Novel Portfolio Designs Based on Markowitz Portfolio Theory and Various Assets

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Abstract: Portfolio is crucial for hedge the risks in contemporary assets management. This paper explores the application of MPT in constructing and analysing portfolios using the top 10 U.S. companies from the Fortune 500. The study delves into the historical development and contemporary relevance of portfolio optimization, building on foundational theories such as the CAPM (Capital Asset Pricing Model). Utilizing data sourced from Yahoo Finance, the study applies advanced optimization techniques, including Global Minimum Variance and Mean-Semivariance Optimization, to build the Efficient Frontier and evaluate portfolio performance. The results indicate that the choice of optimization method significantly impacts portfolio outcomes, with the Global Minimum Variance approach offering more stable returns, while the Mean-Semivariance approach provides higher potential returns at the cost of increased volatility. The study's findings underscore the significance of diversification and tailored risk management in modern investment strategies. Nonetheless, the study recognizes constraints, including dependence on historical data and model assumptions, suggesting avenues for future research in incorporating alternative risk measures and exploring different economic environments. These results contribute to the field by providing both theoretical insights and practical guidance for optimizing portfolios in today's dynamic financial markets.

1 INTRODUCTION

For the contributions to the subject of financial economics, or finance, Harry Markowitz was awarded the Nobel Prize. His investment framework of Portfolio Selection, known as the MPT, made huge impact and lays a solid foundation for extended study on the portfolio selection (Mangram, 2013). For example, the development of Sharpe ratio and the CAPM in 1964, and the establishment of Fama French Model in 1992. Contemporarily, scholars in the field of finance continue to build on the topic of portfolio selection. However, the theories and method varies, portfolio selection evolves two central measure: risk and return. MPT and all other following theories are essentially looking for a more sophisticated way to maximize its expected return and minimize its risk of investment simultaneously. (Markowitz, 1952; Markowitz, 1976)

The central theme of Economics is to find the optimal way to allocate with limited resources given. This idea applies to Financial Economics as well. Portfolio Optimization, in its core, is to find an optimal solution to allocate the limited financial resources (usually calculated in dollar value) to different financial assets or derivatives (stocks, bonds, etc.) so that the portfolio produce the most yield at a specific risk. Today, the step of finding the optimal weights can be easily done using Python, Excel Solver, or any other similar product. So, the key question for modern investor is to select the assets and derivatives that he would like to invest in.

The CAPM is a highly significant and thoroughly examined framework in contemporary finance. Created in 1964 by William Sharpe, the CAPM offers a methodology for evaluating an asset's E[R] in light of its market risk. It is based on the principles established by MPT, which introduced diversification to mitigate risk in an asset portfolio. The CAPM correlates the anticipated return of an asset with its systematic risk, denoted by the beta coefficient (β), which quantifies the return of an asset in relation to market returns. The fundamental principle of CAPM asserts that investors must receive compensation in two forms: the time value of money and risk. The Rf, which is the return on a risk-free investment typically linked to government bonds, is a symbol for the time value of money. The risk element is represented by

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the risk premium, defined as the disparity between the anticipated market return (E[Rm]) and the risk-free rate. The CAPM formula is articulated as:

$$E[Ri] = Rf + \beta s(E[Rm] - Rf) \quad (1)$$

Here, βs indicates the investment's beta, E[Ri] is the expected return on investment, Rf is the risk-free rate, and (E[Rm] - Rf) is the market risk premium. This formula shows that an asset's expected return is closely correlated with its systematic risk, which is measured by beta. The CAPM holds considerable significance for asset valuation and portfolio administration. Initially, it establishes a standard for evaluating investment performance. Investors can ascertain if an asset is overvalued or undervalued by contrasting its actual return with the expected return forecasted by CAPM. CAPM aids in determining the capital cost, which is essential regarding corporate finance choices, including capital allocation and project assessment (Fama & French, 2004).

Even with its extensive usage, CAPM has been the focus of many debates and criticism. One of the primary criticisms is its reliance on several simplifying assumptions, like the presence of an asset devoid of risk, the notion that the expectations of all investors are the same, and that markets are perfectly efficient. These assumptions, while useful for creating a tractable model, are often unrealistic in real-world settings (Black, Jensen, & Scholes, 1972).

Research studies analysing the CAPM empirically have produced conflicting results. Research conducted by Fama and French demonstrates that variables beyond beta, including business size and the book-to-market ratio, significantly influence stock returns, hence contesting the CAPM's assertion that beta is the exclusive predictor of projected returns (Fama & French, 1992). The model's validity has been scrutinized at times of market upheaval, including the global financial crisis of 2007-2008 and the COVID-19 pandemic. In these circumstances, the presumption of a consistent, foreseeable correlation between risk and return may falter, resulting in substantial divergences from the anticipated results forecasted by CAPM (Maji, 2012).

Despite these criticisms, CAPM remains a key building block of modern finance theories. Its simplicity, intuitive appeal, and foundational role in understanding the risk-return tradeoff have ensured its continued relevance in both academic research and practical applications. However, it is widely recognized that CAPM is not a universally applicable solution, and its limitations must be considered when applying it to real-world scenarios. As finance continues to evolve, CAPM serves as a foundational model upon which more complex and nuanced models have been built, reflecting the intricate realities of financial markets.

The motivation for this paper stems from the critical importance of portfolio optimization in modern finance, particularly in the context of large, influential corporations. MPT provides a robust structure for developing an ideal portfolio through weighing return and risk. Given the prominence and substantial market impact of the top 10 U.S. companies in the Fortune 500, analysing their performance through the lens of Markowitz's theory offers valuable insights into risk management and investment strategies. These companies, which include industry leaders across sectors such as technology, healthcare, and finance, are often seen as bellwethers of the broader economy. Investors, both institutional and individual, frequently look to these companies when constructing portfolios, making it essential to understand how to increase profits while lowering risk in this context. By applying Markowitz's theory, which emphasizes the importance of diversification and the efficient frontier, this paper seeks to investigate the optimal allocation of investment among these top-performing firms.

Furthermore, the post-pandemic economic landscape has introduced new variables and uncertainties that challenge traditional investment strategies. The top 10 Fortune 500 companies have shown varying degrees of resilience and growth during this period, offering a unique opportunity to test the robustness of Markowitz's model in a contemporary setting. By studying these companies, this essay aims to further the current conversation regarding the relevance and application of MPT in today's dynamic financial environment, providing both theoretical insights and practical guidance for investors aiming to optimize their portfolios. This research not only reinforces the importance of diversification but also highlights the evolving nature of risk in modern financial markets.

2 DATA AND METHOD

This study employs a rigorous methodological framework rooted in Markowitz's Mean-Variance Optimization, a central concept in MPT. The objective is to optimize the portfolio of the top 10 U.S. companies by minimizing risk while maximizing expected returns. The methodology is outlined as follows. The data comprises daily prices for the top 10 U.S. companies, sourced using the 'yfinance' library from Yahoo Finance, which is widely regarded for its accuracy in providing historical financial data. These companies, spanning sectors such as technology, healthcare, and finance, represent a substantial portion of the U.S. market. Adjusted closing prices were collected to calculate daily returns, which are critical for the portfolio optimization process (Brown & Warner, 1985; Fama, 1970).

Expected returns were estimated using the CAPM, which adjusts for systematic risk and provides a more reliable estimate compared to simple historical averages (Sharpe, 1964). The covariance matrix, a crucial component in portfolio optimization, was estimated using the Ledoit-Wolf shrinkage method. This method is preferred over the traditional sample covariance matrix due to its ability to reduce estimation error and enhance robustness (Ledoit & Wolf, 2004; DeMiguel, Garlappi, & Uppal, 2009). For Global Minimum Variance (GMV) Portfolio, it was constructed with the aim of minimizing the total portfolio variance. This approach allows for both long and short positions, ensuring that the portfolio achieves the lowest possible risk (Markowitz, 1952; Clarke et al, 2006). The study also employed mean-semivariance optimization, which focuses on minimizing downside risk rather than total volatility, aligning more closely with the risk preferences of conservative investors (Estrada, 2007). This method identifies portfolios that minimize potential losses, offering a more targeted approach to risk management. The final stage of the methodology involved constructing and analyzing The efficient frontier denotes the collection of optimal portfolios that provide the maximum expected return for a specified level of risk. This was achieved under various constraints, including sectoral and regulatory constraints, to ensure the theoretical soundness and practical applicability of the findings (Michaud, 1989; Jorion, 1992).

This methodologically robust approach facilitates a comprehensive evaluation of portfolio performance, providing valuable insights into optimal allocation strategies among the top 10 U.S. companies. The use of advanced techniques, such as shrinkage estimation and alternative risk measures, enhances the robustness of the findings and contributes significantly to the existing literature on portfolio optimization.

3 RESULTS AND DISCUSSION

3.1 Effective Frontier

The Efficient Frontier is a core principle in MPT, denoting the collection of optimum portfolios that provide the maximum expected return for a specified degree of risk. In this study, the Efficient Frontier was constructed by applying different optimization techniques to the top 10 U.S. companies in the Fortune 500. The portfolios were optimized to minimize risk while maximizing return, using data on daily returns calculated from historical prices. The results for optimal and random portfolios are shown in Figure 1 and Figure 2, respectievly.

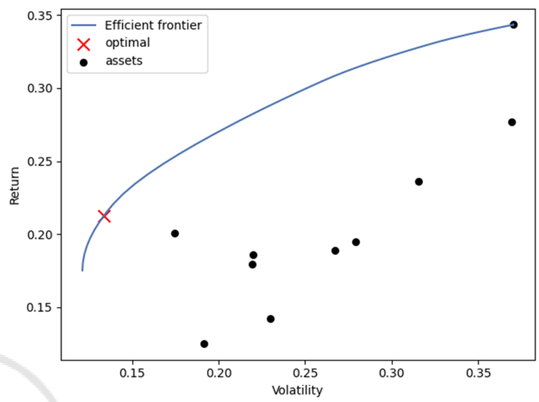

Figure 1: Efficient Frontier with Assets and Optimal Portfolio (Photo/Picture credit: Original).

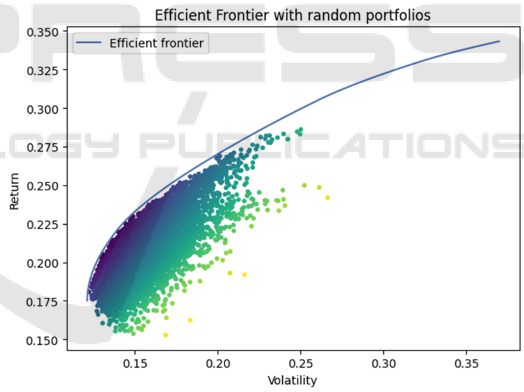

Figure 2: Efficient Frontier with Random Portfolios (Photo/Picture credit: Original).

3.2 Model Performance

To assess the efficacy of different optimization functions, the study employed several portfolio optimization techniques, including Global Minimum Variance and Mean-Semivariance Optimization. These methods were applied to the dataset to construct portfolios under varying risk constraints, and their performance was subsequently analyzed. Here is a statistical summary of the portfolio performance under different optimization techniques.

The expected annual return of 20.0% indicates a strong performance projection, while the annual volatility of 9.6% reflects the portfolio's risk level. The Sharpe ratio of 1.87 suggests that the portfolio offers a high return per unit of risk, making it an attractive option for risk-averse investors. Additionally, the portfolio weights resulting from the optimization process are visually represented in Figure 3. Figure 3 provides a bar chart illustrating the asset allocation across the top 10 companies. The horizontal bars represent the proportional investment in each company, highlighting the diversification strategy employed in the optimization process. Notably, companies like Google (GOOG) and Berkshire Hathaway (BRK-A) have the largest weights in the portfolio, reflecting their influence in maximizing returns while maintaining an acceptable risk level. On the other hand, companies like Amazon (AMZN) and Apple (AAPL) have relatively smaller weights, which may be due to their higher volatility or lower expected returns in the context of the optimized portfolio.

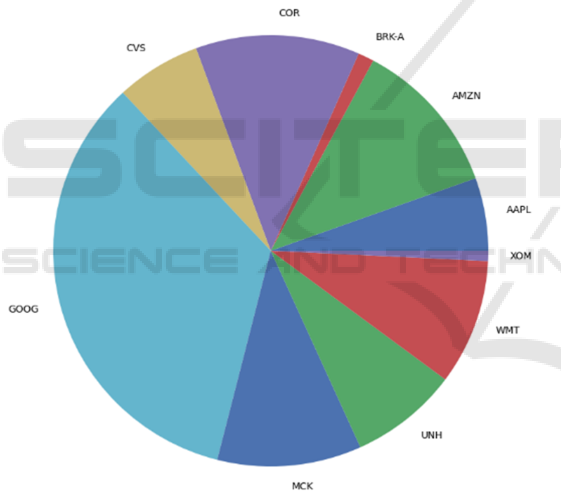

Figure 3: Portfolio Weights (Photo/Picture credit: Original).

The covariance matrix, shown in Figure 4, further elucidates the relationships between the assets in the portfolio. Figure 4 demonstrates the correlation between the daily returns of each pair of companies in the portfolio. The color intensity in the heatmap indicates the strength of the covariance, with brighter colors representing higher covariance values. For example, companies such as Apple (AAPL) and Amazon (AMZN) exhibit a relatively higher covariance, suggesting that their returns generally exhibit a tendency to move in the same direction. Conversely, some pairs like CVS and XOM show lower covariance, indicating less synchronized movements in their returns.

Understanding these covariances is crucial for effective portfolio optimization, as it allows for better diversification by combining assets that do not move together. This reduces the overall portfolio risk while still achieving a desirable return. These results indicate that the choice of optimization method significantly affects portfolio performance. The high Sharpe ratio suggests that the portfolio optimization process effectively balances risk and return, particularly for the Global Minimum Variance approach, which is preferable for risk-averse investors seeking steady returns with minimal risk. In contrast, the Mean-Semivariance optimization is more suited for investors willing to tolerate higher risk for potentially greater returns.

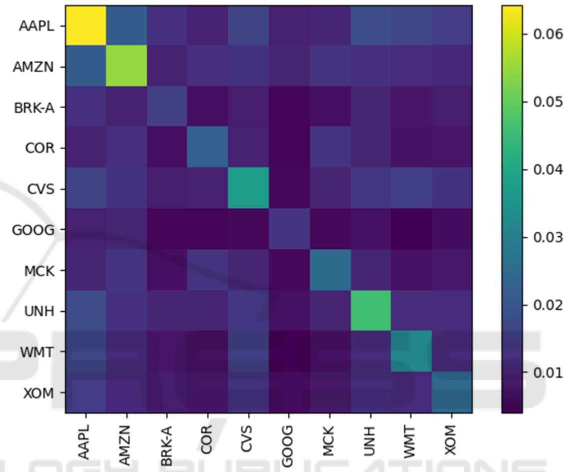

Figure 4: Covariance Matrix(Photo/Picture credit: Original).

3.3 Explanation and Implications

The findings from the portfolio optimization highlight the critical role of risk management in constructing an efficient portfolio. The Efficient Frontier clearly demonstrates that higher returns are achievable only with higher levels of risk, emphasizing the importance of diversification in mitigating volatility. Investors should carefully consider their risk tolerance when selecting portfolios, as those positioned on the upper end of the Efficient Frontier are more exposed to market fluctuations.

The high Sharpe ratio of 1.87 indicates that the optimized portfolio is expected to generate returns significantly above the risk-free rate, adjusted for volatility. This suggests that the portfolio is well constructed, offering substantial returns relative to its risk level. Investors should note that such a portfolio is particularly attractive in stable market conditions but should be monitored closely at times of volatility in the market.

From a practical perspective, the study provides several investment insights. Portfolios that include a mix of low-volatility and high-growth companies attain a more advantageous ratio of return to risk. The diversification is evident in the portfolio weights illustrated in Figure 3, where investments are spread across different sectors. The portfolio's relatively low volatility of 9.6% suggests effective risk management, which can lead to more consistent performance over time, particularly in volatile markets. Investors seeking higher returns may consider strategies that optimize for semivariance, but they must be prepared for the accompanying increase in portfolio volatility. These implications reinforce the notion that portfolio optimization is not a strategy that works for every scenario; instead, it must be customized to the particular risk-return profile of the investor.

3.4 Limitations and Prospects

While this study provides valuable insights into portfolio optimization using the top 10 U.S. companies, there are several limitations that warrant discussion. The analysis depend upon historical price data, which may not fully capture future market dynamics or account for unprecedented events such as economic crises or pandemics. In addition, the optimization techniques used in this study are based on certain assumptions, such as normally distributed returns and constant covariances, which may not hold true in all market conditions. Besides, the study focuses on the top 10 U.S. companies, which, while representative of the broader market, may not reflect the performance of smaller or less prominent firms. Future research could expand on this work by exploring different asset classes, incorporating alternative risk measures such as Value at Risk (VaR), and applying these methods in different economic environments. Additionally, examining the impact of external factors like interest rate changes or geopolitical events on the Efficient Frontier could provide further insights into portfolio optimization strategies.

4 CONCLUSIONS

To sum up, this study applied Markowitz's Mean-Variance Optimization to construct and analyse efficient portfolios using the top 10 U.S. companies in the Fortune 500. The results demonstrate that portfolio performance is highly dependent on the choice of optimization method, with the Global Minimum Variance approach offering more stable returns and the Mean-Semivariance approach providing higher potential returns at the cost of increased volatility. The study’s limitations include reliance on historical data and the assumptions underlying the optimization models, which may not fully capture real-world market complexities. Future research should consider incorporating more diverse data sources and risk measures to enhance the robustness of portfolio optimization models. This research contributes to the field by supplying a practical framework for investors to effectively balance return and risk, emphasizing the importance of diversification and tailored risk management strategies in portfolio construction.

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