Modern Portfolio Theory of Harry Markowitz

Portfolio Weights Are Optimal...

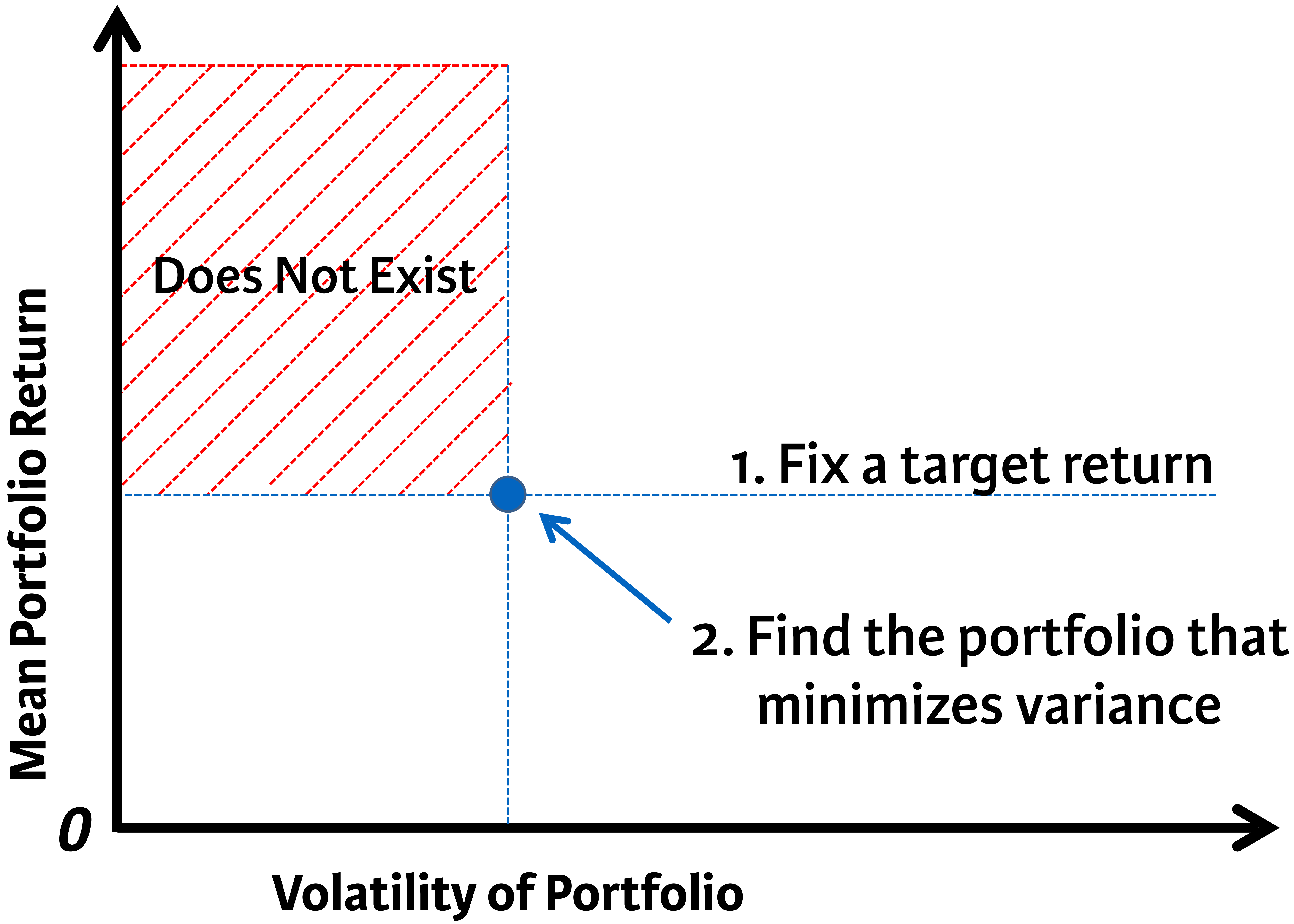
... when they optimize an objective function while satisfying the constraints

Possible Objectives	Possible Constraints
Maximize expected return	Only positive weights
Minimize the variance	Weights sum to 1 (all capital needs to be invested)
Maximize the Sharpe Ratio	Portfolio expected return equals a target value

Harry Markowitz

- Nobel Prize Winner
- Recommends finding optimal portfolios by minimizing portfolio variance
    - Constraint: Expected return should be equal to a pre-specified target return

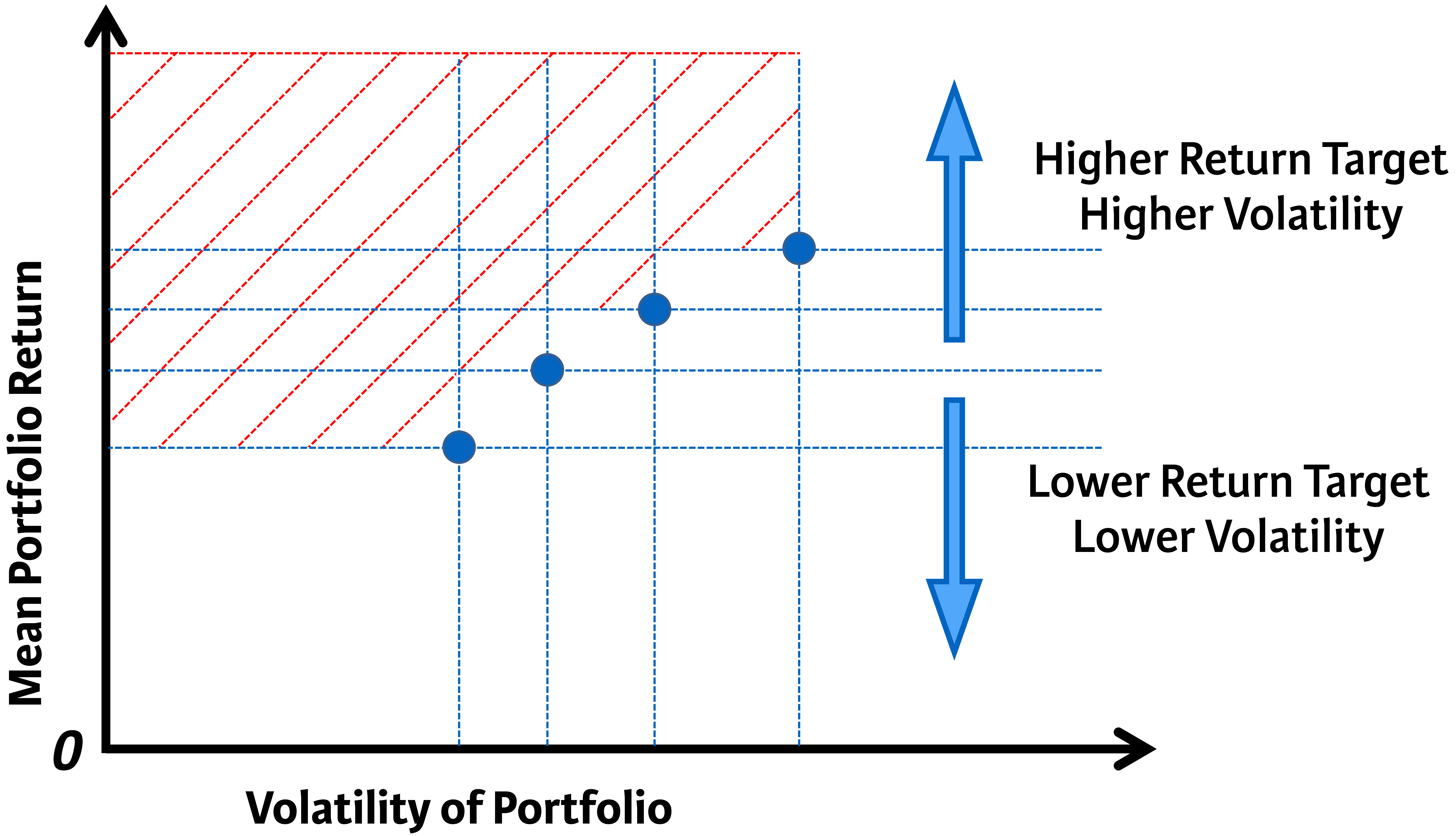
The H. Markowitz Approach



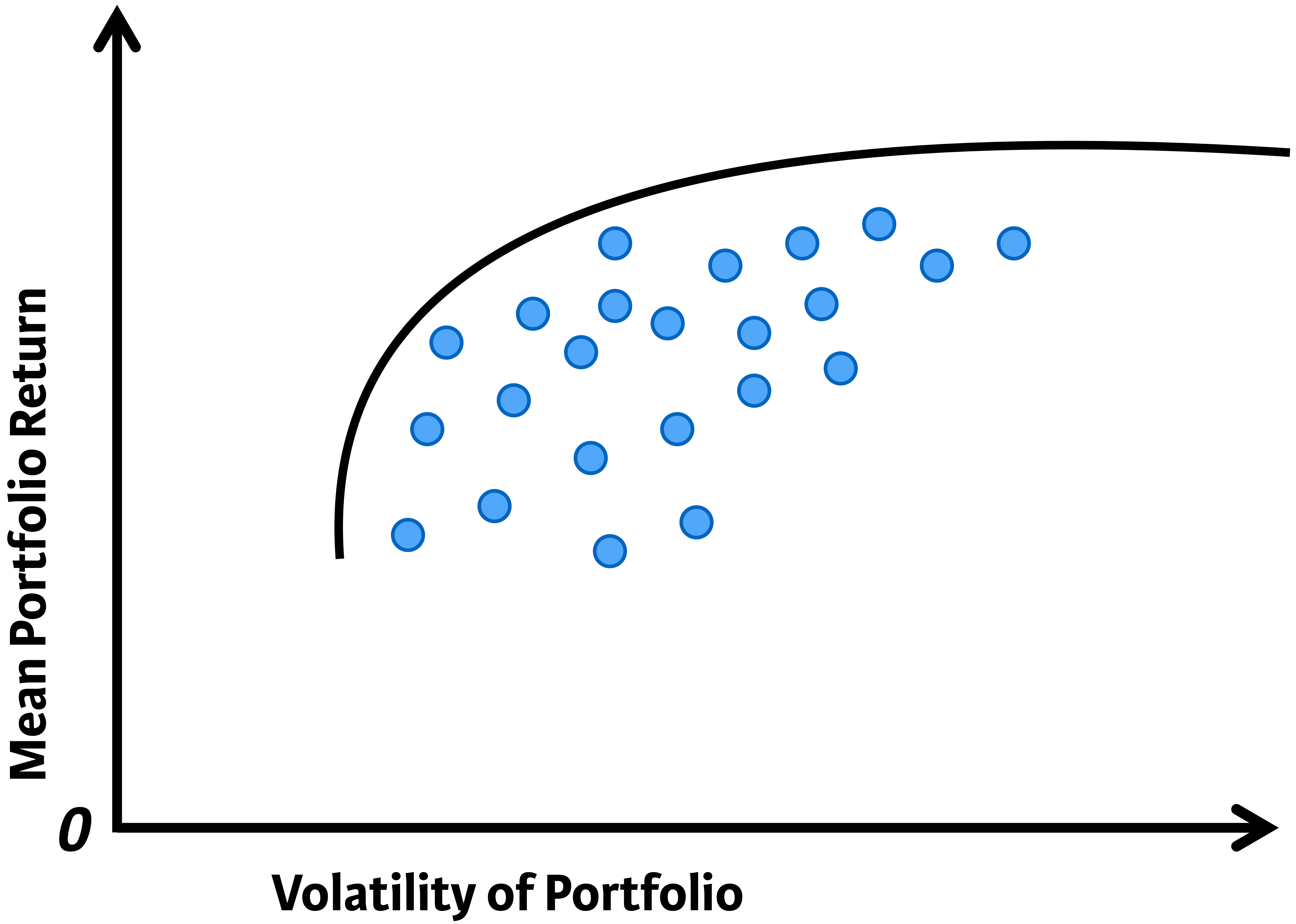
Let's practice!

The Efficient Frontier

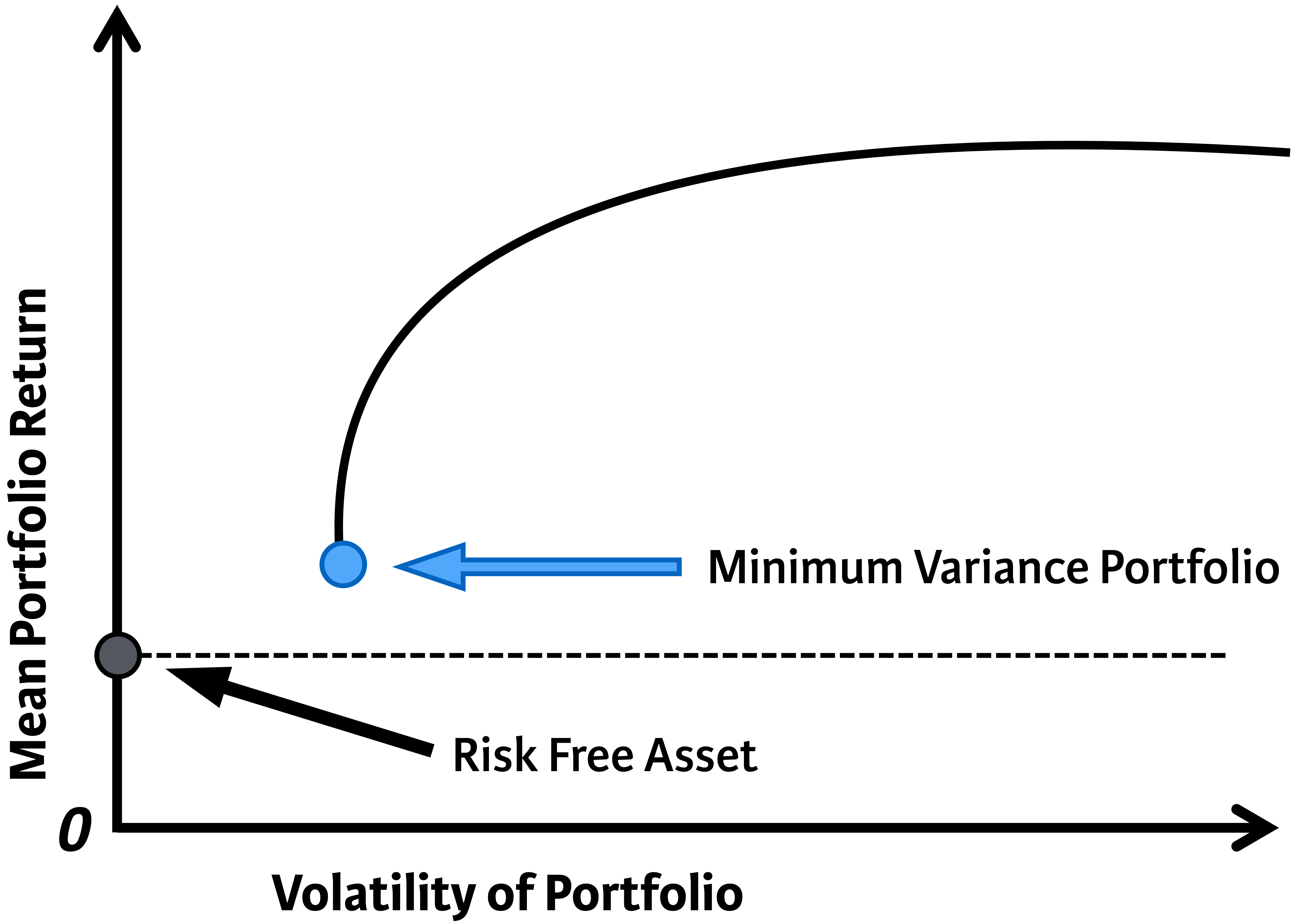
Changing Target Return



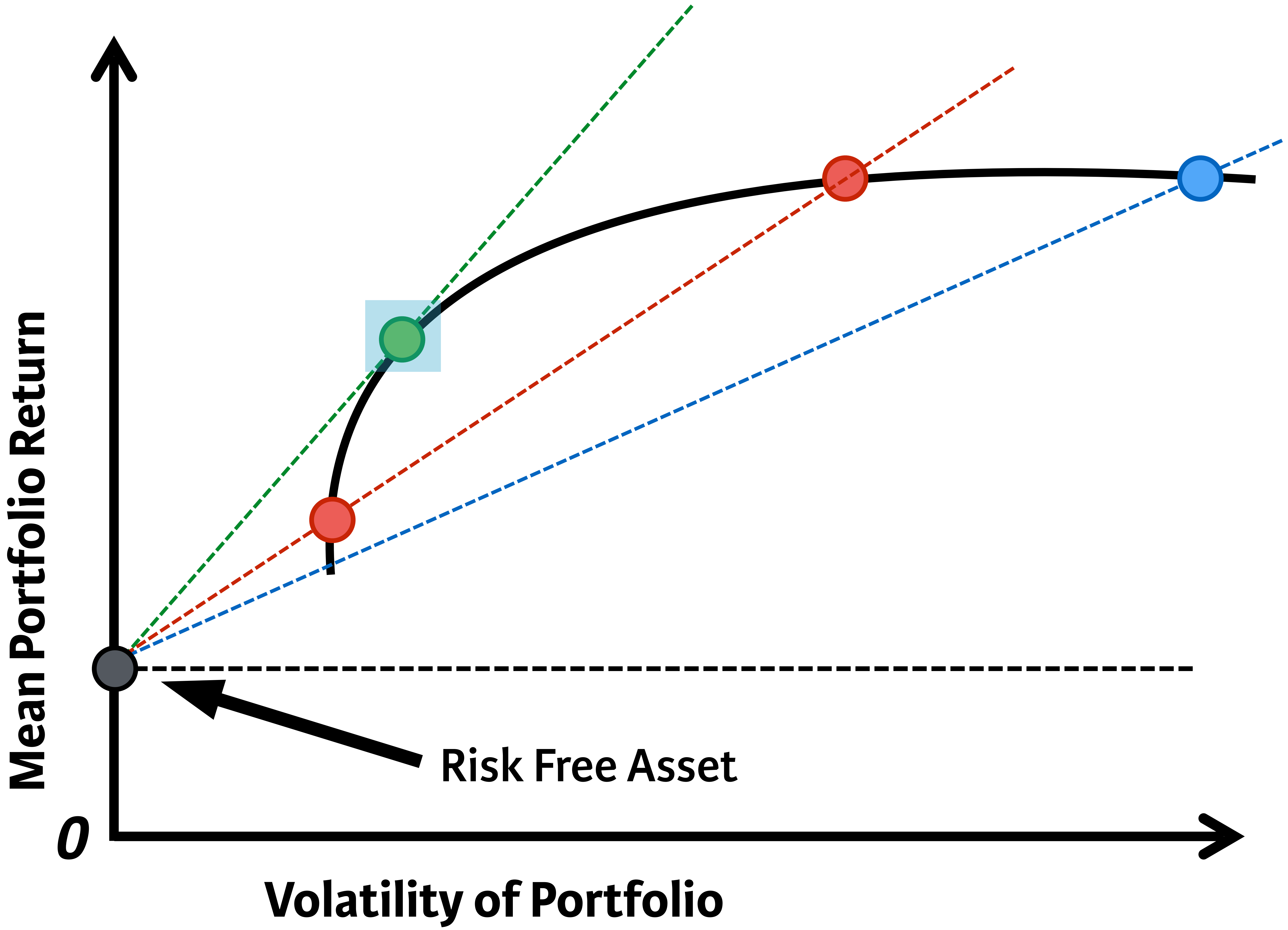
The Efficient Frontier



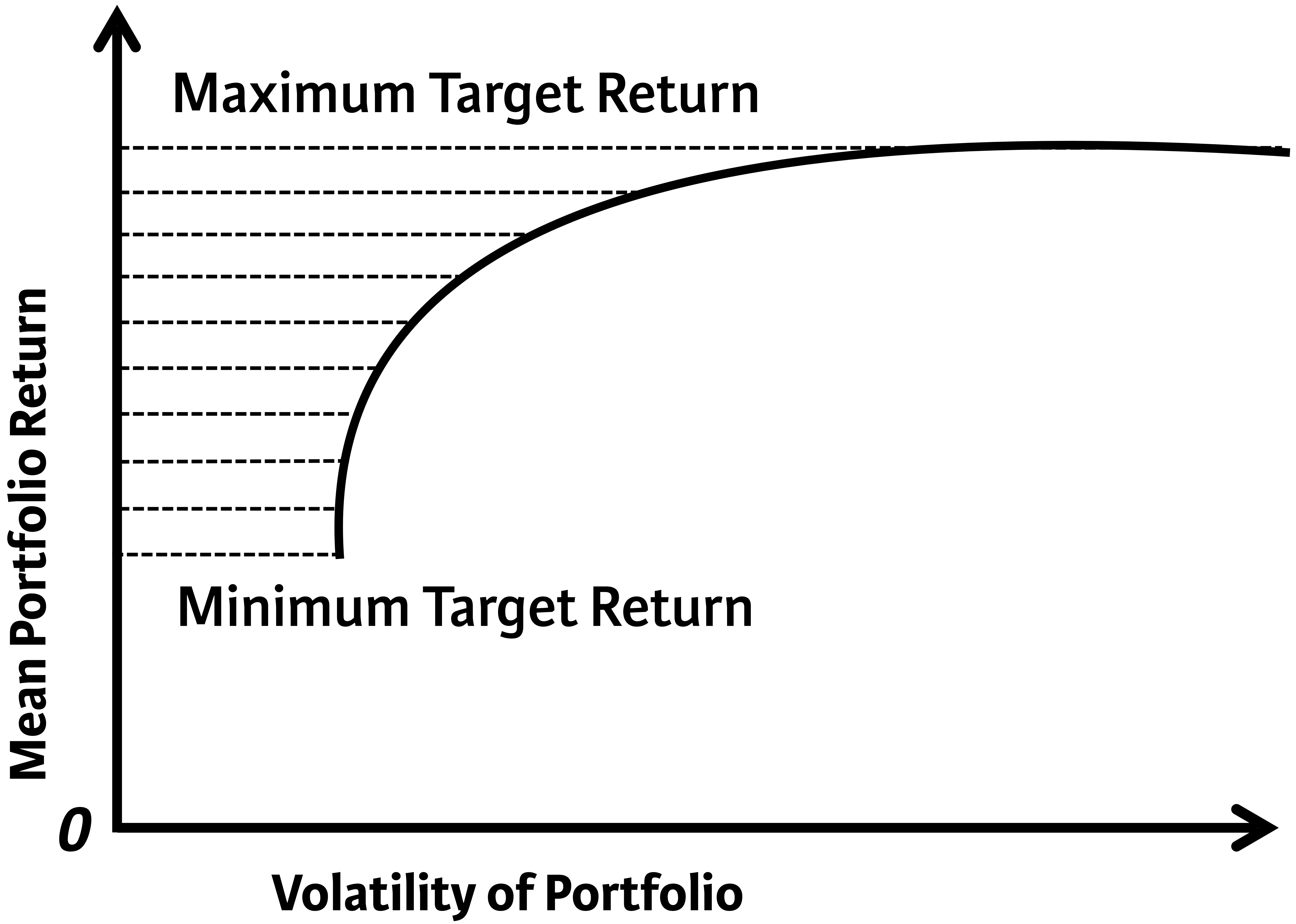
Minimum Variance Portfolio



Maximum Sharpe Ratio Portfolio



Time For Practice



Let's practice!

In-Sample vs. Out-of-Sample

Bad News: Estimation Error

- Limitation to data-driven portfolio allocation:

Use in Practice	Use In Theory
Estimated mean $\hat{\mu}$	True (unknown) mean μ
Estimated variance $\hat{\sigma}^2$	True (unknown) variance σ^2

Optimized weights based on estimated mean & variance: $\hat{w}$	True optimal portfolio: w

Good News: Opportunities

- Do not ignore estimation error
- Use split-sample analysis to do a realistic evaluation of portfolio performance

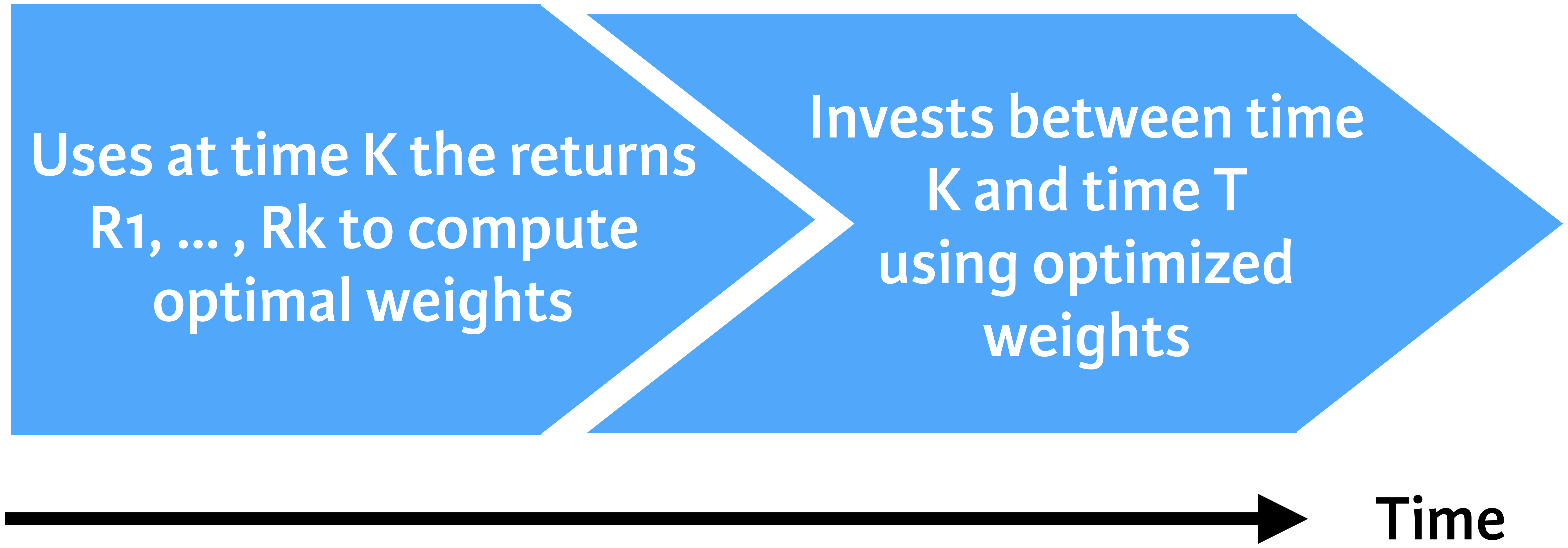
R_1	R_2	...	R_K	R_{K+1}	R_{K+2}	...	R_T

Estimation sample used to find the optimal weights

Out-of-Sample evaluation to give a realistic view on portfolio performance

No Look-Ahead Bias In Optimized Weights

- Split-sample design matches with the investor who:



- Function `window()` to do split-sample analysis in R

Let's practice!