Report for WIDS Project
Topic: Optimal Portfolio Allocation

Introduction:

I chose this project because of my interest in the fields of Finance and Data Analysis. It was muck more than a 4 week project. I learned many new things like

- Some basics of Finance
- Modern Portfolio Theory
- Formulating Optimisation Problems
- Solving them using CVXPY
- Markowitz Mean-Variance Optimisation

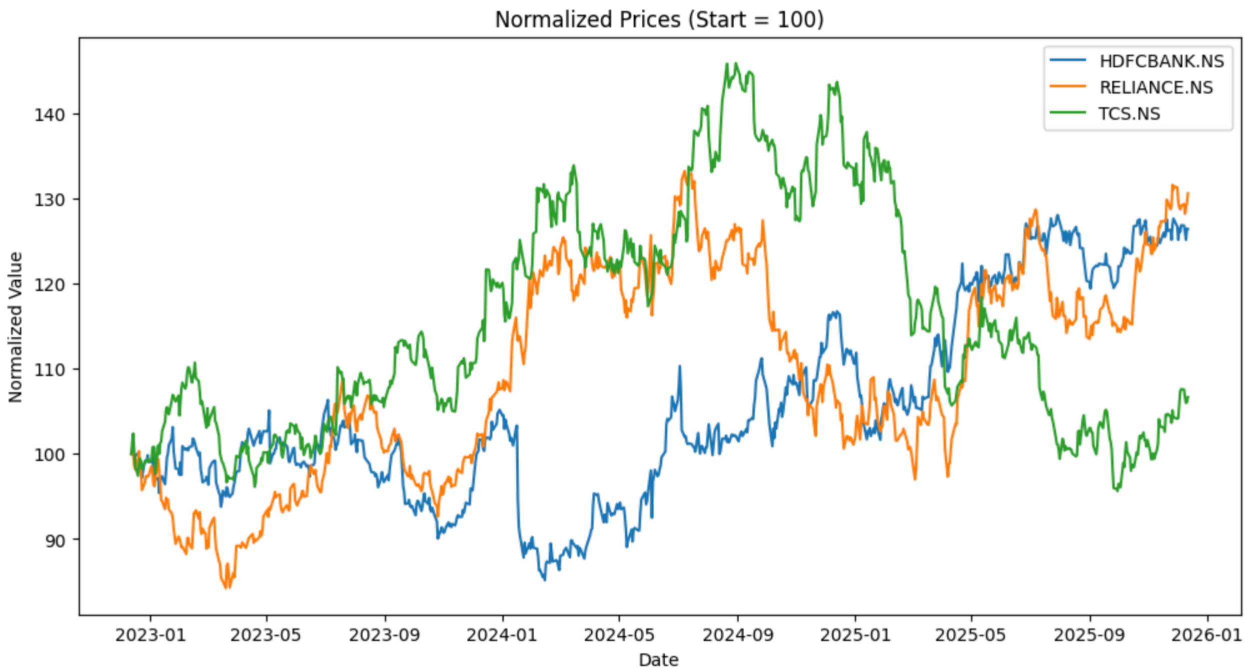
-Prerit Advani
Roll no.: 25B4538
Department: IEOR

Week 1: Introduction to Python and Finance Basics

In the first week I was introduced to Python, which was the programming language used for for all later assignments/projects. Other than that it aimed at familiarising with various finance topics and terminologies used very frequently like Returns and its types, Variance, Portfolios, Diversification and the Need for Optimisation.
During this phase, Python was used to:

- Load and preprocess financial data
- Compute basic statistics such as mean returns and variance
- Visualise asset behaviour over time

This week established the computational and conceptual groundwork for optimisation.



Week 2: Formulating the Portfolio Optimisation Problem

In the second phase, portfolio allocation was translated into a mathematical framework.

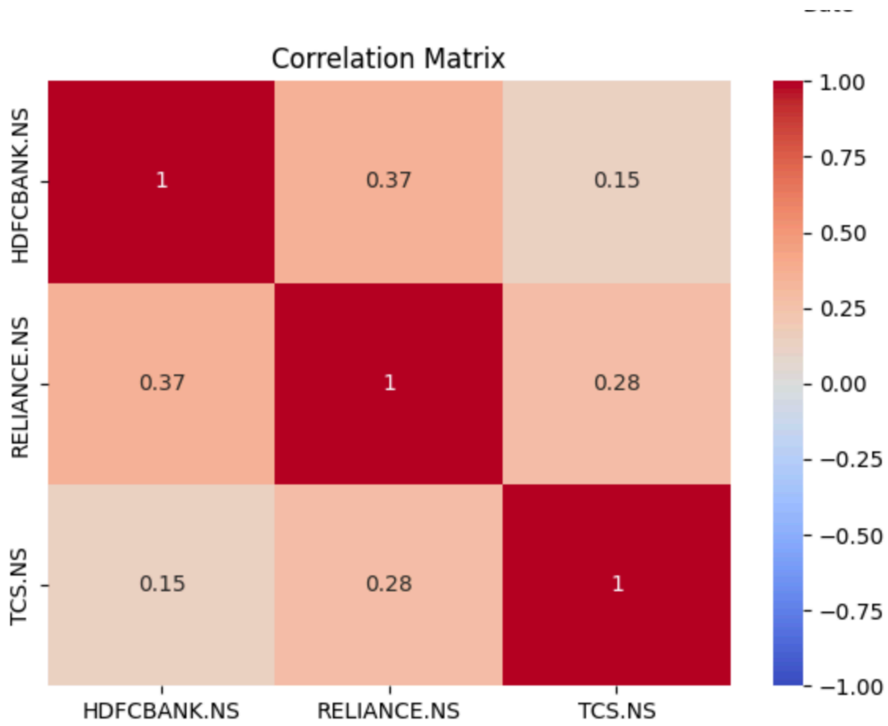
Key concepts:

- Vector representation of asset returns
- Covariance matrix to model joint asset risk
- Portfolio expected return as a weighted sum of individual returns
- Portfolio risk modelled as variance (or standard deviation)

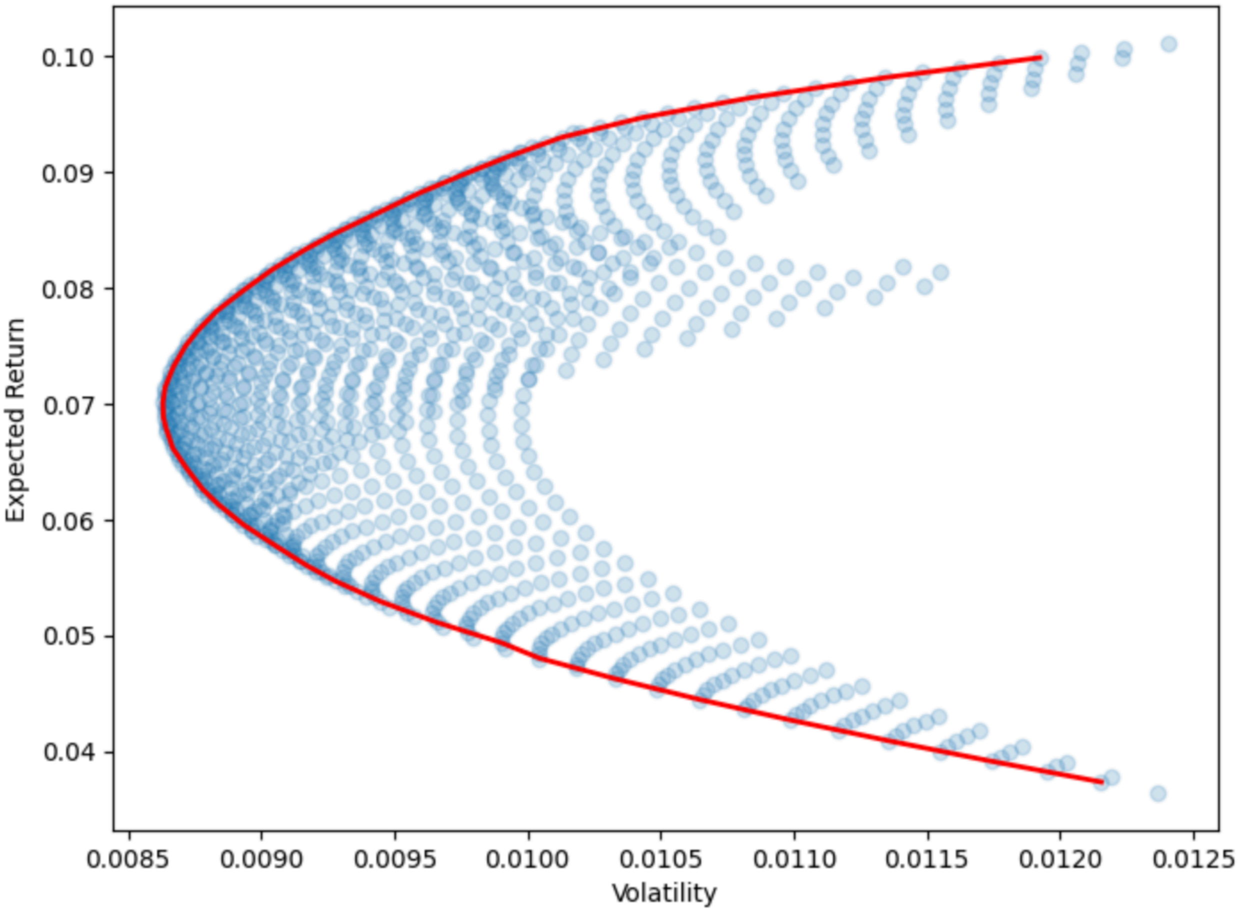
The portfolio optimisation problem was formulated as:

- Objective: Minimise portfolio variance (risk)
- Constraints:
  - Achieve a target expected return
  - Sum of asset weights equals one
  - No short selling (weights ≥ 0)

This formulation prepared the foundation for applying the Markowitz model.



We found out the risk and return for many different possible weights and plotted them on graph. But this was time consuming and less accurate as the weights differ by discrete values so the exact optimum weight may not be found. This issue was addressed in the week 3.



This week was very important as it introduced the idea of the efficient frontier (the red line in the graph) except which all other portfolios were suboptimal and should not be chosen as there is always a better option available which may be either increasing the return at the same level of risk or decreasing the risk without compromising the returns.

Week 3: Markowitz Mean–Variance Optimisation

The third phase involved implementing the optimisation model using convex optimisation techniques.

Key steps:

- Use of CVXPY to define decision variables (portfolio weights)
- Construction of the objective function using the covariance matrix
- Imposition of realistic investment constraints
- Solving the optimisation problem efficiently

Multiple optimisation runs were performed for varying target returns to:

- Generate a set of optimal portfolios
- Construct the Efficient Frontier, which represents the best achievable risk-return trade-offs

The efficient frontier was visualised to analyse how risk increases with expected return.

Here the task we did was same as week 2 but rather than check the risk and return for many possible portfolios we used the Markowitz Mean–Variance Optimisation:

This has 2 common formulations which are as follows:

1. Target Return Constraint:

$$\min_{w} \; w^T \Sigma w \quad \text{s.t. } \mu^T w \geq R$$

i.e. to Minimise risk ensuring a certain return.

2. Risk Return Objective

Where lambda controls risk aversion.

$$\max_{w} \; \mu^T w - \lambda w^T \Sigma w$$

Higher lambda means a safer portfolio. It can be thought of as penalising more for riskier stocks.

Week 4: THE FINAL PROJECT

This week didn't have any new learning content but we had to build a complete portfolio optimiser on our own.

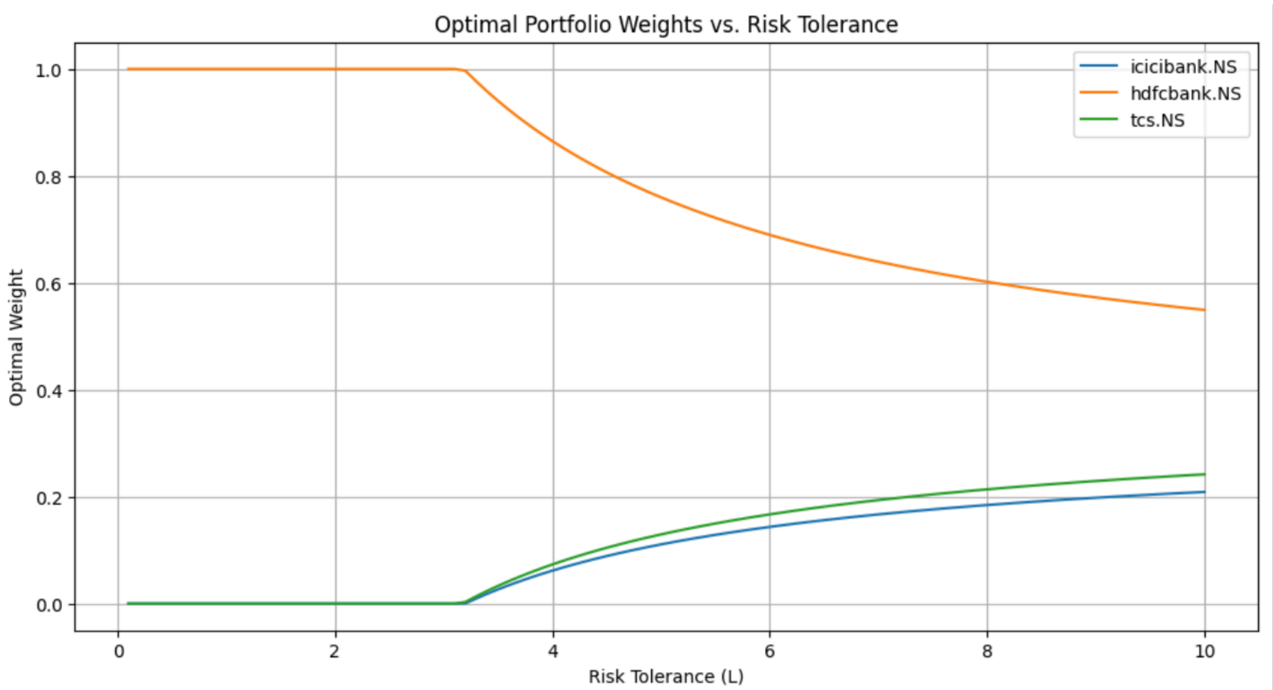
The things which were to be done in the project were as follows:

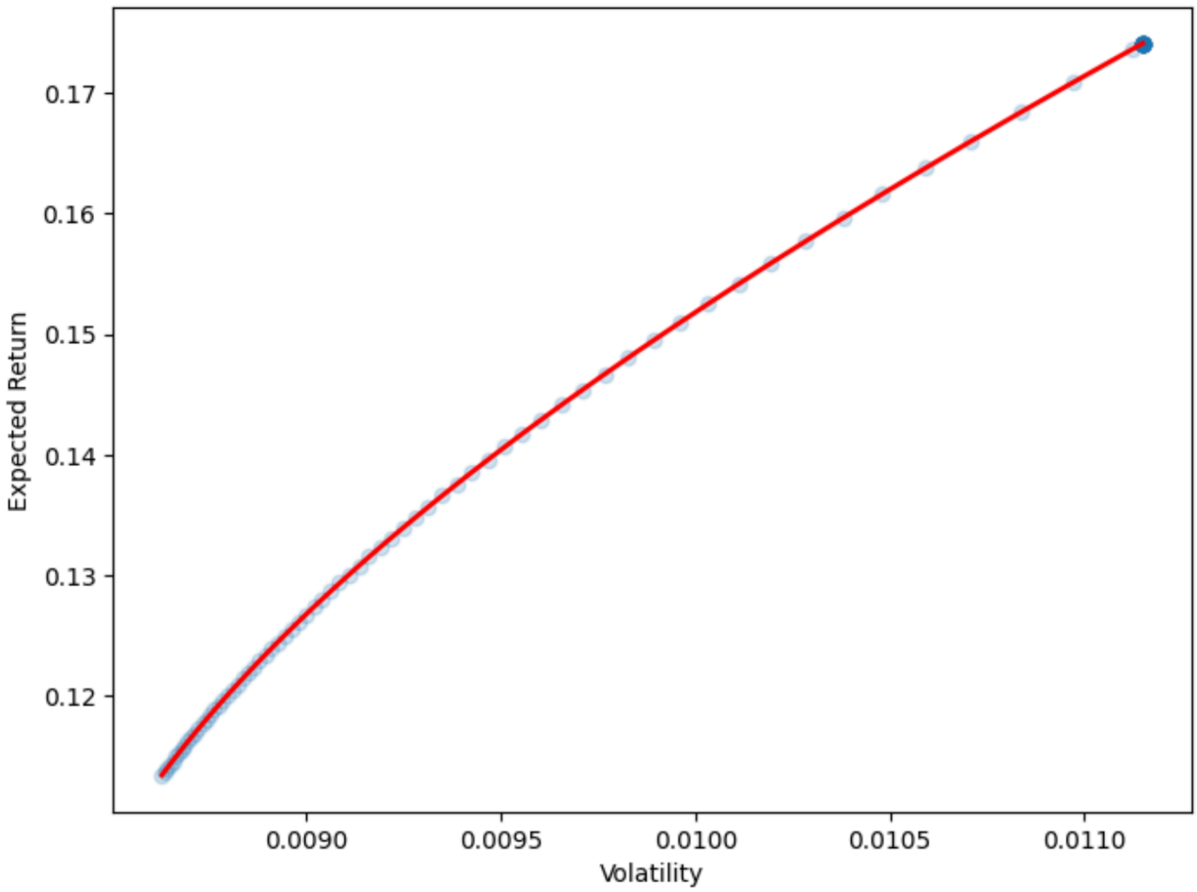
- End-to-end Python implementation
- Optimal asset weight allocation
- Efficient frontier visualisation
- Interpretation of results and investment insights

This phase emphasised practical understanding and creativity by allowing customisation of:

- Asset universe
- Risk tolerance
- Optimisation constraints

I used the risk return objective method shown on the previous page which allowed the users to choose their risk appetite by choosing lambda and also plotted different portfolios obtained by choosing different lambdas in range [0.1 to 10] at gaps of 0.1.




0.17
0.16
0.15
0.14
0.13
0.12
Expected Return
0.0090
0.0095
0.0100
0.0105
0.0110
Volatility

Conclusion:

This project successfully demonstrated how data, mathematics, and optimisation can be combined to solve real-world financial problems. By progressing from basic financial concepts to advanced optimisation techniques, the project provided a holistic understanding of optimal portfolio allocation.

The Markowitz Mean–Variance framework, despite its assumptions, remains a powerful foundational model in modern portfolio theory. This project not only reinforced theoretical knowledge but also emphasised practical implementation and interpretation, bridging the gap between finance theory and real-world application.

Future Scope:

Possible extensions of this project include:

- Incorporating transaction costs and constraints
- Allowing short selling
- Using alternative risk measures (CVaR)
- Applying machine learning for return estimation
- Dynamic portfolio rebalancing