# Portfolio Optimization: A Monte Carlo Simulation Study on Technology Stocks (AAPL, MSFT, NVDA)

Chenyi Zhao
July 27, 2025

**Introduction**

This study investigates portfolio optimization through Monte Carlo simulation, focusing on three prominent U.S. technology stocks: Apple Inc. (AAPL), Microsoft Corp. (MSFT), and NVIDIA Corp. (NVDA). The objective is to evaluate the risk-return tradeoffs of long-only versus long-and-short portfolio strategies using historical data from January 2020 to December 2024. By generating a wide range of random portfolio allocations, we aim to visualize the efficient frontiers and understand the implications of allowing short positions in portfolio construction.

**Data Collection and Preparation**

Daily adjusted closing prices for AAPL, MSFT, and NVDA were collected from Yahoo Finance covering the period from 2020 to 2024. Based on these price data, daily returns were calculated as the percentage change in adjusted closing prices. Using the resulting return series, key portfolio parameters were estimated to support the simulation analysis. Specifically, the annualized expected return for each asset was obtained by scaling the average daily return by a factor of 252, corresponding to the approximate number of trading days in a year. Annualized volatility was derived by multiplying the standard deviation of daily returns by the square root of 252. In addition, the annualized covariance matrix, capturing the interdependence among asset returns, was computed from the covariance of daily returns. This preprocessing approach ensures that the portfolio simulation is grounded in empirical data and reflects the statistical properties observed in historical market behavior.

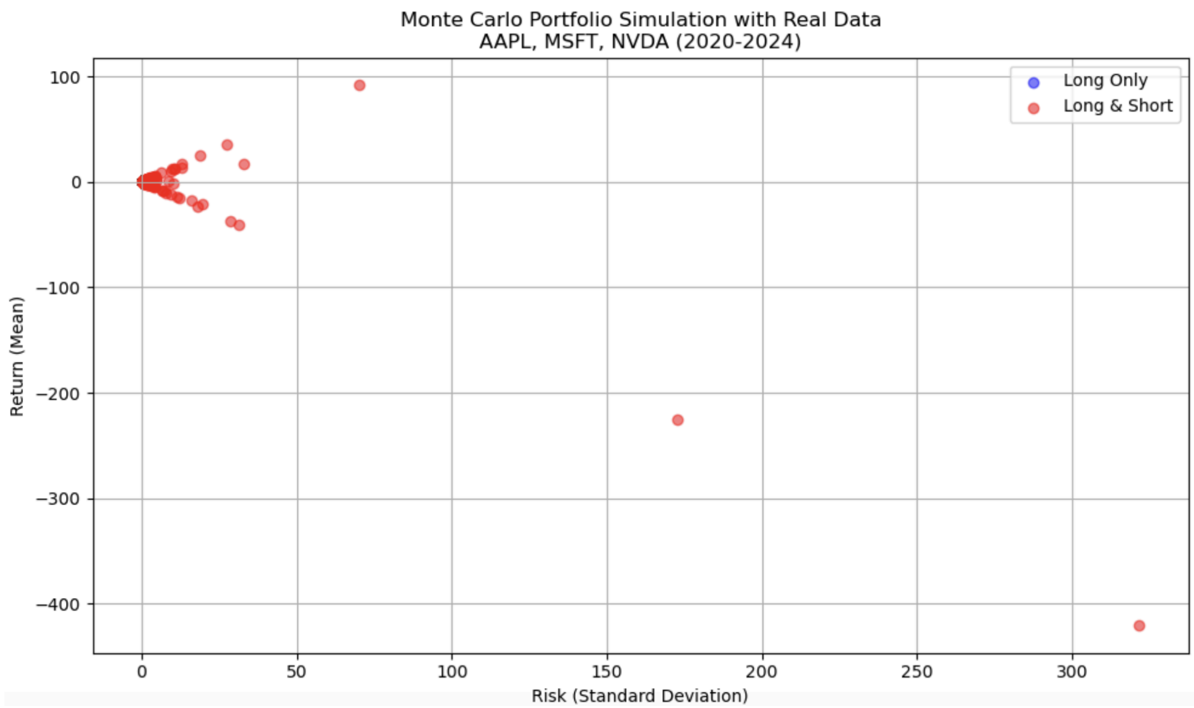
**Methodology**

In this study, a Monte Carlo simulation approach is employed to generate a total of 700 random portfolio allocations under two distinct investment strategies. The first strategy adopts a long-only constraint, whereby all portfolio weights are confined to the range [0, 1] and collectively normalized to sum to one. This reflects a conventional investment setting in which short selling is not permitted. In contrast, the second strategy allows for both long and short positions, with individual asset weights permitted to take values within the range [−1, 1], subject to the same normalization constraint on total capital allocation.

For each simulated portfolio, the expected return and associated risk are computed based on standard portfolio theory. The expected return of a portfolio, denoted as $\mu\_p$, is calculated as the dot product of the portfolio weight vector $w$ and the expected return vector $\mu$, i.e., $\mu\_p = w\text{^}T*\mu$. Portfolio risk, measured as the standard deviation of returns, is computed using the expression $\sigma\_p = sqrt(w\text{^}T*\Sigma w)$, where $\Sigma$ represents the covariance matrix of asset returns. This quantitative framework enables a comparative analysis of the risk-return profiles across different allocation strategies.

**Results**

The simulation results are visualized in the figure below. Each point corresponds to a simulated portfolio, with its expected return on the vertical axis and portfolio risk (standard deviation) on the horizontal axis. Blue points represent long-only portfolios, while red points represent long-and-short portfolios.




The simulation results reveal distinct characteristics between the two investment strategies. Portfolios constructed under the long-only constraint tend to be concentrated within a relatively narrow region of the risk-return space. These portfolios demonstrate moderate levels of both expected return and volatility, a consequence of the restriction that prohibits negative asset weights. This constraint effectively limits the ability to overweight high-return assets through shorting, thereby narrowing the achievable return spectrum.

In contrast, the long-and-short strategy produces a broader and more dispersed distribution of portfolio outcomes. The inclusion of short positions introduces both increased flexibility and amplified risk. As a result, some simulated portfolios exhibit extreme values in terms of both expected return and standard deviation. These outliers typically arise from highly leveraged combinations, where aggressive shorting magnifies both potential gains and losses.

Notably, in both strategies, the left-hand boundary of the return-risk plot traces out what is known as the efficient frontier. This boundary represents the set of portfolios that deliver the highest expected return for a given level of risk. The shape and position of the efficient frontier vary between the two strategies, reflecting the trade-offs and opportunities introduced by the allowance or exclusion of short positions.

**Discussion**

The findings of this analysis underscore the substantive impact that short-selling permissions can have on portfolio construction. Allowing short positions notably broadens the feasible investment space, thereby creating opportunities for portfolios with higher expected returns. However, this expanded opportunity set is accompanied by a marked increase in portfolio volatility and a heightened exposure to tail risks. The emergence of extreme outliers within the short-allowed simulation results reflects the inherent dangers associated with excessive leverage and concentrated short exposures, which can significantly destabilize portfolio performance.

From an applied perspective, investors must carefully balance the theoretical advantages of higher return potential with the practical limitations imposed by real-world financial markets. These include considerations such as margin requirements, borrowing costs, and regulatory constraints on short-selling. For investors with moderate risk tolerance or limited capacity for active risk monitoring, long-only strategies may represent a more prudent and stable approach. In contrast, institutional investors with access to sophisticated risk management systems may be better positioned to pursue long-short strategies, provided that appropriate safeguards are in place to mitigate downside risk and ensure portfolio resilience.

**Conclusion**

This study demonstrates that Monte Carlo simulation is an effective methodological framework for exploring portfolio behavior under alternative investment constraints. By simulating a wide array of asset allocations, the analysis provides insight into how the inclusion of short positions affects both the geometry and the boundaries of the risk-return profile. Specifically, it reveals that while shorting can enhance the attainable return frontier, it also introduces substantial risk asymmetries that must be carefully managed.

Ultimately, the decision to incorporate short positions into a portfolio strategy should be grounded in a clear understanding of the investor's risk tolerance, regulatory environment, and operational capacity for risk control. Flexibility in allocation must be balanced by disciplined oversight to avoid configurations that may lead to unsustainable exposure or excessive volatility.