MSDS 451 Assignment 2: Portfolio optimization

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MSDS 451: Quant Finance

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Problem Description

For this project, I worked to optimize a portfolio based on 4 large-cap stocks. For my 4 assets, I chose Apple ($AAPL), Google ($GOOG), Meta ($META) and Caterpillar ($CAT). These 4 assets were chosen as they are relatively low-risk, large-cap stocks with relatively low individual volatility scores. In order to best optimize the portfolio, a combination of long and short positions will be taken. The objective, in this situation, is to maximize the total return based on an investor's risk tolerance. These four assets show the following values for expected returns and standard deviations:

Asset Name	Annual Returns	Volatitilities
Apple ($AAPL)	-0.012	0.318
Google ($GOOG)	0.153	0.311
Meta ($META)	0.572	0.351
CAT ($CAT)	0.280	0.359

Also, consider the following correlation plot based on a rolling 12-month monthly value return:

	Apple ($AAPL)	Google ($GOOG)	Meta ($META)	CAT ($CAT)
Apple ($AAPL)	1	-0.13	-0.01	0.06
Google ($GOOG)	-0.13	1	0.56	0.17
Meta ($META)	-0.01	0.56	1	0.64
CAT ($CAT)	0.06	0.17	0.64	1

In order to optimize the performance of this portfolio, Monte Carlo Simulations were performed as follows:

- Generate above 700 random allocation sets: 4 X 1 vectors. Each set satisfies the constraint of all weights summing to 1. In fact, once we generate three random numbers for W1, W2 and W3, the 4th can be computed by summing W1, W2, and W3 and subtracting the greater sum from 1. (Miller, 2025)
- Compute the portfolio return of (Returns2) on the vertical axis and (Volatility2) on the horizontal axis. (Miller, 2025)
- Note that many sets of weights will not be optimal, and portfolio returns can be negative.

In this study, 2 main asset management strategies are tested. One with the allowance of short positions, and the other with exclusively long positions. These strategies are then tested against each other to gauge performance, and plotted on a visual. (Miller, 2025)

The Monte Carlo simulation was implemented in R using the MASS library.

Results and Conclusions

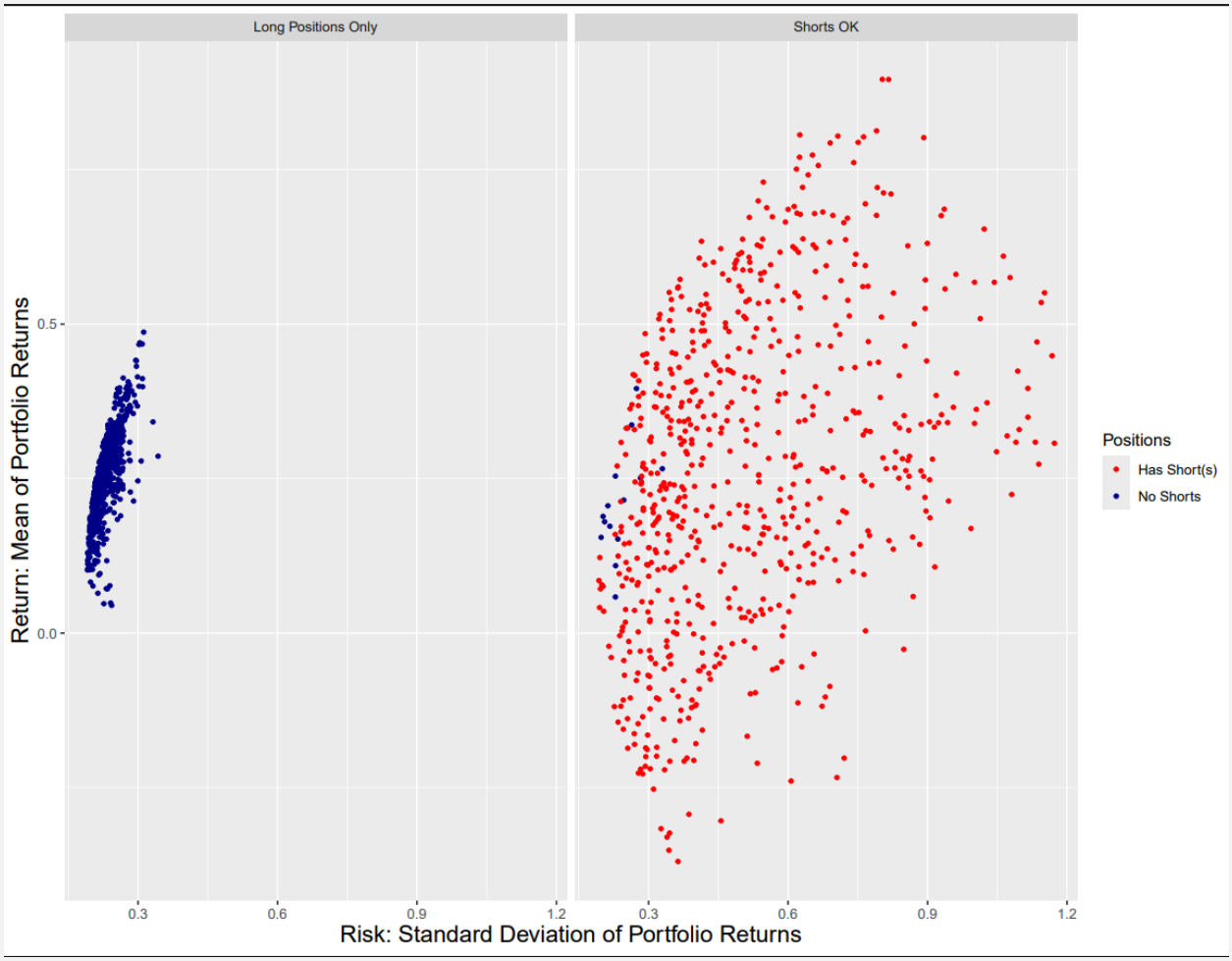
Figure 1 shows the difference in performance between the model allowing for short selling, and the model only allowing for long selling. Portfolios with all positive weights (no shorts allowed) are shown in blue, while with shorts allowed (both weights) are shown in red.

As expected, the long-only options perform rather well, with some examples reaching almost a 0.50 return, but the grouping is a lot tighter, with much smaller variation in the performance of the portfolios. Overall, this would be a very strong and predictable investment based on the simulations.

Also as expected, when short selling is allowed, some values skyrocket to as high as ~ 0.90 return. However, many values also sink to ~0.15 return. By making the investment pool more risky and allowing short selling options, there is potential for a much higher return, but there is also potential for a much lower return. This large scale difference in performance can be allocated to the risk of diversifying an investment structure on large-cap stocks to include betting against them.

Overall, for someone with a moderate risk tolerance, who would be okay with accepting potential losses, you should consider short selling as there can be quite an upside (even up to a 0.40 return bonus).

Figure 1


Long Positions Only
Shorts OK
Return: Mean of Portfolio Returns
0.5
0.0
0.3
0.6
0.9
1.2
Risk: Standard Deviation of Portfolio Returns
Positions
Has Short(s)
No Shorts

References

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