Optimizing Investment in the Automotive Industry: A Modern Portfolio Theory Approach with Tesla, GM, and Hyundai

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Abstract. The automotive manufacturing sector is undergoing a significant transformation, which is mainly driven by innovations in sustainable technology and the increasing demands in electric vehicles (EVs). This transition to environmentally friendly technologies in the industry creates substantial opportunities and challenges for potential investors. The Modern Portfolio Theory (MPT) offers a feasible solution for optimizing investment portfolios by balancing risk and return. This research explores the application of MPT to form an optimal portfolio within the automotive sector, specifically focusing on U.S. stocks from Tesla, General Motors (GM), and Hyundai. Simulations were carried out using six months of data in 2024 from the Nasdaq, and the results showed that a portfolio comprised of Tesla and GM stocks, with zero allocation to Hyundai, offers the optimal balance. The findings highlight the role of correlation analysis and diversification in portfolio management. Overall, this research aims to emphasize the relevance of MPT method in guiding investment decisions in dynamic and innovative markets, as well as providing valuable insights for investors seeking to navigate the evolving landscape of the automotive industry.

Keywords: Modern Portfolio Theory, Portfolio Optimization, Diversification, Sharpe Ratio.

1 Introduction

The automotive industry is undergoing major changes driven by a global emphasis on sustainability and advancements in electric vehicle technology [1]. Increasing environmental concerns and energy challenges have raised the public demand for sustainable and efficient transportation. In specific, European Commission believes moving to green transportation is a solution to reduce global warming; and thus, dozens of policies are implemented to promote this transition, that include limiting the release of the greenhouse gases on newly produced cars [2]. In line with this action, the Department of Energy in the U.S. also aim to facilitate the public adoption of green transportation for 2025; and thus, these policies drive the increasing demand in EV sector [3].

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As the automotive industry shifts toward sustainable practices, companies that adapt quickly and effectively can capitalize on new market opportunities, while those that lag may face significant challenges. For instance, this transition to EV manufacturing particularly brings challenges regarding the supply chain for critical materials like lithium and cobalt, as claimed by researchers, these materials are essential for lithium-ion batteries, which are currently the most efficient and reliable for EVs [4]. The surge in demand for EVs also brings new opportunities for downstream suppliers within the automotive industry, particularly in the battery manufacturing sector.

These trends in the dynamic environment create both opportunities and risks for investors, making portfolio theory intensely relevant. Investors need to carefully balance the risks and returns associated with their investment decisions to navigate this transition successfully. At the heart of this balancing act is the Modern Portfolio Theory (MPT), provides a structured approach to portfolio construction, aiming to optimize returns while minimizing risks [5]. In addition, a systematic approach to portfolio construction is crucial as investors seek to capitalize on these opportunities while mitigating potential risks. Despite its importance, not all investors are equipped with the knowledge or tools necessary to effectively apply MPT in their investment strategies.

This paper aims to provide an insight for future investors in making investment decision in a dynamic environment, by examining the application of Modern Portfolio Theory in the automotive sector. By constructing a portfolio that includes stocks from Tesla, General Motors (GM), and Hyundai, this research will demonstrate how MPT can be employed to find the optimal allocation of investment assigned to each stock.

The methodology of portfolio optimizing under MPT will be explained in detail, encompassing the concept of diversification and statistical measurement for risk and return. Overall, this analysis will highlight the importance of understanding portfolio theory and its practical implications for investment in an industry poised for significant growth and innovation. The results in this research provided an insight for investors in making effective decisions when navigating the complexities of the automotive sector.

By applying MPT to real-world scenarios based on historical data published by Nasdaq, this paper seeks to answer key questions: How can investors use portfolio theory to determine the optimal allocation of weight between Tesla, GM, and Hyundai? What is the optimal weight assigned to each asset that maximize the Sharpe ratio? These questions will be addressed in the following paragraphs, where the methodology of MPT will be detailed and its application in composing a 'risk-return balanced' portfolio will be explored.

2 Methodology

2.1 Background and Concepts of MPT

The Modern Portfolio Theory, initially developed by the Economist, Harry Markowitz, through his research paper Portfolio Selection in 1952 [6]. Markowitz indicates that, instead of the selection of individual asset with focusing on its individual return, the composition of a diversified portfolio as a whole ought to be considered; and thus, influenced the way of investors construct their portfolio [6]. His idea highlights that the actual potential of an portfolio lies in the inter-relationship between its constituent assets. This understanding led to a more holistic view of portfolio management, under MPT, the selection of a mix of assets can optimizes the return without further increasing the overall risk, laying the foundations of modern investment management [5]. The concept of diversification and risk and return are crucial to the implication of MPT.

Diversification. Markowitz's insight for diversification was that, by holding multiply assets classes, the overall risk for portfolio falls without lowering its return [6]. By this stand, investors can potentially avoid the risk specific to individual assets; hence, mitigating the unsystematic risk that can be diversified [7]. In other words, by investing in two different stocks instead of just one, the gains from one stock can offset the losses from the other, this refers to be the one of the benefits that diversification can offer. The rationale behind diversification is that the returns of different assets do not perfectly correlate with each other [6].

The role of correlation analysis in diversification. In specific, the effectiveness of diversification is influenced by the correlation between the chosen assets, which reflects how the return from two individual assets in the portfolio move in relation to each other, with values ranging between -1 and +1. For instance, assuming that asset A was already invested, and aim to reduce the unsystematic risk by including another asset B in our portfolio. To understand the role of correlation analysis in portfolio diversification, now consider three extreme cases for correlation of +1, 0, and -1.

$Corr(A, B) = 1$, this means that selecting asset B offers no diversification benefit since the gain from asset A and B tend to increase or decrease together by the same amount, the unsystematic risk remains undiminished.

$Corr(A, B) = 0$, two assets are independent of each other, in this case, diversification is ideal, as the performance of one asset does not predict the performance of the other.

$Corr(A, B) = -1$, two assets will move in exactly opposite directions and this is deal for diversification. For instance, the gains in asset A can offset losses in asset B, thereby lowering the portfolio risk significantly.

Markowitz indicates that, as the correlation between asset returns is less than perfectly positive, diversification can reduce risk without compromising the expected return [6]. Therefore, the diversification approach enables investors to smooth out the potential impacts of volatility and reduce the overall risk without necessarily lowering returns. Apart from that, evaluating the return and risk for the diversified portfolio is equally important in shaping investment decisions under MPT.

Statistical Measures for Risk and Returns. Modern Portfolio Theory initially assume that investors behave rationally (risk-averse investors) and seek to maximize returns for a certain level of risk. The presence of uncertainty in investment is crucial for understanding how a rational investor behaves, though the diversification of investment is a reasonable adopted strategy as it helps to minimize this uncertainty [8]. To investigate how the return and risk are associated under MPT, the portfolio’s expected return and its volatility can both be mathematically interpreted. The general formula used for the portfolio return calculation can be expressed as Equation (1) [9]; and the return is subject to the constraint where the total share of capital allocation to all assets in the portfolio added up to 100% or 1, which can be expressed as Equation (2) [9].

$$E(r_p) = \sum_{i=1}^{n} w_i \cdot E(r_i) \tag{1}$$

$$s.t. \sum_{i=1}^{n} w_i = 1 = 100\% \tag{2}$$

Where n is the number of individual assets, $E(r_p)$ is the expected return of the overall portfolio, $E(r_i)$ represents the expected return of an individual asset i, and w_i is the share of asset i in the portfolio.

According to Francis and Kim [9], the volatility of the return refers to be the risk. This measurement also reflects the effectiveness of diversification process in minimizing the risks. The formula of portfolio variance calculation is stated as Equation (3).

$$\sigma_p^2 = var[r_p] = \sum_{i=1}^{n} \sum_{j=1}^{n} w_i w_j \sigma_{ij} \tag{3}$$

Where n is the number of individual assets in the portfolio, σ_p^2 means Variance of the portfolio, σ_{ij} represents the covariance between returns on assets i and j, w_i is the share of asset i in the portfolio, and w_j is the share of asset j in the portfolio.

The volatility, measured by the standard deviation of the return is stated as Equation (4) [9].

$$\sigma_p = \sqrt{var[r_p]} = \sqrt{\sigma_p^2} \tag{4}$$

By assessing the volatility of each portfolio's return, the portfolio with a higher standard deviation σ_p implies its expected return is even spread out over a set of possible outcomes, so the risk is higher. Moreover, if one holds more assets in the portfolio, the volatility of its expected return falls, and hence lowers the risk. This is suggested by the law of large number, and also in line with the traditional approach of simple diversification for reducing the total risk [7].

3 Portfolio Optimization Under MPT

Markowitz suggested that, a certain level of risk and return is carried out by each portfolio of asset classes; for each specific level of risk, there is only one portfolio that offers the highest possible return [6]. The portfolio optimization under MPT is a process of selecting the optimal investment allocation from a combination of assets concerning the trade-off between risk and return. This process relies on the concepts of the Efficient Frontier, Capital Market Line (CML), and the Sharpe ratio calculation, which serve as key tools in identifying optimal portfolios [9].

Efficient Frontier. The Efficient Frontier refers to be one of the key pillars of MPT, representing a set of portfolios that offer the highest possible expected return for each level of risk [10]. To construct the Efficient Frontier, an investor must analyze a large number of potential portfolios, each with different combinations of assets. By calculating the expected return and risk for each portfolio, one can plot these portfolios on the graph. The Efficient Frontier can be graphically represented in Fig. 1, as an upward-sloping curve where the y-axis represents expected return of the portfolio $E(r)$ and the x-axis represents the volatility of the portfolio's return σ.

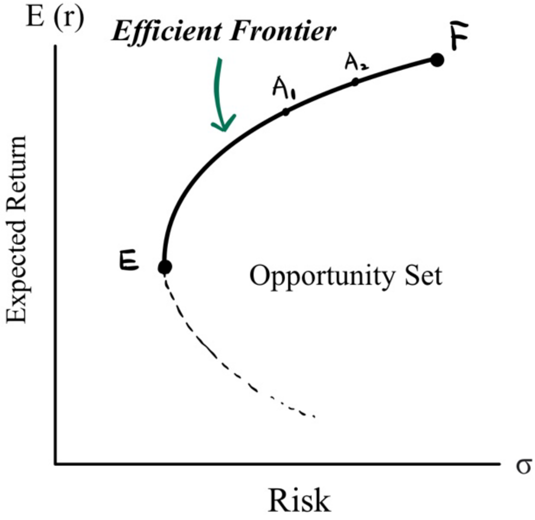

Fig. 1. The Efficient Frontier and opportunity set

As stated by Francis and Kim, a portfolio is said to be efficient if it either yields greater return than other portfolio in the same risk class or it takes lower risk than others with the same return [9]. In Figure 1, the portfolios that lies on the efficient frontier EF, such as A_1 *and* A_2, are all efficient as no other portfolio can provide a higher return without increasing risk. They hence dominate other possible portfolios in the opportunity set; and for risk-averse investors, optimal portfolio will be located on the upward-sloping concave efficient frontier by the definition Efficient Frontier Theorem [9].

Risk-free Assets & Capital Market Line. Instead of considering the portfolio contains only risky assets, investors can also invest in a risk-free asset i.e., a government bond, in a combination with risky assets. The Capital Market Line (CML) represents the set of portfolios that optimally combine the risk-free asset with risky assets, thereby achieving the highest possible return for a given level of risk [9]. In Figure 2, the CML is derived by drawing a tangent from the risk-free interest rate r_f to the Efficient Frontier.

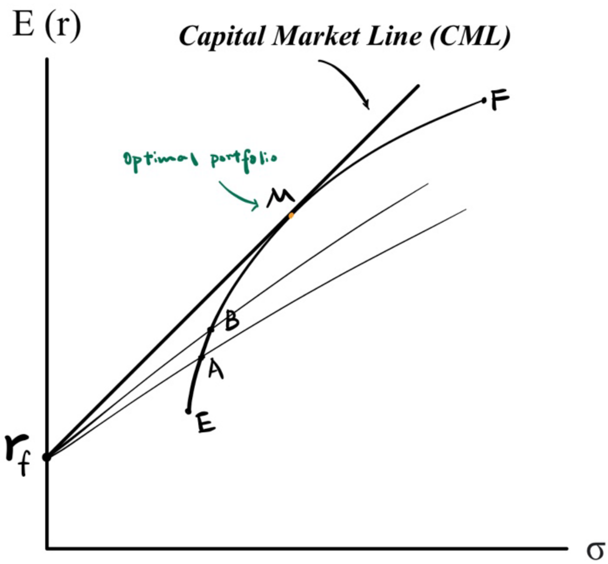

Fig. 2. Combining the risk-free asset with various risky portfolios

In Fig. 2, the market portfolio at point M is considered the optimal portfolio of risky assets because it offers the best risk-return trade-off, which is located at point of tangency with the Efficient Frontier EF [9].

4 The Sharpe Ratio

The Sharpe ratio, introduced by William F. Sharpe, is a measure of risk-adjusted return. According to William. F. Sharpe, the reward-to-variability ratio was primarily developed as a tool that is used to evaluate investment portfolios with different return and risk [11]. The index is calculated by dividing each portfolio's risk premium by its relative risk. The Sharpe ratio calculation is expressed as Equation (5) [9].

$$Sharpe\ Ratio = \frac{Risk\ Premium}{portfolio\ risk} = \frac{E\left(r_p\right) - r_f}{\sigma_p} \tag{5}$$

Sharpe's index breakdown both the return and its risk statistic into a single index that allows for comparison and make investment decision. Based on historical values of return (r_p) and risk (σ_p), The optimal portfolio is found as the one in the opportunity set that has the highest Sharpe ratio. By ranking the Sharpe ratio, the market portfolio has the highest Sharpe ratio than other possible portfolios in the opportunity set, which is depicted in Fig. 3.

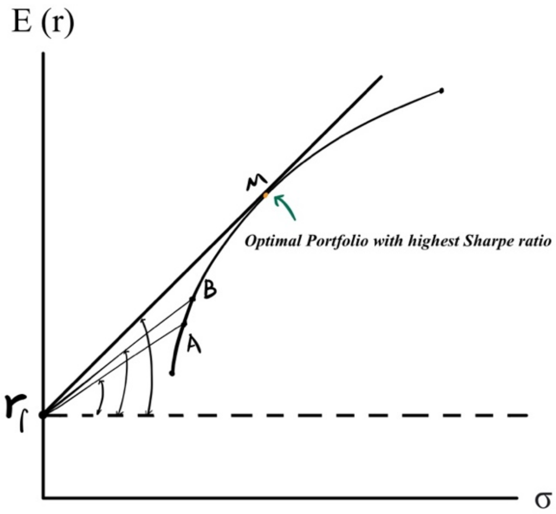

Fig. 3. Rank portfolios from different risk classes using Sharpe ratio

5 Real life example in apply MPT to investment portfolio

5.1 Portfolio Construction

Application of MPT in Automotive Industry. To address the necessity for investors to understand and apply portfolio theory, especially in volatile and rapidly evolving sectors like automotive manufacturing. The automotive industry is now undertaking a transformative phase with advancements in production of EVs [1]. According to Valladares Montemayor and Chanda, the top 10 automotive fortune 500 firms and the industry is currently shifting from internal combustion engine (ICE) cars to EVs as a sustainable transportation solution [12]. This creates a unique opportunity for investors to exploit on the growth potential of firs such as Tesla, GM, and Hyundai that are at the forefront of this revolution.

The role of diversification in portfolio construction. Stocks of Tesla, General Motors (GM), and Hyundai are chosen to build a diversified portfolio, where investing in each firm obtains distinct and strategic advantages that ensures diversification within the industry. In specific, such portfolio construction are feasible to capture the growth in green energy vehicle as well as traditional ICE vehicles.
Tesla Motor stands out as a leader in the EV market; and it is also worth mentioning its rise from an alternative energy start-up to becoming a major manufacture of battery electric vehicles in the motor industry in North America [13]. The portfolio can capture the growth potential in the EV sector by including Tesla. In terms of diversification, a combination of a pure EV play with traditional car manufacturers allows an investor to

benefit from increasing demand for new-emerged EVs while maintaining exposure to the still-profitable traditional automotive market.

5.2 Determine the Optimal Portfolio

Expected return and risk associated with individual assets. The stock opening and closing prices for each stock in the portfolio in 2024 from January to July is collected. Then determine the monthly yield for Tesla, GM, and Hyundai by dividing the changes in stock price in each month (measured by end-of-month price minus the beginning-of-month price) by the stock price in the beginning of each month. This calculation is mathematically expressed as Equation (6).

$$\text{Stock yield} = \frac{\text{end-of-month stock price - beginning-of-month stock price}}{\text{beginning-of-month stock price}} \tag{6}$$

By calculating the average return of a stock in a specific month, the performance of each individual stock in the portfolio is revealed. The historical share price between January and July in 2024 for Tesla (TSLA), General Motor (GM), and Hyundai (HYMTF) that were listed by Nasdaq Stock Exchange (https://www.nasdaq.com/) on 16th August 2024 are represented along with their associated monthly stock yield in Table 1, 2, and 3.

Table 1. Stock prices and yield for Tesla, from January to July in 2024.

Months	Opening Share Price ($)	Closing Share Price ($)	Stock yield (%)
January	248.42	187.29	-24.60
February	188.86	201.88	6.89
March	202.64	175.79	-13.25
April	175.22	183.28	4.60
May	179.99	178.08	-1.06
June	176.29	197.88	12.25
July	209.86	232.07	10.58

Table 2. Stock prices and yield for General Motor, from January to July in 2024.

Months	Opening Share Price ($)	Closing Share Price ($)	Stock yield (%)
January	36.05	38.8	7.63
February	38.87	40.98	5.43
March	40.99	45.35	10.64
April	45.4	44.53	-1.92
May	44.47	44.99	1.17
June	45.74	46.46	1.57
July	46.68	44.32	-5.06

Table 3. Stock prices and yield for Hyundai, January to July in 2024.

Months	Opening Share Price ($)	Closing Share Price ($)	Stock yield (%)
January	41.3	42.55	3.03
February	44.45	57.69	29.79
March	59.01	57.4	-2.73
April	57.81	57.765	-0.08
May	57.525	56.38	-1.99
June	56.38	65.25	15.73
July	65.505	59.53	-9.12

The expected return for each company stock is derived from calculating the average annual yield for each stock, based on historical six-month stock yield data from February to July. In addition, the risk is computed using = STDEV formula in Excel, this is done to evaluate the volatility of historical yields associated with each stock. The return and risk associated with each stock in the portfolio are summarized in Table 4.

Table 4. Expected return and risk associated with GM, Tesla, and Hyundai

Portfolio	GM	Tesla	Hyundai
Expected Return	0.24	0.4	0.63
Standard Deviation	0.06	0.09	0.15

Correlation Estimation. As discussed in the Section 2.1, evaluating the correlation between assets is beneficial to portfolio management. For instance, diversification is ideal as the correlation between stocks held in the portfolio is negative. Based on the historical yield associated with each asset, = CORREL function is used to calculate the correlation coefficient between the three assets in the portfolio. The result is shown in Table 5 below.

Table 5. Correlation between Tesla, GM, and Hyundai based on historical yields

Assets	Correlation Coefficient
Tesla & GM	-0.2571
GM & Hyundai	0.4709
Tesla & Hyundai	0.3476

A portfolio with stocks that have low or negative correlations will generally have lower risk than a portfolio with stocks that are highly positively correlated. This is because a positive gain from some stocks can balance the loss from others, smoothing out the overall portfolio returns. In Table 5, a negative correlation between Tesla and GM is found, $Corr(Tesla, GM) = -0.2571$, suggesting that as Tesla's stock yield increases, GM's stock yield tends to decrease. Hence, by including both Tesla and GM are ideal for portfolio diversification, the risk associated with the portfolio tend to be necessarily lower since the negative correlation can offset losses in one stock with gains in the other.

Expected return and risk for portfolio. The expected return of each stock for Tesla, GM, and Hyundai can be denoted by $\bar{r}_T$, $\bar{r}_G$, and $\bar{r}_H$, respectively. The notation w_T, w_G, and w_H represent the weight of capital allocation assigned to each stock where $w_T + w_G + w_H = 1$. The portfolio return can be calculated by multiplying the expected return of individual assets by its share of allocation and adding them together, which can be expressed as Equation (7).

$$\bar{r}_p = \bar{r}_T w_T + \bar{r}_G w_G + \bar{r}_H w_H \quad (7)$$

Portfolio variance calculation is written as Equation (8).

$$\sigma_p^2 = {w_T}^2{\sigma_T}^2 + {w_G}^2{\sigma_G}^2 + {w_H}^2{\sigma_H}^2 + 2 \times w_T w_G \sigma_{T,G} + 2 \times w_T w_H \sigma_{T,H} + 2 \times w_G w_H \sigma_{G,H} \quad (8)$$

The risk associated with the portfolio can be calculation by Equation (9).

$$\sigma_p = \sqrt{\sigma_p^2} \quad (9)$$

Based on these formula and calculation, the return and risks of the portfolio can be determined for any given share of investment allocate to Tesla, GM, and Hyundai.

Optimal Portfolio Formation. The optimal allocation of weights to Tesla, GM, and Hyundai is determined as the one with the highest Sharpe ratio than other portfolios in the opportunity set. The comprehensive set of possible portfolios that consist of 160 data points is built by randomly adjusting the share of allocation between these stocks. This is done to stimulate a range of potential risk-return combinations, which is graphically represented in Fig. 4.

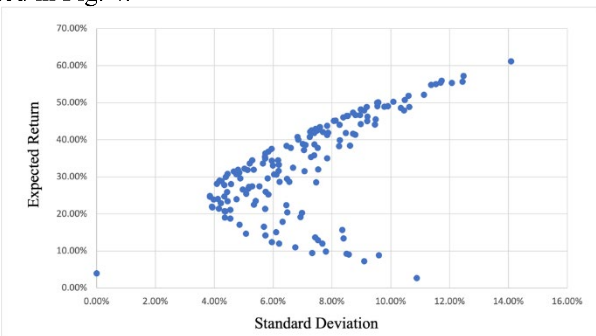

Fig. 4. Comprehensive set of 160 possible portfolios

To obtain a comprehensive set of portfolios, randomize the proportion of each stock invested by setting =RANDBETWEEN (0,1000)/1000 to w_T and w_G. The constraint is that each weight assigned to Tesla, GM, and Hyundai added up exactly to 1, which is achieved by setting $w_H = 1 - w_T - w_G$.

According to the data from Board of Governors of the Federal Reserve System (US), retrieved from FRED [14], the 10-year U.S. treasury yield was around 3.95%. on August 9, 2024. This is used as a risk-free interest rate $r_f = 3.95\%$, and the calculation of Sharpe ratio for each randomized possible portfolio is expressed as Equation (10), which represents the portfolio's risk-adjusted return.

$$Sharpe\ ratio = \frac{E[r_p] - 3.95\%}{\sigma_p} \tag{10}$$

After a range of possible portfolios is built through randomization the allocation of weights, the Excel's Solver add-in is used to optimize the portfolio by determine the amount of share assigned to each stock that gives the highest Sharpe ratio.

To define this optimization problem, the choice variable is the weights for each stock, set the objective function to be the Sharpe ratio, and the constraint is defined as the total weight assigned is 1. In the Solver dialog box, the cells in the Excel spreadsheet that contain the weights for each stock are identified as the choice variable and set the objective to be the cell containing the Sharpe Ratio calculation. After running the solver, the optimal allocation of weight to each stock is determined and listed in Table 6.

Table 6. Optimal allocation of weight to each stock in the portfolio

Portfolio	GM	Tesla	Hyundai
Weight (%)	57.41	42.59	0

These represent the optimal allocation of capital between stocks of Tesla, GM, and Hyundai in the portfolio, which yields an expected return of 30.81% with a standard deviation of 4.45%. This optimal portfolio should lie on the Efficient Frontier and be the most efficient portfolio in terms of risk-adjusted return, as indicated by the highest Sharpe ratio, which is graphically illustrated in Fig. 5.

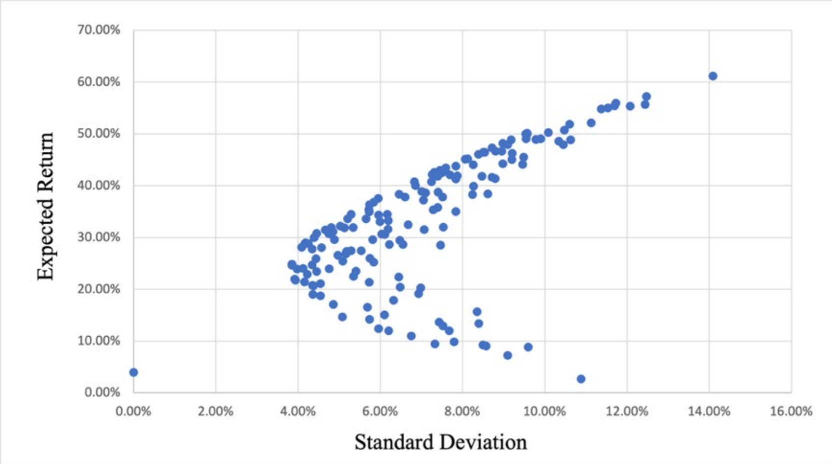

Fig. 5. Optimal portfolio is found with the highest Sharpe ratio

The optimal allocation assigns 57.41% of the portfolio to GM, 42.59% to Tesla, and 0% to Hyundai, including a negatively correlated assets (Tesla and GM) while does not assign any weight to Hyundai since it offers less additional perks in reducing portfolio risk. In specific, the inclusion of both Tesla and GM in the portfolio provides a natural hedge, where the losses in one stock are potentially offset by gains in the other. Yet, including Hyundai brings less benefits in risk reduction since it has positive correlation with both Tesla and GM.

From the aspect of different sectors within the industry, these results suggest a strategy that taking account the complementary benefit and market positions of Tesla and GM in the industry. In specific, Tesla's innovative edge in the EV sector and the solid market position of GM as a traditional auto manufacturer create a portfolio that is resilient against potential industry fluctuations [13].

Based on the findings of the result, although the Hyundai individually offers the highest expected return of 63%, investors tend to prioritize firms that are not only offer strong individual performance prospects but also contribute to a well-balanced and diversified portfolio. This underscores the critical role of correlation in diversification, which is in line with the central idea of Modern Portfolio Theory.

6 Conclusion

In conclusion, the application of MPT to the automotive manufacturing industry demonstrates the importance of strategic portfolio construction in optimizing investment outcomes. The rapid evolution of the automotive sector, characterized by the shift towards electric vehicles and sustainable technologies, indeed create a plenty of opportunities for investors.

Through building a portfolio that includes Tesla and General Motors, while excluding Hyundai, this paper illustrates how MPT can be effectively used to maximize the

Sharpe Ratio, thereby achieving the optimal risk-adjusted returns. Through simulating a comprehensive set of portfolios and optimizing the Sharpe ratio, the results implies that it is optimal for investors to assign 57.41% and 42.59% of capital to General Motor and Tesla, respectively. Yet, the exclusion of Hyundai underscores the critical role of correlation in diversification. Under MPT, this can be rationalized as Hyundai offers a high expected return individually, its inclusion does not significantly contribute to diversifies the portfolio's risk due to its positive correlation with Tesla and GM. This study highlights the need for investors to carefully consider the inter-relationship between asset correlations as well as market positions when constructing portfolios and making investment decisions. As the automotive industry proceed to innovate and adapt, MPT continues to be a valuable approach for investors seeking to capitalize on growth while managing risks in a fast-changing environment.

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