [10,11].

5 Conclusion

Based on historical data from five companies in China's New Energy Vehicle (NEV) industry, this paper applies the Markowitz portfolio model to calculate the optimal investment portfolio and verify its effectiveness. The results show that this portfolio achieved a return of 41.1% during the backtesting period, with a Sharpe ratio of 0.08. Compared to the non-short-selling portfolio and the equally weighted investment, the risk was significantly reduced, while returns were improved. By optimizing the portfolio based on historical data, risks can be effectively diversified, resulting in relatively stable returns. This demonstrates that the Markowitz model has a certain degree of reliability and practical value in real-world applications.

This paper provides the following investment recommendations: By observing the five stocks in the rapidly growing NEV industry, it was found that not every stock in a booming industry will yield favorable returns. Therefore, it is advisable to opt for diversified investments to mitigate risks, achieving a balance between gains and losses. For investors, selecting an appropriate number of assets to invest in is crucial. Investing in too few stocks increases the unsystematic risk, while blindly adding more assets to avoid unsystematic risk can lead to lower overall returns. Given the limitations of the Markowitz theory itself and the differences in financial markets across countries, it is unwise to blindly apply the Markowitz portfolio model for investment. One should also consider the fundamentals of different assets and whether they belong to a dividend-paying industry.

References

1. J. Shao, H. Yu, S. He, Analysis and Impact Study on the Main Factors of China's New Energy Electric Vehicle Development Based on a Mathematical Model. Adv. Appl. Math. 13, 133-140 (2024) (in Chinese)

2. Xinhua, China’s NEV industry revs up on powerful engine. Gov.cn. Retrieved from: https://english.www.gov.cn/news/topnews/202204/17/content_WS625b4c87c6d02e533532970f.html#:~:text=China%27s%20NEV%20industry%20revs%20up%20on%20powerful%20engine,times%20year-on-year%20in%20the%20first%20quarter%20of%202022. (2022-04-17)
3. Y. Zeng, J. Zhang, Q. Zhang, An Empirical Study of the Markowitz Model in Optimal Stock Portfolio Selection. J. Xiangtan Norm. Univ. (Soc. Sci.) 31, 88-91 (2009) (in Chinese)
4. X. Fan, Markowitz Theory and Investment Portfolios in China's Stck Market. Q. Econ. 29, 13-21 (2020) (in Chinese)
5. H. M. Markowitz, Portfolio Selection. J. Finance 7, 77-91 (1952)
6. P. Jorion, Bayesian and CAPM Estimators of the Means: Implications for Portfolio Selection. J. Bank. Finance 15, 717-727 (1991)
7. K. Liu, Construction of Investment Portfolios Using Markowitz Theory. Mod. Commerce, 36, 44-45 (2018) (in Chinese)
8. Y. Wang, Application of Markowitz Mean-Variance Theory in Energy Futures Portfolio Optimization. Comput. Mod. 7, 11-15 (2020) (in Chinese)
9. W. Wu, L. Zhao, Research and Empirical Analysis of Optimal Portfolio on Shenzhen Stock Exchange Based on Markowitz Portfolio Model. J. Xuzhou Inst. Technol. (Nat. Sci.) 38, 17-21 (2023) (in Chinese)
10. Q. Liu, Balance of Risk and Return: An Empirical Analysis Based on the Markowitz Model. Financ. Forum, 45, 49-54 (2019) (in Chinese)
11. Y. Li, L. Yu, Analysis of Optimal Security Portfolios Based on the Markowitz Theory. Financ. Account. Monthly, 11, 53-55 (2013) (in Chinese)