Research on Optimization of Investment Portfolio in the New Energy Vehicle Industry Chain

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Abstract. The urgent environmental problems caused by global climate change have propelled the rise of the new energy vehicle industry. Nations and business are also focusing on the research and promotion of this industry. Due to the fast development, investors face both promised investment opportunities and complicated challenges. Against this backdrop, a vital issue, which is how to choose the optimal investment portfolio to achieve the maximum possible return while experience the lowest possible risk, arises. This paper collects the closing price of stocks from 5 companies in different sectors of the new energy vehicle industry, with the period from 19 August 2022 to 18 August 2023 and then computes the variance of closing price and average return of the stocks, finally uses the COVAR function in excel to obtain the covariance matrix. After processing the data, the paper applies the Markowitz mean-variance model to obtain the optimal portfolio formation. Results show that this industry may not be a good choice for investors currently since all three portfolios show negative returns, while the negativity do not completely negate the long-term potential of this industry as the development of the industry can be influenced by various factors. It is therefore to conduct deeper research to better understand the industry dynamics and future trend.

Keywords: Portfolio Theory; New Energy Vehicle; Markowitz Mean-Variance Model.

1. Introduction

In recent years, the increasingly severe environmental issues brought about by global climate change have led to the emergence of pressing concerns. As a significant field of sustainable development and environmental protection, the new energy vehicle (NEV) industry is gradually replacing traditional fuel vehicles as the primary driving force of the global automobile industry. An escalating number of nations and businesses have actively engaged in the research and development (R&D), production, and promotion of NEV as a result of society's increased focus on sustainable development. The NEV industry chain, which spans a variety of areas from battery technology to charging infrastructure and intelligent manufacturing, has become a crucial part of the global economy [1].

To further encourage the development of NEV, the Chinese government has implemented a series of supportive policies such as free parking and vehicle tax reduction and exemption for NEV in some regions [2]. With the support of these policies, the NEV industry gained access to more funding and resources for technological innovation. Factors such as improvements in the battery energy density and research into rapid charging technology have significantly accelerated the growth of this industry. According to the statistical data from the China Association of Automobile Manufacturers (CAAM), China's production and sales of new energy cars reached 4.59 million and 4.53 million units respectively, from January to July 2023, making a year-on-year growth rate of 40% and 41.7% respectively. Meanwhile, the penetration rate, or the proportion of NEV sales to total new vehicle sales, reached 29%. The rapid development offers wide opportunities for investors while brings much more complicated investment environment and risky challenges. Against this backdrop, a key question is how to select the optimal investment portfolio from a multitude of NEV manufacturers, components suppliers and related technological companies to achieve the maximum portfolio return with lowest possible risk.

In this context, this paper selects 5 companies in different sectors of the NEV industry and collects the closing price of each company from 19 August 2022 to 18 August 2023, Then the paper will apply Markowitz mean-variance model to explore the construction of optimal investment portfolio within the NEV industry chain [3]. This study has important implications for investors, entrepreneurs, and government. Through an in-depth analysis of investment opportunities and risks within the NEV industry, investors will gain valuable insights into and capitalize on the potential of this developing industry. Simultaneously, offering effective investment strategies can attract more funds into the industry and thus promoting its sustainable development, contributing to the fulfillment of upcoming green transportation initiatives, and serving as a reference for government policies.

2. Literature Reviews

In 1952, the mean-variance model, was introduced by an American economist Harry Markowitz, who published an article titled "Portfolio Selection" in the "Journal of Finance". This model is regarded as the foundation of financial quantitative investment as this theory has dominated subsequent study in this area and transformed the landscape of the portfolio theory. Markowitz pointed out that investors should build portfolios from a variety of assets rather than investing solely in particular stocks. Therefore, investors' top concerns should be how to allocate an ideal portfolio that either maximizes returns under a given risk or minimizes portfolio risk under a given return [3]. Foreign research into portfolio theory and its application began much earlier. In 2007, Prattley et al. applied portfolio theory to devise surveillance strategies, in order to allocate the most effectively level of limited resources for each disease or region within a certain time periods, given a level of risk and uncertainty [4]. Ivanova and Dospatliev selected 50 stocks traded on Bulgarian Stock Exchange in 2017, with time period between January 2013 and December 2016, and thus formed the optimal portfolios based on the Markowitz theory, providing Bulgarian investors with useful information to build their own portfolios with respect to their own risk preference [5]. In 2022, by utilizing the Markowitz 2.0 model, Mir et al. proposed efficient water allocation strategies in drought-prone areas like the Helmand River Basin and formed an efficient frontier between the expected return and conditional value at risk as to balance potential long-term growth and short-term loss [6].

Though Chinese research and application of portfolio theory started relatively late, Chinese scholars have made many crucial and breakthrough contributions in this field. Chen made use of the modern portfolio theory in 2012 to build the optimal investment portfolio of new energy power generation companies, providing technical support for these enterprises [7]. In 2012, Fan collected the Chinese inbound tourism data in 2011 and then applied analytical methods such as qualitative research, together with the portfolio theory to forecast the number of China's inbound tourism in 2015 and try to reach an optimization of that number. This research provided extremely useful suggestions and insights into China's inbound tourism, promoting the economic development [8]. In 2022, Ni collected data for 15 companies' stock in Hong Kong stock market and then, using both Markowitz model and Index model, this paper obtained the optimal portfolio formation by processing and analyzing the data, finally concluded that the index model is a better tool for investors who want to enter the Hong Kong stock market to build their portfolio [9]. In same year, Tan and Xu analyzed the data of listed manufacturing companies in China from 2007 to 2018, concluding that under the profit maximization motive, there is an optimal level of financialization equilibrium [10].

Even though current research about application of portfolio theory, more specifically, Markowitz model, has made some progress in the NEV industry chain, there is no literature that employs portfolio theory in in-depth study to examine its application in this area. By applying the Markowitz portfolio theory, this study will fill in this research gap, aiming to identify the method for creating the ideal portfolio in the NEV industry chain and balancing risk and return.

3. Data and Methodology

3.1 Data Resources

This paper first randomly chose 30 new energy industry chain companies from upstream (extraction, production, and processing of raw materials), midstream (production and recycling of car parts and accessories) and downstream (complete vehicles) of NEV industry. During the process of data processing, it is surprised that more than 20 companies showed negative expected return within the one-year period. Thus, the paper chose 4 of the companies from different streams of the industry that experienced positive expected return, namely Weichai Power Co., Ltd (WeiChai Power), Chaozhou Three-Circle (Group) Co., Ltd (CCTC), Changshu Automotive Trim Co., Ltd (CAIP) and Jinhong Gas Co., Ltd (Jinhong). Then the paper added one more company, BYD Co., Ltd (BYD), which is a leading corporation in the industry. For the risk-free rate, this paper used Shanghai Interbank Offered Rate (Shibor). The closed price of stocks and Shibor were all gathered from CSMAR, also known as China Stock Market & Accounting Research Database, and the sample period is from 8.19 in 2022 to 8.18 in 2023, to capture changes under different market conditions. Following the collection of data, a series of steps including data cleaning and missing values and outliers handling were taken to preprocess the data in order to guarantee the accuracy and consistency.

3.2 Selected Parameters

The primary parameters used in Markowitz model are return and risk. In this study, we compute the daily return for each company using formula (1):

$$return_t = \frac{P_t - P_{t-1}}{P_{t-1}} \tag{1}$$

Where P_t is the closing price of the stock on day t, and P_{t-1} is the closing price of the stock on day t-1. The average return across the period will provide an overall measure of the performance of the company.

According to the mean-variance model and literature study, variance (or standard deviation σ) is used to measure risk as this statistical concept measures how far a given asset's returns deviate from the average return, and thus serves as an indicator of the investment's volatility. The variance of individual asset i, which is represented as σ_i^2, can be directly calculated using formula (2):

$$\sigma_i^2 = \frac{1}{n-1}\sum_{j=1}^{n}(x_{ij} - \bar{x}_i)^2 \tag{2}$$

Where x_{ij} represents jth individual return of asset i, $\bar{x}_i$ is the average return of asset i, and n is the number of data points. Since the paper collected one-year period data from 5 NEV companies, in this case n is 364 and i ranges from 1 to 5.

3.3 Model Establishment

The Markowitz mean-variance model is the model established in this paper. The main idea of the model is, by diversification, investors can achieve a balance between return and risk, ultimately resulting in more efficient and optimal portfolios. More specifically, Markowitz model suggests that investors' investment decisions should not solely depend on one asset but should spread across various assets with different level of return and risk.

According to the model, the expected return on the portfolio is the weighted sum of return on each asset and the risk (represented by variance of weighted sum) can be obtained by the property of variance. Mathematically can be represented as equation (3)-(5):

$$r_p = \sum_{i=1}^{10} \omega_i r_i \tag{3}$$

$$\sigma_p^2 = \sum_{j=1}^{10}\sum_{k=1}^{10} \omega_j \omega_k \sigma_{jk} \tag{4}$$

$$\sum_{1}^{10} \omega_l = 1 \; and \; 0 \leq \omega_l \leq 1 \; for \; l \in \{1, 2, \dots, 10\} \tag{5}$$

where r_p is the return on the portfolio, r_i is the return on asset i, ω_i is the weight for asset i, and σ_{jk} is the covariance between return on asset j and that on asset k. In this case, covariance evaluates the degree of relationship between different assets, assisting investors in understanding how the volatility of various portfolio components is related.

The objective of the model is to maximize the portfolio return while minimizing the portfolio risk. In other words, this paper is aiming to solve the following system of equations:

$$\begin{cases} \max\left(r_p = \sum_{i=1}^{10} \omega_i r_i\right) \\ \min\left(\sigma_p^2 = \sum_{j=1}^{10} \sum_{k=1}^{10} \omega_j \omega_k \sigma_{jk}\right) \\ s.t. \sum_{1}^{10} \omega_l = 1 \; and \; 0 \leq \omega_l \leq 1 \; for \; l \in \{1, 2, \dots, 10\} \end{cases} \tag{6}$$

Here the paper assumes that weight is non-negative. The solution to (6) leads to a fundamental concept called efficient frontier, which represents the set of all possible optimal combinations of assets that achieve maximum returns at each level of risk. However, determining the optimal portfolio formation also depends on the risk-free asset and its rate of return. The Capital Market Line (CML) is a line drawn from the risk-free rate to the efficient frontier. Portfolio returns are impossible to attain when one is above the CML, while portfolios that are below the CML have high risk and low returns. The CML can be expressed as equation (7), with risk (standard deviation σ) on the x-axis and return r on the y-axis:

$$r = r_f + \frac{r_p - r_f}{\sigma_p} \times \sigma \tag{7}$$

where r_p and σ_p are the portfolio return and portfolio risk respectively, and r_f is the risk-free rate of return. The gradient of the CML, also known as the Sharpe ratio, essentially measures the additional return an investor receives for assuming additional risk. A higher Sharpe Ratio indicates a more attractive risk-to-reward profile. Therefore, the optimal portfolio formation is obtained when the CML is tangential to the efficient frontier, where the Sharpe ratio is maximized, according to portfolio theory.

4. Results and Discussion

To compute the weight of the portfolio asset to solve the optimization problem, this paper used the method of quadratic programming, which can be realized by much software. This study chose Microsoft Excel, making use of the solver function.

Firstly, according to the Markowitz mean-variance model, the paper computed expected return of each company by averaging its daily returns, as shown in table 1.

Table 1. Computation of Expected Return (ER)

	Weichai Power	BYD	CCTC	CAIP	Jinhong
ER	0.0305%	-0.0980%	0.0583%	0.0686%	0.0927%

Then, table 2 illustrated the covariance matrix among these five firms. Finally, setting the objectives and constraints and applying the solver function will give the weights of each firm in the portfolio. However, different aims have different results. This study will set three objectives and analyze each resulting portfolio combination.

Table 2. Covariance Matrix

	Weichai Power	BYD	CCTC	CAIP	Jinhong
Weichai Power	0.00029	0.00011	8.67E-05	0.00012	5.14E-05
BYD	0.00011	0.00039	7.85E-05	0.00026	0.000105
CCTC	8.67E-05	7.84E-05	0.00040	0.00012	0.00016
CAIP	0.00012	0.00026	0.00012	0.00085	0.00015
Jinhong	5.14E-05	0.00011	0.00016	0.00015	0.00065

4.1 Minimizing Risk

In the case that investors only wish to minimize the portfolio risk, with no requirements for the return, the solver function gives the following portfolio weighting:

Table 3. Weighting of Portfolio 1

	Weight (W)	ER	W*ER
Weichai Power	0.3879	0.0305%	0.0118%
BYD	0.2267	-0.0980%	-0.0222%
CCTC	0.2370	0.058%	0.0138%
CAIP	0.0179	0.0686%	0.0012%
Jinhong	0.1305	0.0927%	0.0121%

As shown on table 3 and table 6, the optimal weighting for WeiChai Power, BYD, CAIP and Jinhong is 0.3879, 0.2267, 0.2370, 0.0179 and 0.1305 respectively. Weichai Power obtains the largest weight, although its expected return is not the highest. In this case, the portfolio risk, measured by standard deviation, reaches the minimum, 0.0130. Meanwhile, the paper also computes the Sharpe ratio, which equals -1.089. The negativity indicates that either the expected return is less than the risk-free rate, or the expected return is negative. Indeed, according to the statistics, the portfolio return is 0.0168%, far smaller than the risk-free rate 1.43%.

4.2 Maximizing Return and Minimizing Risk

However, investors do not solely wish to minimize the risk, they prefer highest expected return while keeping portfolio risk as low as possible. This objective is equivalent to maximize the ratio of $\frac{ER}{Risk}$. Thus, the weighting can be obtained by following the same procedure:

Table 4 illustrates that the five weightings are 0.1532, 0, 0.29, 0.1604 and 0.3964 respectively. While the weight of Jinhong is the greatest, constituting nearly 40% of whole portfolio, that of BYD is zero, which may due to its negative expected return. Moreover, according to table 6, the return of the second portfolio outperformed that of the first by a considerable margin, standing at 0.0694% as opposed to the 0.0168% of the first portfolio. Additionally, portfolio 2 boasts the greatest $\frac{ER}{Risk}$ ratio of 0.0439, a notable improvement compared to the first portfolio's ratio of 0.0129.

Table 4. Weighting of Portfolio 2

	W	ER	W*ER
Weichai Power	0.1532	0.0305%	0.0047%
BYD	0	-0.0980%	0%
CCTC	0.29	0.058%	0.0169%
CAIP	0.1604	0.0686%	0.0110%
Jinhong	0.3964	0.0927%	0.0368%

4.3 Maximizing Sharpe Ratio

Theoretically, higher Sharpe ratio indicates higher attractiveness of an investment and therefore portfolio with maximum Sharpe ratio is preferred. Table 5 showed the corresponding weights that maximize the Sharpe ratio:

Table 5. Weighting of Portfolio 3

	W	ER	W*ER
Weichai Power	0	0.0305%	0%
BYD	0	-0.0980%	0%
CCTC	0	0.058%	0%
CAIP	0	0.0686%	0%
Jinhong	1	0.0927%	0.0927%

The result is quite intriguing. Four out of the five stocks bear no weight, while the remaining one, namely Jinhong, occupies the entire weightage. As summarized in table 6, it is noteworthy that the resulting portfolio return is the highest among all three portfolios, attributable to the fact that the expected return of Jinhong is the most substantial. Meanwhile, the Sharpe ratio reaches a maximum of -0.525, despite it is still negative.

Table 6. Statistics of 3 Portfolios

	Portfolio 1	Portfolio 2	Portfolio 3
ER(Portfolio)	0.0168%	0.0694%	0.0927%
Risk-Free rate	1.43%	1.43%	1.43%
Portfolio Risk (Std)	0.0130	0.0158	0.0255
ER/Risk	0.0129	0.0439	0.0364
Sharpe Ratio (SR)	-1.089	-0.8607	-0.525

In all three cases, the Sharpe ratio appears to be negative. Scrutinizing the data reveals that the negativity is again, caused by the negative market risk premium (i.e., the difference between a market portfolio's projected return and the risk-free rate). Consequently, portfolio obtained by maximizing the Sharpe ratio lacks significant reference value to investors. However, the first two portfolios cleverly employ the Markowitz mean-variance model, aiming to maximize returns while limiting risk. It is therefore reasonable for investors to take the weightings of these two portfolios into consideration when making investment decision.

5. Conclusion

This paper concentrated on the optimal portfolio formation based on NEV industry chain. Using Shibor as risk-free rate, this study employed the Markowitz mean-variance model to analyze the closing price of stocks of five companies from different sectors, with the time period from August 19, 2022 to August 18, 2023. Three portfolios were gained from three different perspectives: minimizing risk, maximizing $\frac{ER}{Risk}$ ratio, and maximizing the Sharpe ratio. However, the result showed that, during the selected time period, all portfolio returns were below the risk-free rate, leading to negative Sharpe ratio. This situation may indicate the poor performance of the NEV industry and greatly limited the evaluation of the portfolio effectiveness.

During the research process, this paper only considers the closing price of five companies' stock during only one year period to represent the whole NEV industry chain. It is necessary to enhance an in-depth investigation of internal factors within the industry, collecting more data and statistics from longer period to obtain better understanding of the market performance and industry dynamics. Moreover, Markowitz model assumes stable expected portfolio return, which is unrealistic due to market fluctuation. Therefore, more complex models are worth exploring to capture the instability of the market in future study.

To conclude, this study provides investors with a preliminary framework for the investment in the NEV industry. Despite the unfavorable prospects in this industry, future research and technological advancements may uncover investment opportunities in this field.

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