Post-Graduation in Data Science for Finance

Asset Pricing & Portfolio Management

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Empirical Analysis of Financial Market Returns and Performance of Alternative Portfolio Investment Strategies

- Individual Part

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1. Introduction

In this analysis, we examine the construction and performance of a new set of strategies, including the Quintile Portfolio, the Hierarchical Risk Parity Portfolio, and the Mean-Semivariance Skewness Portfolio. Each of these strategies offers a unique approach to portfolio optimization, incorporating factors such as risk clustering, statistical asymmetry, and volatility-based asset selection to address specific investor objectives and market challenges.

This report extends the previous Group analysis by applying the same universe of assets, price data, and backtesting methodology to the new set of alternative portfolio strategies. In line with the original analysis, we will focus on evaluating how each strategy performs under a consistent framework of asset selection and time period sampling, facilitating direct comparisons to prior results.

Although results can vary based on the chosen dataset and the specific conditions of the markets, this analysis will once again start by focusing on the outcomes for Dataset 1, covering October 15, 2019, to October 13, 2021, examining how the different strategies make their optimization decisions. Then, we will conduct a broader review of the distribution of key metrics across all simulations to gain a more robust understanding of each strategy's performance under varying conditions.

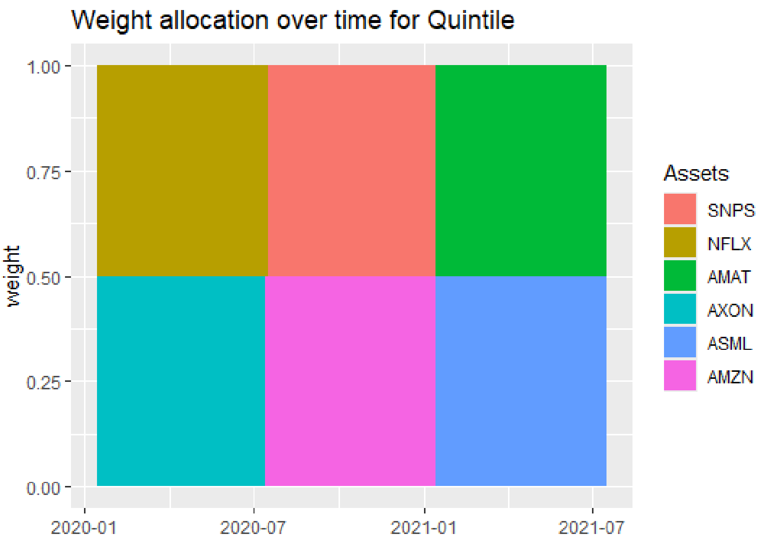
2. Analysis of Investment Strategies

2.1. Quintile Portfolio

In this section, we explore the methodology of constructing the Quintile Portfolio, a straightforward yet effective strategy based on ranking assets by their historical mean return. The strategy begins by evaluating the mean return of each asset in the dataset. Once the assets are ranked in descending order by their mean returns, the portfolio allocates weights equally among the top two performers in the ranking, disregarding all other assets. This approach ensures simplicity while capitalizing on recent strong performance, under the assumption that it may persist in the short term.

The rationale behind the Quintile Portfolio lies in its focus on momentum and performance persistence. By narrowing the portfolio to the top-performing assets, the strategy inherently assumes that these assets are likely to sustain their positive trajectory. While this simplification can expose the portfolio to concentration risk, it also avoids the need for complex optimization processes or reliance on covariance structures, making it an accessible choice for investors seeking high returns with minimal computational effort.

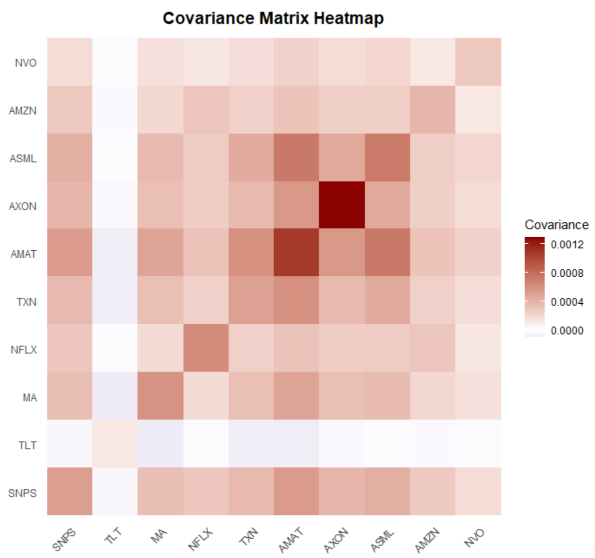
Analyzing the weight allocation over time for the Quintile portfolio reveals the clarity of its methodology. By ranking assets every six months and allocating equal weight to the top two performers, the strategy adapts dynamically to the changing market conditions. Throughout the sample, the portfolio alternated between different asset pairs as the leading performers. Initially, the top two performers were NFLX and AXON, followed by SNPS and AMZN, and later AMAT and ASML. This reflects the fluctuations in return characteristics over the period, with the leading assets changing during each rebalancing window. Notably, the strategy consistently avoided allocating any weight to TLT, MA, TXN, or NVO, which indicates that these assets were never among the highest return performers during the backtest. This behavior underscores the Quintile Portfolio’s focus on maximizing return potential through a systematic, yet flexible, ranking and allocation method.

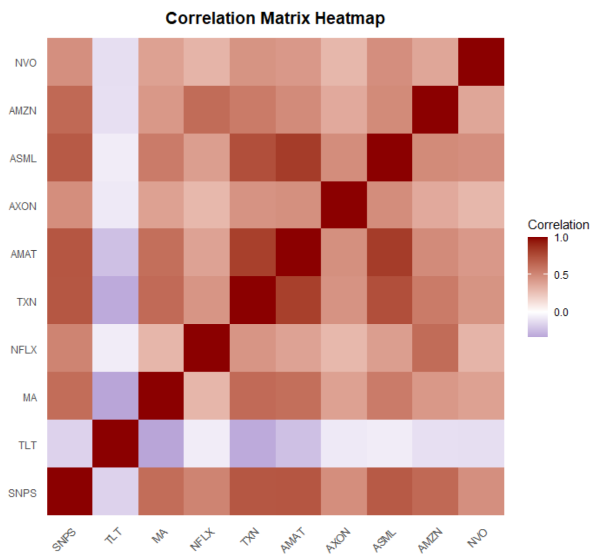


2.2. Hierarchical Risk Parity Portfolio (HRPP)

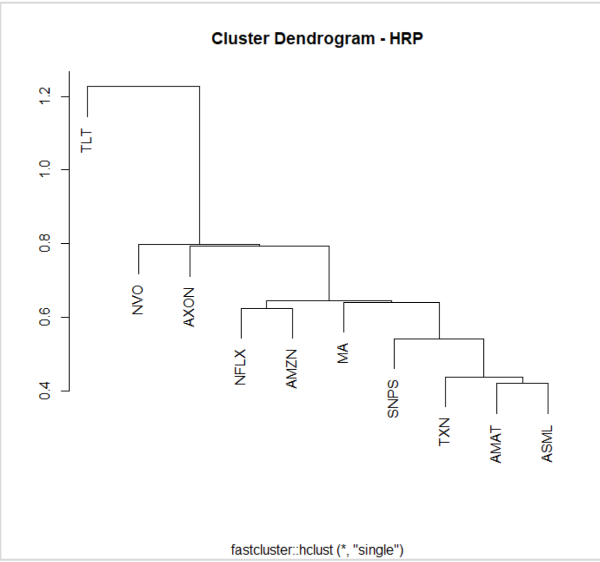
The Hierarchical Risk Parity Portfolio (HRPP) builds on traditional risk parity approaches by incorporating hierarchical clustering to manage asset correlations and optimize risk distribution within clusters. This strategy unfolds in three main stages. First, Hierarchical Tree Clustering is applied to the correlation matrix to identify patterns among assets, producing a dendrogram that visually organizes assets based on their correlations. This process effectively groups assets with higher correlations, separating outliers. Following this clustering, Matrix Seriation reorders assets according to the dendrogram, organizing them to reflect hierarchical relationships and enabling clear differentiation between clusters. Finally, Recursive Bisection assigns weights recursively across the asset hierarchy, ensuring a balanced risk contribution within each cluster while recognizing the distinctive risk characteristics of different groups.

Analyzing this methodology using the full dataset ex-post provides insights into the HRPP's decision-making framework. Heatmaps of the correlation and covariance matrices reveal significant relationships among assets, highlighting AXON as the asset with the highest variance, AMAT and ASML with the strongest covariances, suggesting a close relationship between these semiconductor stocks, while TLT consistently shows minimal covariances with other assets. The correlation analysis similarly isolates TLT, underscoring its lower correlation profile in comparison to other assets.

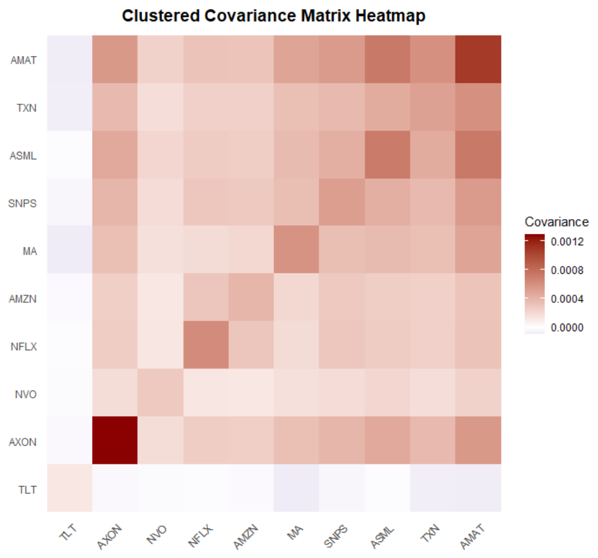


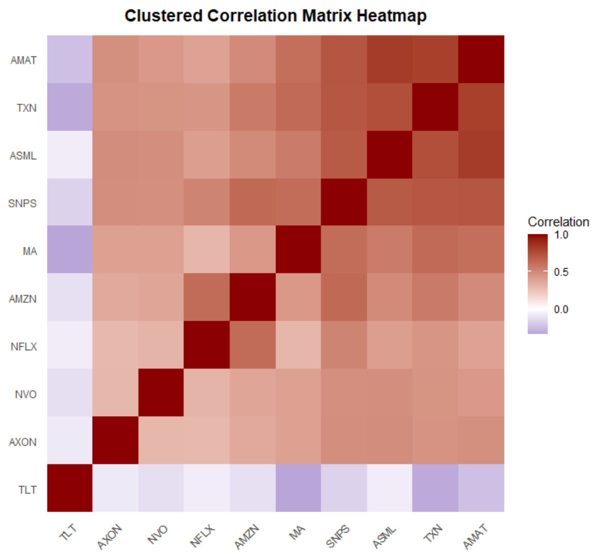


Within the dataset's dendrogram, TLT's separation from other assets is immediately apparent, reflecting its distinct role as a low-volatility bond asset. This separation is expected due to the historically lower variance associated with treasury bonds relative to equities, underscoring the impact of asset classes on correlation structure.

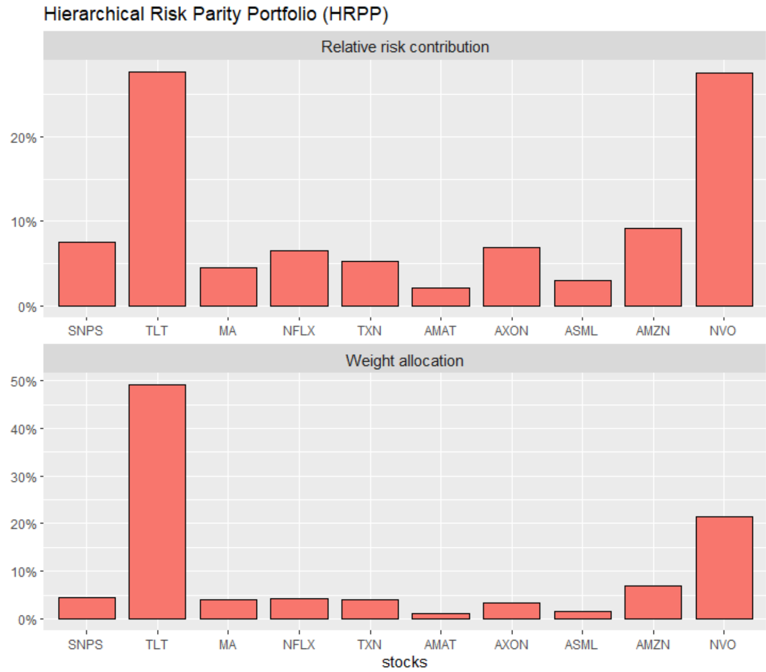


Following the initial clustering, the dendrogram reorders the assets into clusters, and the heatmaps of the clustered correlation and covariance matrices illustrate these clustering effects. In these reordered matrices, TLT stands as a clear outlier on the left edge, reinforcing its distinction from stocks, while clusters among stocks, such as NFLX with AMZN and a group including SNPS, ASML, TXN, and AMAT, emerge based on shared characteristics. These clusters align with sectoral affiliations and reflect intra-sector relationships, demonstrating how the clustering captures nuanced interdependencies.

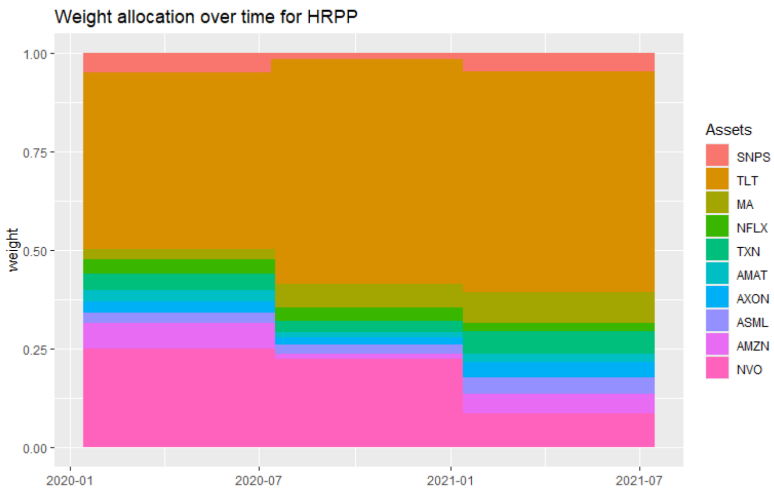




Examining the HRPP’s weight allocation and relative risk contribution shows that the strategy assigns substantial weight to TLT, equating its weight to that of all other stocks combined. This allocation reflects the HRPP’s prioritization of minimizing risk through balanced clusters and highlights the low-risk role of bonds in the overall portfolio. NVO, a standout stock, emerges as the second-highest weighted asset and shares an equivalent relative risk contribution with TLT, pointing to its low covariance and correlation profile relative to other stocks. Interestingly, NVO’s independence from other clusters becomes evident through its prominent weighting, suggesting that it effectively forms its own cluster, distinct from the rest of the stocks.



Finally, observing the weight allocation over time during the backtest period provides a dynamic view of the HRPP's adaptation to evolving asset relationships. The changing weights reveal a gradual increase in TLT's weight as NVO's weight decreases, reflecting shifts in correlation and covariance among assets. This adaptive adjustment maintains cluster risk parity by increasing the allocation to the bond cluster as NVO becomes increasingly correlated with the stock cluster. This evolution underscores the HRPP's sensitivity to changes in asset dynamics and its flexibility in reallocating weights to sustain balanced risk distribution within clusters, adapting to real-world conditions where correlations and risk profiles are constantly evolving.



2.3. Mean-Semivariance Skewness Portfolio (MSVSP)

The Mean-Semivariance Skewness Portfolio (MSVSP) expands on traditional portfolio theory by incorporating both skewness and semivariance, providing a nuanced approach to risk and return that accounts for the asymmetrical distribution of returns. This approach is particularly valuable as it addresses the downside risk (semivariance) while seeking positive skewness, both of which are desirable for risk-averse investors aiming to reduce downside exposure and enhance the probability of higher-than-average returns. Building upon the methodology in Brito, Sebastião, and Godinho (2015)[1], this strategy optimizes portfolio selection by maximizing skewness and minimizing semivariance, thus creating a portfolio that performs effectively across both dimensions.

$$\max_{w \in R^N} k(w) = w^T M_3 (w \otimes w)$$

$$\min_{w \in R^N} \Sigma_B(w) = w^T M_2^-(w) w$$

$$s.t.\ w^T \mathbf{1} = 1;\ \ w_i \geq 0, i = 1, \dots, N$$

Where

$$k(w) = E\,[(R(w) - \mu(w))^3] = w^T M_3 (w \otimes w)$$

is the skewness of a portfolio, $\otimes$ denotes the Kronecker product, and M_3 is the coskewness matrix of dimension N x N^2, which can be represented by N matrixes A_{ijk} with dimension N x N each, such that

$$M_3 = [A_{1jk}\ A_{2jk}\ \dots\ A_{Njk}]$$

where j, k = 1, …, N, and the individual elements of the coskewness matrix can be obtained as

$$a_{ijk} = \frac{1}{T} \sum_{i,j,k=1}^{N} \sum_{t=1}^{T} (r_{t,i} - \mu_i)(r_{t,j} - \mu_j)(r_{t,k} - \mu_k),$$

[1] Rui Pedro Brito & Hélder Sebastião & Pedro Godinho, 2015. "Efficient Skewness/Semivariance Portfolios," GEMF Working Papers 2015-05, GEMF, Faculty of Economics, University of Coimbra.

and

$$\Sigma_B(w) = \sum_{i=1}^{N} \sum_{j=1}^{N} w_i w_j cs_{ij} = w^T M_2^-(w) w,$$

is the semivariance of a portfolio, where $M_2^-(w)$ is the cosemivariance matrix in which each entry cs_{ij} is given by

$$cs_{ij} = \frac{1}{T} \sum_{k \in U} (r_{k,i} - B)(r_{k,j} - B),$$

with U representing the indices where returns were negative for any asset, and B a defined benchmark value – in this case set to zero.

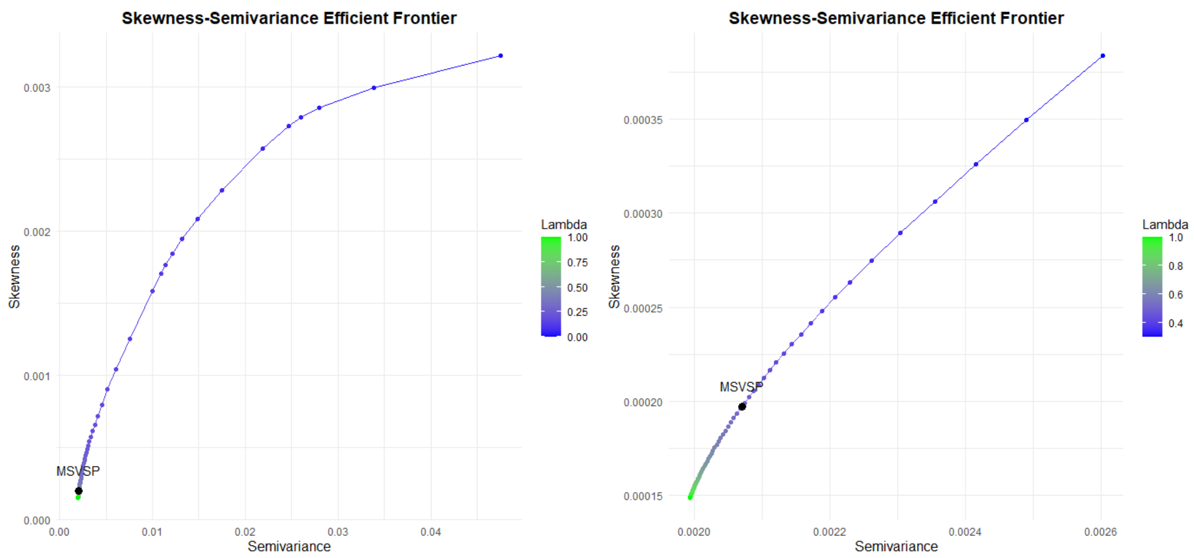
Formulating this as a dual-objective optimization problem, the MSVSP simultaneously maximizes skewness and minimizes semivariance, a task made computationally feasible through a Constrained Optimization by Linear Approximation (COBYLA) approach. Despite skewness being a tensor cube - a third-moment statistic in three-dimensional space - COBYLA facilitates a convex solution, allowing for the creation of a skewness-semivariance efficient frontier that represents the optimal trade-offs between these factors.

$$\max_{w \in R^N} \gamma\, k(w) - \lambda\, \Sigma_B(w)$$

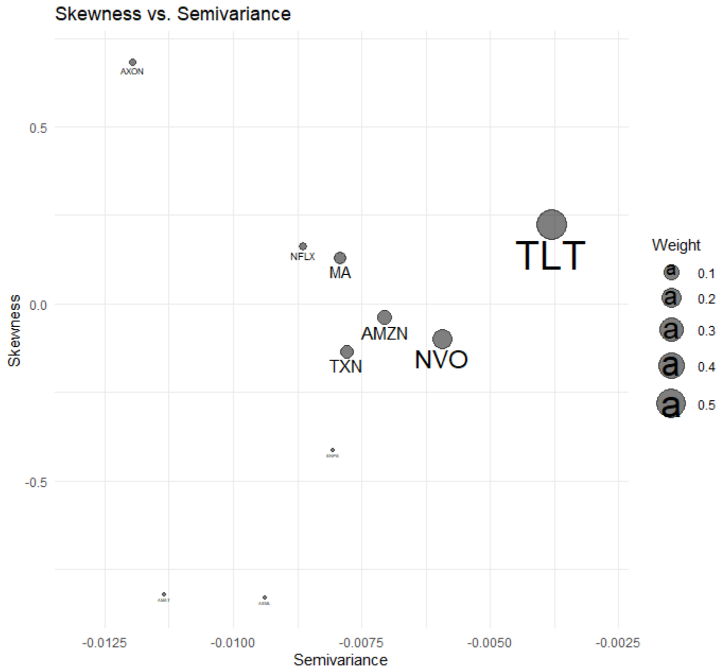
$$s.t.\ w^T \mathbf{1} = 1;\ w_i \geq 0, i = 1, \dots, N$$

Where γ and λ are, respectively, the skewness and semivariance coefficients that translate the investors risk preferences.

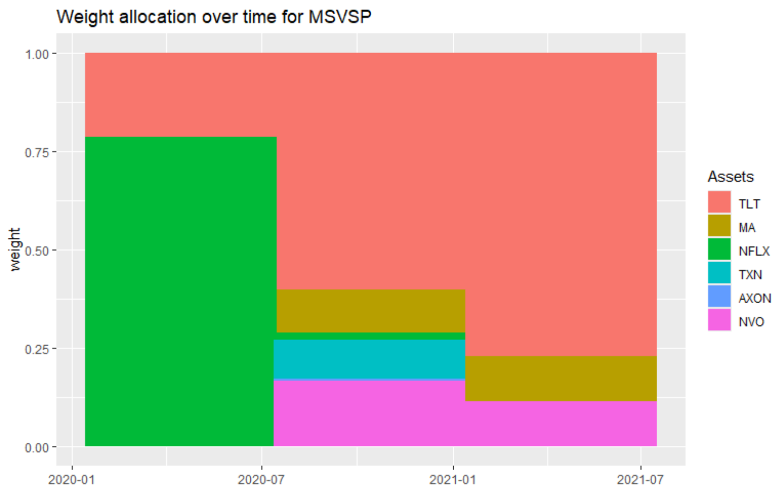
Analyzing the strategy's results ex-post using the entire dataset, we explored the range of risk-aversion coefficients to compute a series of optimized portfolios that together form the skewness-semivariance efficient frontier. This frontier illustrates how increased aversion to risk significantly impacts portfolio positioning, as reflected in the steep drop in semivariance and skewness across the initial range of low risk-aversion parameters. As the efficient frontier progresses, it quickly converges to the minimal semivariance region, underscoring the sensitivity of portfolio allocation to even slight shifts in risk aversion. By zooming into this efficient frontier, we observe the MSVSP's positioning when configured with default parameters (γ = 1 and λ = 0.5), revealing a clear trade-off between skewness and semivariance, and clarifying how varying risk aversion directly influences portfolio composition.



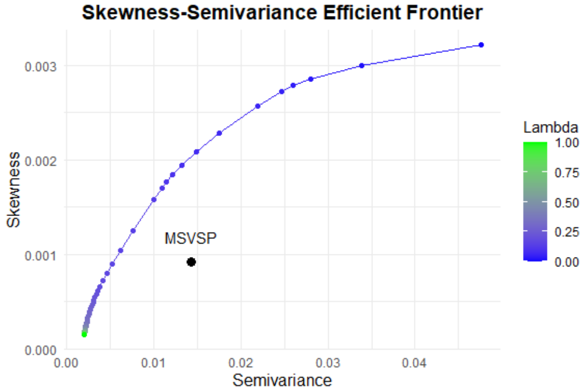
A closer look at the skewness versus semivariance plot for each asset further elucidates the strategy's allocation decisions. TLT stands out as the asset with the most favorable combination of skewness and semivariance, resulting in its highest portfolio weight. This allocation is followed by stocks like NVO, AMZN, TXN, and MA, demonstrating the strategy's search for assets with balanced skewness and low semivariance. AXON, while exhibiting the highest skewness, receives a minimal weight due to its disproportionately high semivariance, illustrating the balancing act inherent in the MSVSP. The strategy's allocations to AMAT and ASML, which show relatively more favorable semivariances but low skewness, are similarly constrained, highlighting the portfolio's prioritization of skewness alongside manageable semivariance.



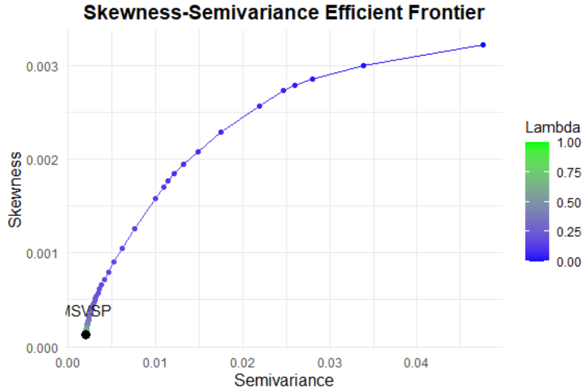
Furthermore, tracking MSVSP's weight allocation over the backtesting period reveals the evolving nature of the portfolio’s strategy in practice. Initially, the allocation leans heavily on both NFLX and TLT, suggesting the appeal of NFLX’s skewness potential and TLT’s low semivariance. However, as the backtesting progresses, NFLX’s weighting quickly diminishes to zero, with TLT taking on a dominant role. This shift indicates changing conditions in skewness and semivariance dynamics, as the initial skewness opportunity fades, prompting the portfolio to concentrate on the more stable bond asset. This evolution in allocation reflects the MSVSP’s adaptability and the impact of its risk parameter in dynamically responding to shifts in the risk-return landscape.



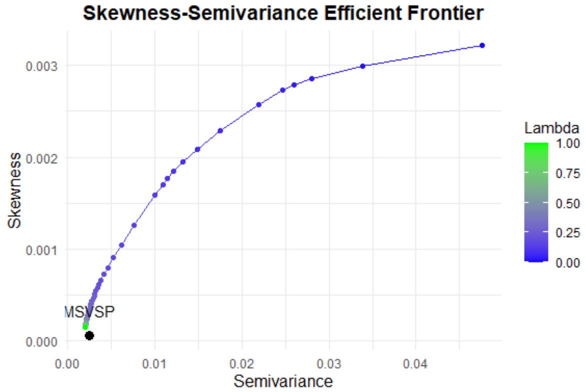
Finally, a comparative analysis of the portfolio's position at each rebalancing point relative to the efficient frontier provides further insight into the evolving dynamics of skewness and semivariance. Initially, the MSVSP lies significantly distant from the efficient frontier, reflecting the early emphasis on skewness potential and its divergence from a purely risk-minimizing approach. However, by the second and third rebalancing moments, the portfolio's positioning converges notably closer to efficiency. Both of these points are situated near the minimum semivariance position on the frontier, underscoring the diminishing influence of skewness dynamics over time. This evolution suggests that the advantages of skewness became increasingly elusive as the sample progressed, while the benefits of semivariance minimization remained prominent and drove the portfolio toward greater efficiency. This shift highlights the dynamic interplay of these factors and the strategy's ability to adapt to changing market conditions.



Rebalancing Moment 1



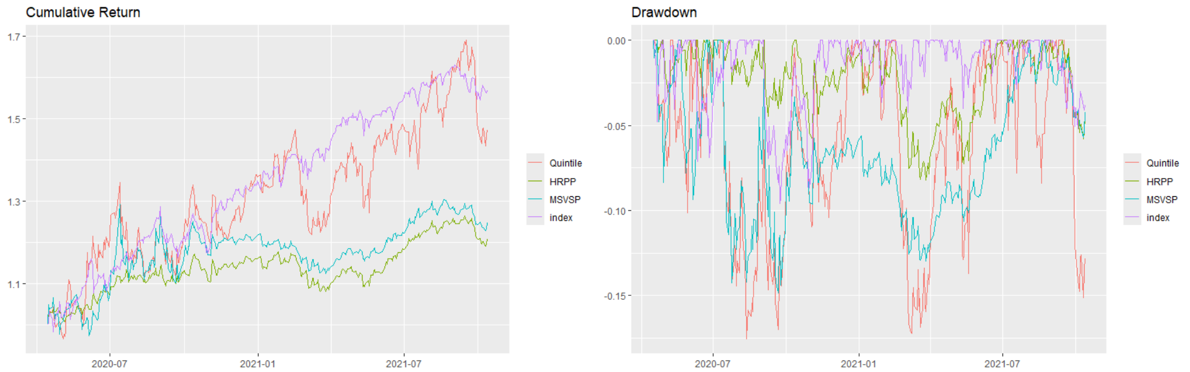
Rebalancing Moment 2



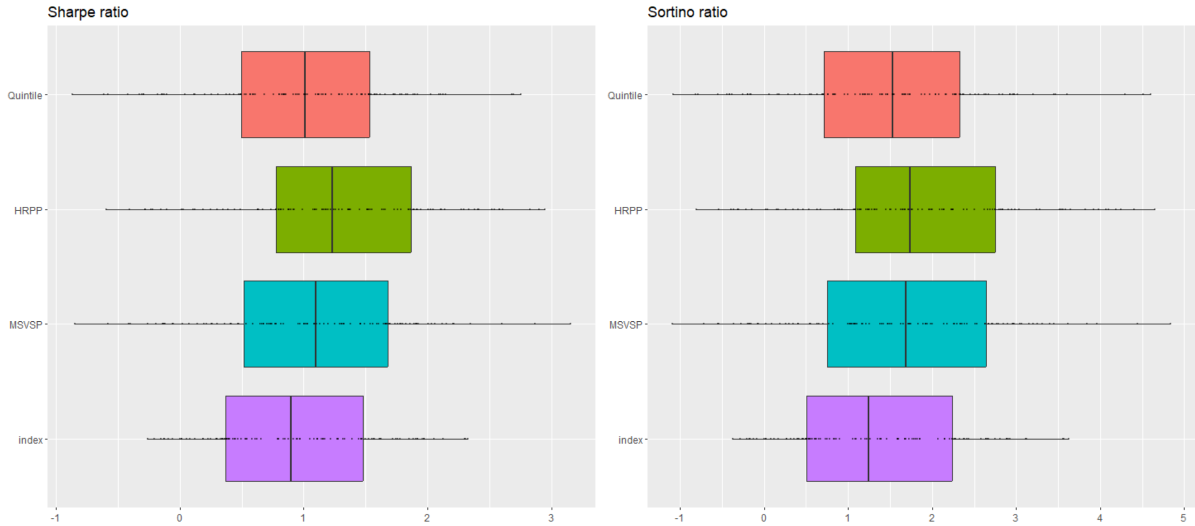
Rebalancing Moment 3

2.4. Backtest Performance Analysis

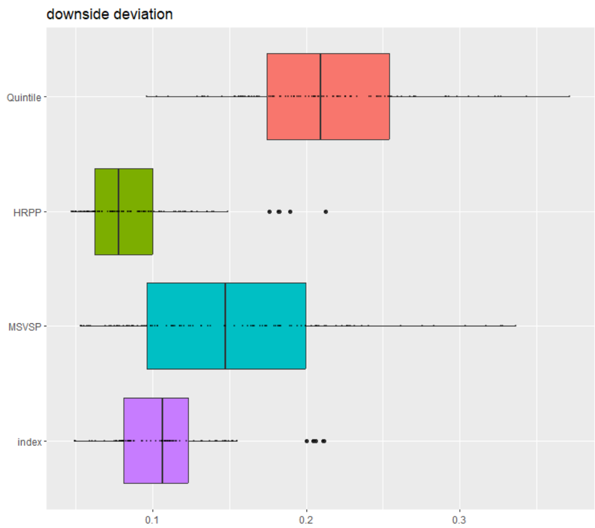
The performance analysis of the backtest encompasses all strategies, offering a comprehensive comparison of their behavior and outcomes. Examining the cumulative return plot reveals the distinct characteristics of each strategy. The Quintile portfolio demonstrates significant return potential, delivering results comparable to the market index, but its high returns come with pronounced volatility. In contrast, the HRPP and MSVSP emphasize risk control, evident in their more modest yet stable returns. The drawdown plot reinforces this distinction, with the Quintile portfolio experiencing the highest drawdowns, exceeding 15% on three occasions, while the MSVSP shows greater exposure to drawdowns than the index due to its skewness-driven focus. Meanwhile, the HRPP achieves its risk minimization objective with drawdowns consistently remaining below 8% throughout the sample.



Extending the analysis across all simulations, the Sharpe ratio boxplot provides further insights. While the HRPP exhibits the highest average Sharpe ratios, the MSVSP shows both the highest and lowest values, reflecting its wide variability. This variability suggests that the MSVSP may not be optimal for consistent risk-adjusted returns when measured by the Sharpe ratio, which penalizes both positive and negative extremes due to its reliance on standard deviation. A Sortino ratio analysis, however, offers a more tailored perspective, as it evaluates returns against downside deviation, aligning better with the MSVSP's objective of managing downside risk. However, the Sortino ratio boxplot underscores the variability of the MSVSP while indicating that all strategies deliver comparable results, albeit with more volatility than the index.



The downside deviation boxplot sheds light on the drivers of these outcomes. The MSVSP's focus on skewness appears to amplify downside risk, resulting in substantial variability in downside deviation and consequently affecting its risk-adjusted performance metrics. The Quintile portfolio, as expected, demonstrates the highest downside deviations due to its lack of risk control measures. The HRPP, by contrast, consistently achieves low downside deviation, reinforcing its capacity to mitigate risk effectively. Nonetheless, the similarity of Sharpe and Sortino ratio distributions across strategies suggests that the HRPP achieves modest returns rather than extraordinary ones.



The median results performance table highlights the distinct characteristics of the strategies. The HRPP delivers the best median performance across all metrics, aside from mean annual return, aligning with its emphasis on risk reduction. The Quintile portfolio's strengths in delivering high returns become evident, while the dual objectives of the MSVSP - balancing skewness and semivariance - stand out. Notably, the Value at Risk (VaR) and Conditional Value at Risk (CVaR) metrics differentiate the strategies. The HRPP, MSVSP, and Quintile portfolios show increasing VaR levels, with the Quintile portfolio underperforming the market index. In contrast, only the HRPP matches the market in CVaR, demonstrating its robust risk management capabilities. These findings underscore the diverse risk-return tradeoffs presented by these alternative investment strategies, reflecting their unique approaches to portfolio construction and management.

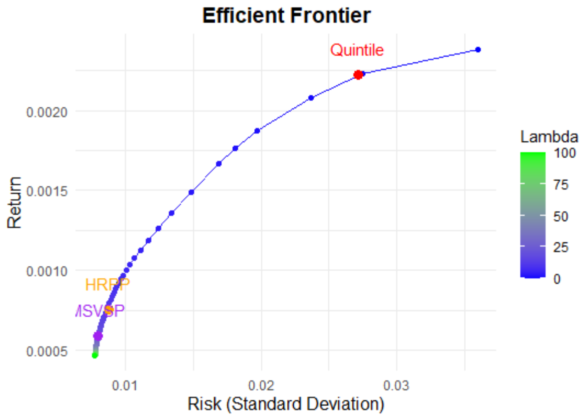
Performance table

	Sharpe ratio	max drawdown	annual return	annual volatility	Sortino ratio	downside deviation	Sterling ratio	Omega ratio	VaR (0.95)	CVaR (0.95)
HRPP	1.23	9.0%	14.0%	12.0%	1.74	0.08	1.44	1.24	1.0%	2.0%
MSVSP	1.10	18.0%	20.0%	22.0%	1.68	0.15	1.33	1.22	2.0%	3.0%
Quintile	1.01	26.0%	31.0%	31.0%	1.53	0.21	1.28	1.21	3.0%	4.0%
index	**0.90**	**13.0%**	**13.0%**	**15.0%**	**1.24**	**0.11**	**1.10**	**1.18**	**2.0%**	**2.0%**

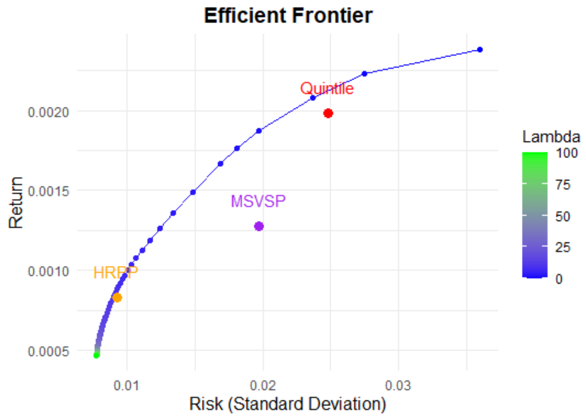
Table 1: Median Performance

Finally, we plotted the strategies against the classical Markowitz Mean-Variance Efficient Frontier to assess their efficiency in traditional terms. In the context of the dataset, the ex-post analysis reveals a strong alignment with their respective methodologies. Both the HRPP and MSVSP exhibit near-efficient positions on the lower end of the risk spectrum, affirming their risk-focused design. Meanwhile, the Quintile Portfolio distinguishes itself by achieving total efficiency in a higher return position, emphasizing its focus on return maximization over risk management.

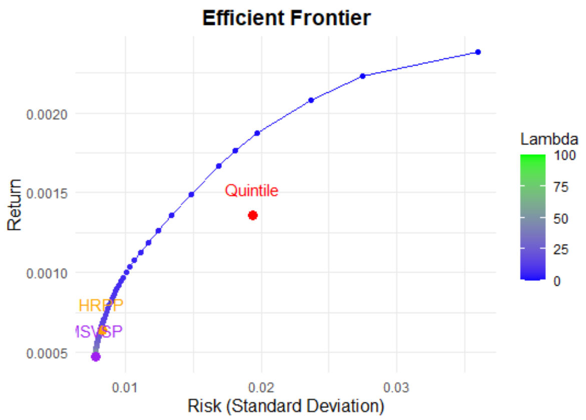
Examining the evolution of portfolio positions through the rebalancing periods provides further insights into their behavior. The HRPP demonstrates remarkable stability, maintaining positions close to the efficient frontier with consistently low risk. This highlights its unwavering focus on minimizing risk, even amidst evolving market dynamics. In contrast, the Quintile Portfolio showcases the most erratic behavior, never attaining efficiency across the rebalancing periods and reflecting its aggressive and return-driven approach. The MSVSP, however, illustrates a nuanced progression: while initially positioned far from efficiency due to its emphasis on skewness, it gradually shifted its focus towards minimizing semivariance. By the second and third rebalancing periods, the MSVSP achieved the lowest risk among all strategies - surpassing even the HRPP - though at the cost of reduced returns. This dynamic underscores its ability to adapt to changing skewness and semivariance opportunities over time, reinforcing the trade-offs inherent in its methodology.



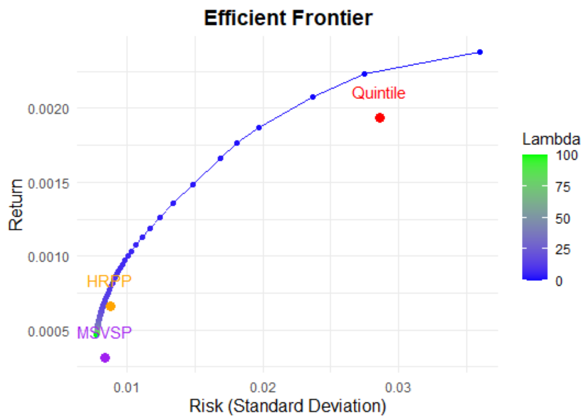
Efficient Frontier: Ex-post



Efficient Frontier: Rebalancing Moment 1



Efficient Frontier: Rebalancing Moment 2



Efficient Frontier: Rebalancing Moment 3