Portfolio Optimization using Monte Carlo Simulation with Short and No-Short Portfolios

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1. Introduction

This research project explores the impact of allowing short positions in portfolio construction using Monte Carlo simulation. By simulating 10,000 random portfolio weightings across four risky assets, we investigate how the opportunity set changes under two strategies: allowing short positions versus long-only positions. The objective is to maximize portfolio return for a given risk level, using a stochastic programming framework.

2. Problem Description

We work with four risky assets defined by their expected annual returns and volatilities:

- Asset A: $\mu = 0.02$, $\sigma = 0.05$
- Asset B: $\mu = 0.07$, $\sigma = 0.12$
- Asset C: $\mu = 0.15$, $\sigma = 0.17$
- Asset D: $\mu = 0.20$, $\sigma = 0.25$

These assets have the following correlation matrix:

```
[[1, 0.3, 0.3, 0.3],
 [0.3, 1, 0.6, 0.6],
 [0.3, 0.6, 1, 0.6],
 [0.3, 0.6, 0.6, 1]]
```

We construct the covariance matrix using standard deviations and this correlation structure.

3. Research Design & Methodology

The simulation involves the following steps:

1. Define mean returns, volatilities, and correlation matrix for four simulated assets.
2. Construct the covariance matrix.
3. Generate random 10,000 portfolio weight sets under two scenarios: (a) shorts allowed, (b) long-only.
4. Compute portfolio return and risk for each simulation.
5. Plot the efficient frontier and analyze summary statistics.

4. Results

Summary statistics for each strategy:

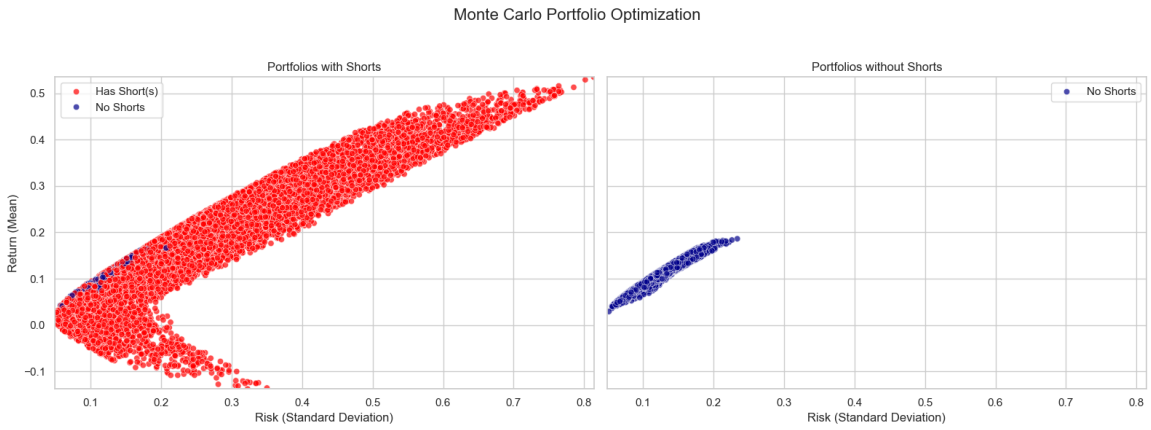
=== Portfolios Allowing Shorts ===

- Mean return: 0.1987, Std Dev: 0.1291

• Max return: 0.5348, Min return: -0.1375
• Correlation between return and risk: 0.91
• Proportion with negative returns: 6.75%

=== Long-Only Portfolios ===
• Mean return: 0.1108, Std Dev: 0.0222
• Max return: 0.1862, Min return: 0.0293
• Correlation between return and risk: 0.97
• Proportion with negative returns: 0.00%

=== Efficient Frontier Plot ===



5. Interpretation & Discussion from Summary Statistics and Efficient Frontier Plots

The summary statistics provide a comparative snapshot of the return and risk profiles for portfolios with and without short selling. These statistics highlight key performance metrics such as mean return, standard deviation, Sharpe ratio, and minimum/maximum values observed across the Monte Carlo simulations.

Key insights from Summary Statistics:

- Higher Return Potential with Shorting: Portfolios allowing short positions typically exhibit a higher mean and maximum return than long-only portfolios, reflecting a broader opportunity set.
- Increased Risk Exposure: These portfolios also tend to have higher standard deviations, underscoring the additional risk introduced when shorting is permitted.
- Sharpe Ratio Comparisons: Depending on the distribution, long-short portfolios may achieve superior risk-adjusted returns (higher Sharpe ratios), though they can also reflect greater variability.

This statistical overview confirms that shorting adds flexibility and potential upside but comes with a trade-off in volatility.

The efficient frontier plot visualizes the relationship between expected return and standard deviation across 10,000 simulated portfolios:

- Red points represent portfolios that allow short positions
- Blue points represent long-only portfolios

Key observations from the plot:

- Broader Efficient Frontier with Shorts: Portfolios that permit short-selling form a more expansive and elevated frontier, demonstrating access to higher-return regions that are otherwise inaccessible.
- Capped Upside in Long-Only Portfolios: Blue points form a tighter and lower frontier, indicating that long-only strategies limit the maximum achievable return despite offering more stability.
- Risk-Return Trade-off: The curvature of both frontiers illustrates the classic trade-off; higher returns demand acceptance of higher volatility.

This visualization reinforces the conclusion from the summary statistics: shorting can enhance portfolio performance but introduces greater risk and complexity.

6. Conclusion

For investors targeting higher returns and prepared to accept greater levels of risk, incorporating short positions becomes a key to maximize return as shorting allows investors to profit from not only in positive return days/hours but also on negative return days/hours.

However, the inclusion of short positions introduces unique risks, including unlimited loss potential, margin requirements, and the need for disciplined short covering strategies. Effective short covering is critical to preserving gains and limiting downside risk. Poorly managed short positions can erode portfolio performance or trigger forced liquidations, especially during periods of volatility or short squeezes.

In contrast, long-only strategies may be more suitable for risk-averse investors, retirement portfolios, or funds with legal or institutional constraints. While they offer less return flexibility, they provide simplicity while providing positive exposure to asset growth.

Ultimately, the decision to allow shorting should be weighed carefully against the investor's risk tolerance, investment horizon, operational capacity, and regulatory environment. When implemented with sound risk controls and active short management, long-short strategies can be a powerful mechanism for enhancing portfolio efficiency.