Value at Risk (VaR) Using Historical, Parametric, & Monte Carlo Simulation for Portfolio Risk

1. Introduction

Risk management is a critical aspect of financial decision-making, particularly in portfolio management. Value at Risk (VaR) is a widely used risk metric that estimates the potential loss in a portfolio over a given time frame at a specific confidence level. This project aims to analyze portfolio risk using multiple VaR methodologies, including historical VaR, parametric VaR, and Monte Carlo simulation.

2. Objective

The primary objectives of this analysis are:

- Calculate **Historical VaR** based on past portfolio returns.
- Estimate **Parametric VaR** using mean-variance assumptions.
- Implement **Monte Carlo Simulation** to generate potential future portfolio returns and assess risk.
- Compare the results of different VaR methodologies to evaluate portfolio risk comprehensively.

3. Dataset

The dataset used in this analysis consists of historical stock prices sourced from **Yahoo Finance** via the yfinance Python library. The dataset includes adjusted closing prices for multiple assets in the portfolio over a defined time period.

4. Methodology

4.1 Data Preprocessing

- Extract historical price data from Yahoo Finance.
- Compute daily portfolio returns based on asset weights.
- Check for missing data and handle outliers if necessary.

4.2 Value at Risk (VaR) Approaches

4.2.1 Historical VaR

- Uses actual past return data to determine the loss threshold at a given confidence level (e.g., 95% or 99%).
- This method is **non-parametric**, meaning it does not assume any particular distribution.

4.2.2 Parametric VaR (Variance-Covariance Method)

- Assumes that returns follow a normal distribution.
- Computes VaR using the formula:

  $VaR=\mu-z\cdot\sigma$

  where

  - μ = mean return
  - σ = standard deviation of returns
  - z = z-score corresponding to the confidence level (e.g., 1.65 for 95%, 2.33 for 99%)

4.2.3 Monte Carlo Simulation

- Generates multiple random portfolio return scenarios based on statistical assumptions.
- Uses a large number of simulations to estimate the probability distribution of portfolio returns.
- VaR is derived from the simulated distribution at the chosen confidence level.

5. Results & Analysis

5.1 Comparative Analysis of VaR Methods

- **Historical VaR** captures real market movements but is limited by past data.
- **Parametric VaR** is computationally simple but assumes normality, which may not always hold.
- **Monte Carlo simulation** provides flexibility but requires computational power and accurate assumptions.

5.2 Visualization

- Distribution of portfolio returns.
- VaR estimates plotted for different methods.
- Monte Carlo simulation results showing potential loss scenarios.

6. Conclusion

This analysis provides a comprehensive evaluation of portfolio risk using different VaR methods. Historical and parametric VaR offer straightforward risk estimates, while Monte Carlo simulation allows for a broader range of future scenarios. The choice of methodology depends on the portfolio's characteristics and risk tolerance.

7. Future Improvements

- Incorporate **Expected Shortfall (Conditional VaR)** for a more comprehensive risk measure.
- Extend Monte Carlo simulations to account for **fat-tailed distributions**.
- Apply **stress testing** to analyze extreme market conditions.

8. References

- Jorion, P. (2007). *Value at Risk: The New Benchmark for Managing Financial Risk*.
- Hull, J. (2015). *Options, Futures, and Other Derivatives*.
- Yahoo Finance API Documentation.