Scilab case study project on Portfolio Optimization Using Mean-Variance Model

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Abstract

Making investment decisions is not always straightforward, especially when there is a need to balance risk and return. This project focuses on portfolio optimization using the Mean-Variance model, which helps in selecting a combination of assets that can give better returns with controlled risk.

In this work, historical stock data will be used to calculate important values such as expected return, variance, and covariance between different assets. These values will then be applied to find an optimal portfolio allocation. The idea is to understand how different assets behave together and how risk can be reduced by proper distribution of investment.

Scilab will be used to perform the required calculations and to visualize the results. Graphs like the efficient frontier will be plotted to show the relationship between risk and return for different portfolio combinations.

Overall, this project aims to give a practical understanding of how basic mathematical and statistical concepts can be used in financial decision-making. It also shows how tools like Scilab can help in analyzing data and supporting better investment choices..

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1. Introduction

Portfolio optimization is a central concept in financial analysis because investors usually seek a balance between maximizing return and minimizing risk. In practical investing, selecting a single stock may lead to concentrated risk, while investing in multiple assets without proper analysis may produce suboptimal results. A systematic framework is therefore required to distribute investment across assets in a rational manner.

The Mean-Variance model, proposed by Harry Markowitz, provides such a framework. It evaluates a portfolio using two primary statistical measures: expected return and variance. Expected return indicates the average gain that may be obtained, whereas variance and standard deviation indicate the volatility associated with that return. The covariance among assets is also important because it helps explain how the assets move relative to one another. By combining assets that do not move exactly alike, an investor may reduce overall portfolio risk through diversification.

In this case study, three Indian stocks were selected for analysis: Reliance Industries, TCS, and Infosys. Historical stock prices were collected and arranged in a CSV dataset. The data was processed in Scilab, where daily returns, mean returns, and covariance values were computed. Based on these values, 5000 portfolios with random weight combinations were generated. Their returns and risks were measured, and the minimum variance portfolio was identified. This project offers a practical demonstration of how statistical techniques and optimization concepts can be applied to support better investment decisions.

2. Problem Statement

Investors often face difficulty in deciding how much money should be allocated to each asset in a portfolio. If the allocation is done without statistical analysis, the resulting portfolio may carry unnecessary risk or fail to achieve a satisfactory return. This challenge becomes more important when multiple assets are involved, since the investor must consider not only the performance of each asset individually but also the way the assets behave together.

The present case study addresses this problem by applying the Mean-Variance model to a three-stock portfolio. The aim is to determine how historical stock data can be used to calculate daily returns, estimate expected returns, measure covariance, and construct portfolios with different weight combinations. From these portfolios, the study identifies the one with the minimum variance, which represents the lowest-risk allocation among the simulated combinations.

The solution is implemented in Scilab through a structured procedure: data loading, return calculation, covariance estimation, random portfolio generation, risk-return computation, and graphical visualization. The final objective is to show that even a simple three-asset portfolio can be analyzed scientifically and that diversification can be studied in a clear, quantitative manner.

3. Basic Concepts Related to the Topic

a) Portfolio

A portfolio is a collection of financial assets held by an investor. In this study, the portfolio consists of three stocks: Reliance, TCS, and Infosys.

b) Return

Return represents the gain or loss produced by an asset over a period of time. In this project, daily return is calculated from consecutive daily prices.

c) Risk

Risk refers to the uncertainty or volatility associated with the return of an asset or portfolio. In the Mean-Variance framework, risk is measured using variance and standard deviation.

d) Diversification

Diversification means spreading investment across more than one asset. When assets do not move exactly in the same way, diversification can reduce overall portfolio risk.

e) Expected Return

Expected return is the average return estimated from historical observations. It is used as an indicator of likely performance.

f) Variance

Variance measures how widely returns vary around their mean. A higher variance indicates greater uncertainty.

g) Covariance

Covariance measures how two assets move together. A positive covariance means the assets tend to move in the same direction, while a lower covariance can improve diversification benefits.

h) Mean-Variance Analysis

Mean-Variance Analysis is a portfolio evaluation method that compares portfolios based on expected return and risk. It is one of the foundational models in modern portfolio theory.

i) Monte Carlo Simulation

Monte Carlo Simulation is a technique in which many random portfolios are generated and evaluated. In this study, 5000 random portfolios are created to explore the possible risk-return combinations.

j) Daily Return Formula

$$R_{i,t} = \frac{P_{i,t+1} - P_{i,t}}{P_{i,t}}$$

where $R_{i,t}$ is the daily return of asset i, and $P_{i,t}$ is its price on day t.

k) Mean Return

$$\mu_i = \frac{1}{n}\sum_{t=1}^{n} R_{i,t}$$

l) Covariance

$$\mathrm{Cov}(i,j) = \frac{1}{n-1}\sum_{t=1}^{n} (R_{i,t} - \mu_i)(R_{j,t} - \mu_j)$$

m) Portfolio Return

$$E(R_p) = \sum_{i=1}^{m} w_i \, \mu_i$$

n) Portfolio Variance

$$\sigma_p^2 = W\Sigma W^T$$

o) Portfolio Risk

$$\sigma_p = \sqrt{W\Sigma W^T}$$

p) Weight Constraint

$$\sum_{i=1}^{m} w_i = 1$$

q) Annualized Return

$$\mu_{annual} = \mu_{daily} \times 252$$

r) Annualized Risk

$$\sigma_{annual} = \sigma_{daily} \times \sqrt{252}$$

4. Flowchart

Figure 1: Master flowchart for Mean-Variance portfolio optimization

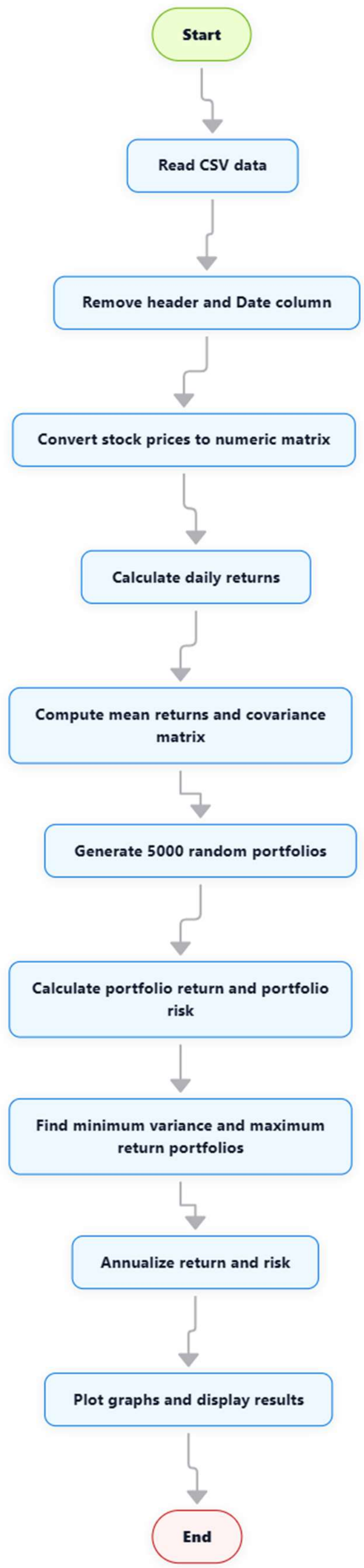


Figure 2: Simulation flowchart for random portfolio generation

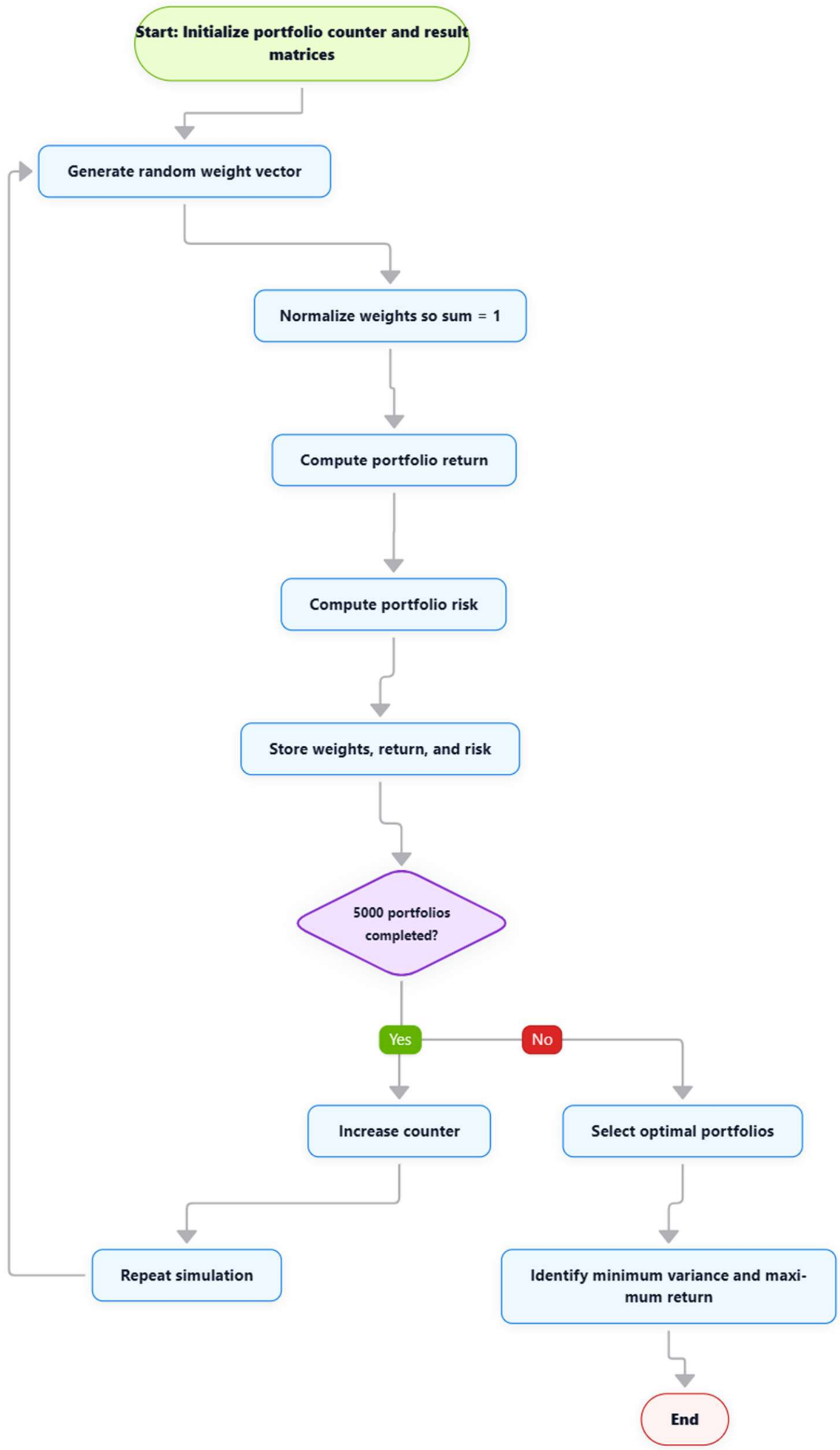
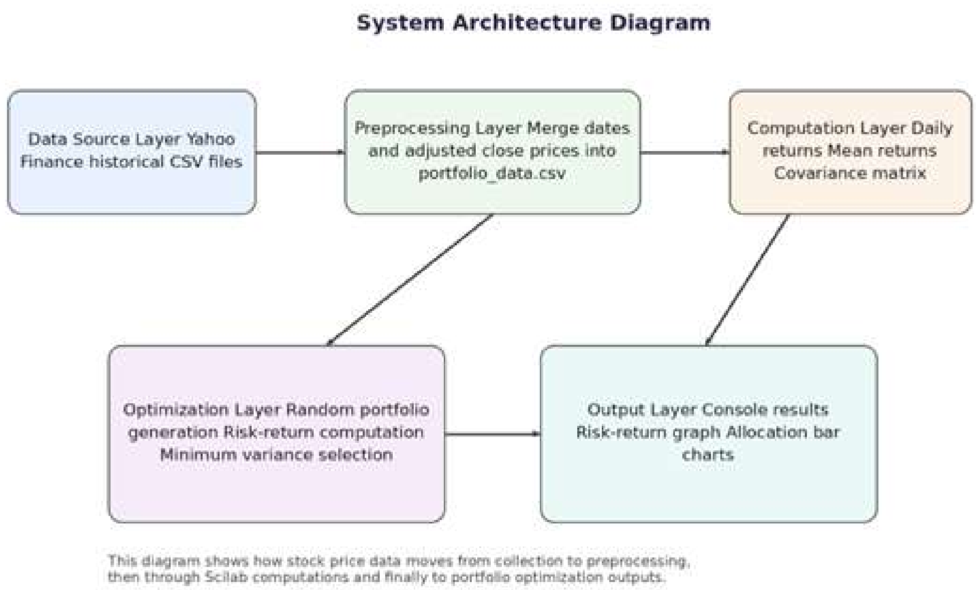


Figure 3: System architecture of the Scilab-based portfolio model



5. Software/Hardware Used

Software

- Scilab 2026.0.1
- Microsoft Excel
- Microsoft Word

Hardware

- Personal computer or laptop
- Windows operating system
- Minimum 4 GB RAM

Dataset

The dataset consists of one year of stock price data for Reliance Industries, TCS, and Infosys. The CSV file contains four columns: Date, Reliance, TCS, and Infosys. In the Scilab program, the date column is excluded from numerical computations and only the price columns are converted into a numeric matrix.

6. Procedure of Execution

Step 1: Prepare the dataset

Download or collect the historical stock price data for Reliance, TCS, and Infosys. Merge the cleaned adjusted close values into a single CSV file named portfolio_data.csv. Ensure that the columns are arranged as:

Date, Reliance, TCS, Infosys

Step 2: Place the dataset in the correct folder

Save the CSV file inside the data folder so that the Scilab script can access it using the relative path:
../data/portfolio_data.csv

Step 3: Open Scilab and set the working directory

Open Scilab and change the current working directory to the folder containing the .sce script.

Step 4: Initialize the environment

The script begins with:

- clc;
- clear;
- close;

These commands clear the console, remove old variables, and close previous graph windows.

Step 5: Read the CSV file

The script reads the CSV file using csvRead(). Because the first column contains dates, the file is first treated as raw data.

Step 6: Remove non-numeric information

The first row contains headers and the first column contains dates. These are removed using:

- row removal for the header
- column removal for the date field

The remaining data is converted into numeric format and stored in the matrix prices.

Step 7: Determine data dimensions

The program uses:

- number of rows = number of trading days
- number of columns = number of assets

In this project, the data contains 247 trading days and 3 assets.

Step 8: Calculate daily returns

A nested loop is used to compute daily returns for each asset using consecutive price values. The output is stored in the matrix returns.

Step 9: Display preliminary outputs

The program prints:

- number of trading days
- number of assets
- first 10 rows of daily returns
- mean daily returns
- covariance matrix

These values are important because they confirm that the dataset has been loaded and processed correctly.

Step 10: Compute mean returns and covariance matrix

The mean return of each asset is computed using mean(), and the covariance matrix is computed using cov(). These are the main statistical inputs required for portfolio optimization.

Step 11: Generate random portfolios

The script sets:

- number of portfolios = 5000

For each portfolio:

1. random weights are generated
2. the weights are normalized so their sum becomes 1
3. the expected portfolio return is computed
4. the portfolio risk is computed using the covariance matrix
5. the results are stored in separate matrices

This loop is the core of the simulation.

Step 12: Identify the minimum variance portfolio

After all portfolios are generated, the script searches for the portfolio with the smallest risk value. The corresponding weight vector is stored as the minimum variance portfolio.

Step 13: Identify the maximum return portfolio

The script also finds the portfolio with the highest expected return among the generated portfolios.

Step 14: Annualize portfolio metrics

The mean returns and covariance matrix are annualized using the standard factors:

- 252 trading days for returns
- $\sqrt{252}$ for risk

This gives annualized return and annualized risk for the selected portfolio.

Step 15: Plot the graphs

The script creates three plots:

1. risk-return scatter plot
2. minimum variance portfolio allocation bar chart
3. maximum return portfolio allocation bar chart

These plots help interpret the results visually.

Step 16: Save screenshots for the report

After execution, screenshots should be taken of:

- first 10 rows of daily returns
- mean daily returns
- covariance matrix
- minimum variance portfolio output
- risk-return graph
- minimum variance allocation graph
- maximum return allocation graph

7.Result

The Scilab implementation successfully computed daily returns, mean returns, covariance values, and portfolio-level statistics for a three-asset portfolio. The code generated 5000 random portfolios and evaluated each one in terms of expected return and standard deviation. Based on the simulation, the program identified both the minimum variance portfolio and the maximum return portfolio.
The intermediate outputs showed that the dataset contained 247 trading days and 3 assets. The first 10 rows of the daily return matrix confirmed that the stock prices had been converted correctly into return series. The mean daily returns summarized the average performance of the selected assets, while the covariance matrix revealed how the returns of Reliance, TCS, and Infosys moved relative to one another. These outputs formed the basis for portfolio risk-return computation.

The minimum variance portfolio allocated the highest proportion of capital to Reliance and

TCS, with only a small share allocated to Infosys. This suggests that, over the selected historical period, Reliance and TCS contributed more effectively to reducing overall portfolio volatility. The annualized values further showed the long-run interpretation of the daily portfolio estimates. Although the annualized return of the minimum variance portfolio was slightly negative, the result is still meaningful because the focus of this portfolio is risk minimization rather than return maximization.

The risk-return graph displayed a cloud of 5000 portfolios, with each point representing a different weight combination. The red-marked point indicated the minimum variance portfolio, and the green-marked point indicated the maximum return portfolio. This plot clearly illustrated the trade-off between risk and return. The bar graphs provided an intuitive view of how the weights were distributed in the selected portfolios. Overall, the results confirm that the Mean-Variance framework can be implemented effectively in Scilab for a realistic stock market case study.

The project was implemented in Scilab using matrix operations and statistical calculations. The stock price data was read from the CSV file and stored in a price matrix. Daily returns were calculated using consecutive price values. The mean of the returns and covariance matrix were then computed. A Monte Carlo simulation approach was used to generate 5000 portfolios with random weight combinations. For each portfolio, expected return and risk were calculated. The portfolio with the minimum standard deviation was selected as the minimum variance portfolio.

Mention:

- Number of trading days: 247
- Number of assets: 3

7.1 Intermediate Outputs

```
"Number of trading days:"
 247.
"Number of assets:"
 3.
"First 10 rows of daily returns:"
-0.0006451   0.0078813  -0.0090463
 0.0284031   0.0076668   0.0045292
 0.016477    0.0068811   0.0221909
-0.0033191  -0.0021676  -0.0194349
 0.0068154   0.029749    0.0366179
 0.0012308  -0.0033402  -0.0023731
-0.0009219   0.0136407   0.0059807
 0.0525992  -0.0013052   0.0012836
 0.0225744   0.0084217   0.0103907
 0.0037865  -0.005414    0.0017362
```

Figure 2: First 10 rows of daily returns

The daily returns matrix shows the percentage change in stock prices from one day to the next.

```
"Mean daily returns:"
 0.0003378  -0.0008782  -0.0002048
```

Figure 3: Mean daily returns of selected assets

The mean daily returns indicate the average return generated by each asset during the observed period.

```
"Covariance matrix:"
 0.0001667   0.000044    0.0000509
 0.000044    0.000184    0.0001701
 0.0000509   0.0001701   0.0002533
```

Figure 4: Covariance matrix of asset returns

The covariance matrix shows the relationship among the returns of the three stocks and helps determine the combined portfolio risk.

7.2 Minimum Variance Portfolio

The minimum variance portfolio is the portfolio that provides the lowest overall risk among all generated portfolios. It is useful for investors who prefer lower volatility.

From the Scilab output, the minimum variance portfolio weights were:

- Reliance = 0.5336
- TCS = 0.4397
- Infosys = 0.0267

Daily expected return: -0.000211

Daily risk: 0.010455

Annualized return: -0.053256

Annualized risk: 0.165966

```
  "----- Minimum Variance Portfolio -----"
Reliance weight = 0.5297
TCS weight = 0.4383
Infosys weight = 0.0320
Daily Expected Return = -0.000213
Daily Risk = 0.010455
Annualized Return = -0.053562
Annualized Risk = 0.165965
```

Figure 5: Minimum variance portfolio weights, return, and risk

The output shows that the optimal low-risk allocation places the highest weight in Reliance and TCS, with only a small allocation to Infosys. This means that during the selected period, the combination of Reliance and TCS contributed more effectively to reducing portfolio risk

7.3 Graphical Analysis

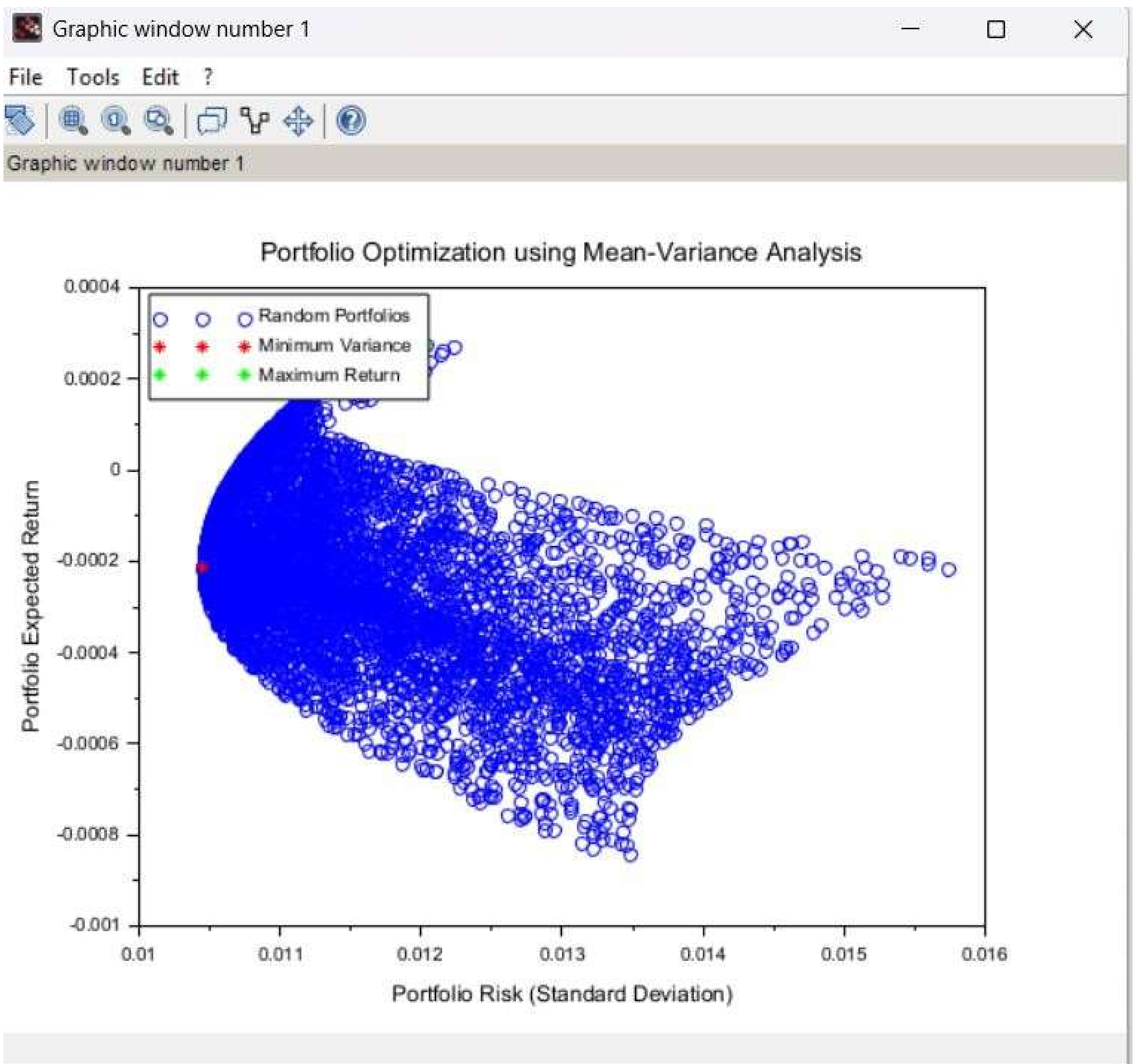


Figure 6: Risk-return graph of random portfolios

The risk-return graph shows the tradeoff between expected return and portfolio risk for 5000 randomly generated portfolios. Each blue point represents one portfolio. The red marked point indicates the minimum variance portfolio, while the green marked point indicates the portfolio with maximum return.

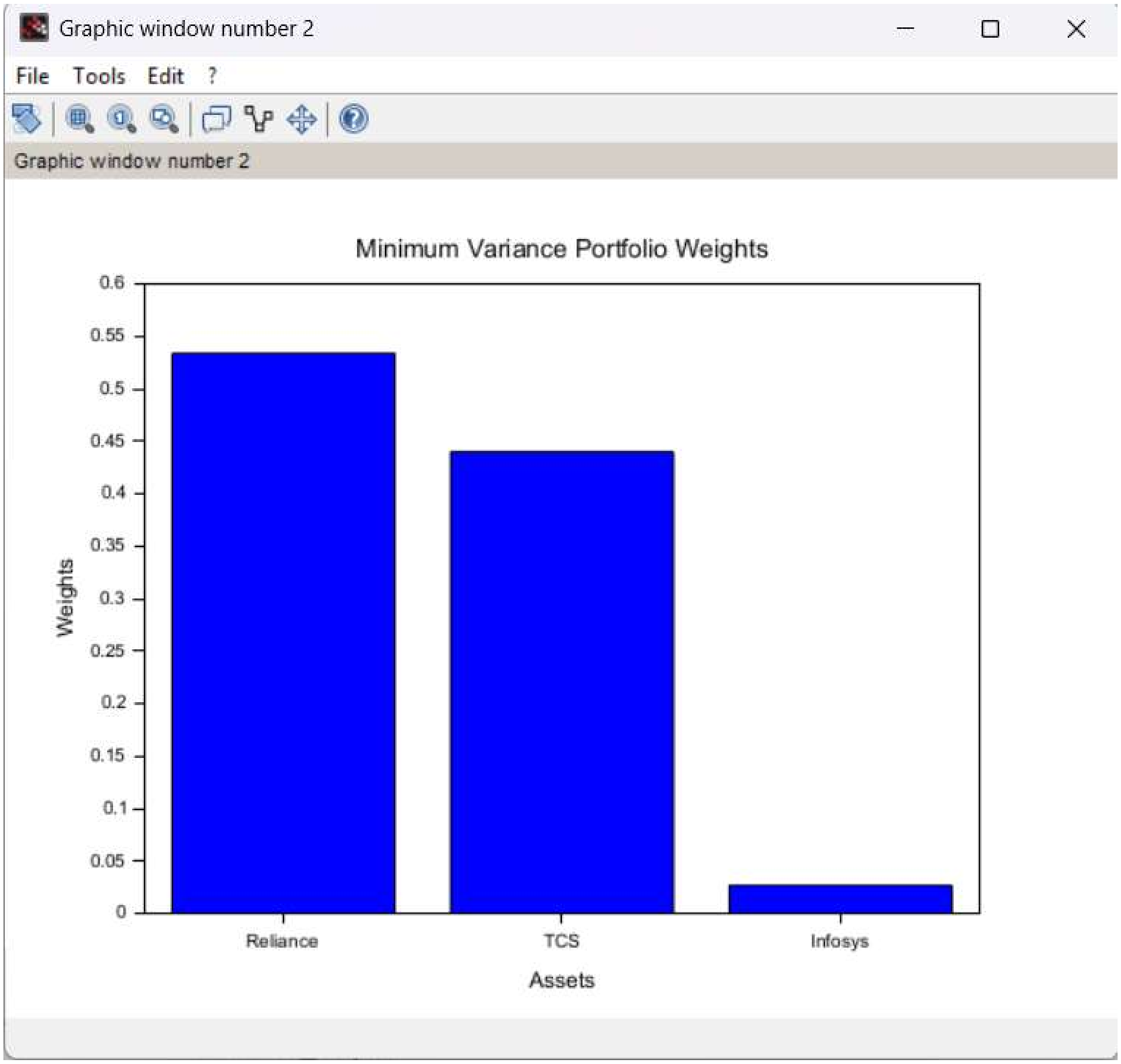


Figure 7: Asset allocation in the minimum variance portfolio

The bar graph clearly shows the proportion of total investment allocated to each stock in the minimum variance portfolio. Reliance has the highest allocation, followed by TCS, while Infosys has the smallest allocation.

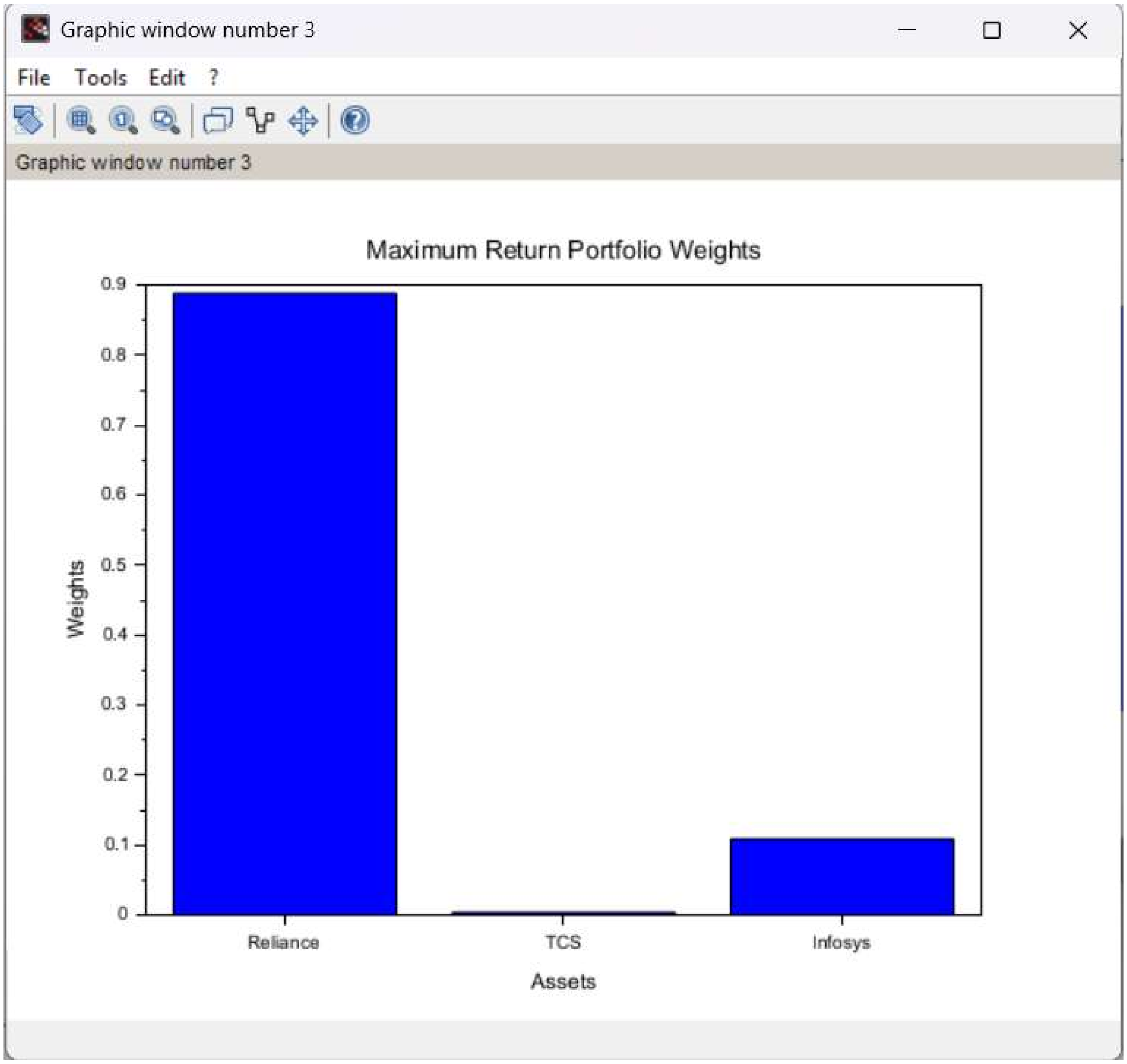


Figure 8: Asset allocation in the maximum return portfolio

8.References

1. Harry Markowitz, "Portfolio Selection," Journal of Finance, 1952.

   Link: https://onlinelibrary.wiley.com/doi/10.1111/j.1540-6261.1952.tb01525.x

2. Yahoo Finance historical stock data pages for Reliance, TCS, and Infosys.

   Links:
   https://finance.yahoo.com/quote/RELIANCE.NS/history/?period1=1744554217&period2=1776090214

   https://finance.yahoo.com/quote/TCS.NS/history/?period1=1744554301&period2=1776090299

Infosys Limited (INFY.NS) Stock Historical Prices & Data - Yahoo Finance