Portfolio Volatility Forecasting and Risk Analysis

Group 3: Thu Trang Bach, Rhichard Koh, Mohsin Mohammed, Thu Tra Truong

Abstract

This study analyzes the risk characteristics of a multi-asset financial stock portfolio using daily price data from a Kaggle dataset. We address three primary research questions: (1) how sectoral diversification influences overall portfolio volatility, (2) how portfolio risk behaves during market crises such as the COVID-19 crash, and (3) how to generate forward-looking volatility and Value-at-Risk (VaR) estimates using time-series forecasting and Monte Carlo simulation. The analysis utilizes realized volatility, Holt exponential smoothing, and simulated return paths. Results show that diversification reduces annualized volatility by approximately 25.5%, the COVID-19 period generated dramatic spikes in volatility, Holt's method forecasts a near-term volatility of 16.84%, and simulated 30-day VaR suggests potential losses of up to 14.63% in extreme conditions. These findings provide insight into portfolio risk behavior, stress resilience, and forward-looking risk estimation.

1 Introduction

Financial markets exhibit time-varying volatility driven by economic cycles, investor sentiment, and external shocks. Portfolio managers must measure diversification benefits, monitor crisis-induced volatility spikes, and forecast future risk levels. This study analyzes a portfolio of financial stocks using historical data to quantify the benefits of diversification, examine volatility behavior during stress periods, and provide forward-looking risk estimates.

Building on a previous Kaggle project focused on static VaR and CVaR, our work extends the analysis by adding volatility forecasting, crisis-period analysis, and diversification metrics. Our objective is to develop a complete risk management framework for understanding how portfolio volatility evolves under normal and stressed conditions.

2 Dataset Description

We use the `stock-portfolio-data-with-prices-and-indices` dataset from Kaggle, including:

- **portfolio_prices.csv**: daily OHLC and adjusted closing prices
- **SP500.csv**: S&P 500 benchmark index
- **Portfolio.csv**: portfolio composition, sectors, and weights

Key variables include the date, ticker, adjusted close price, sector, and daily returns. The dataset provides sufficient granularity to construct a multi-asset portfolio and analyze volatility dynamics.

3 Methodology

3.1 Portfolio Construction

Daily returns were calculated for each stock as:

$$r_t = \frac{P_t - P_{t-1}}{P_{t-1}}$$

Portfolio returns were generated by weighting individual stock returns according to the portfolio allocation.

3.2 Realized Volatility

We compute the 30-day rolling annualized volatility:

$$\sigma_{30d}(t) = \sqrt{252} \cdot \text{std}\left(r_{t-29:t}\right)$$

This measure forms the basis for diversification impact, crisis risk analysis, and forecasting.

3.3 Holt Exponential Smoothing Forecasting

Future volatility was forecasted using the Holt method:

$$\begin{aligned} \ell_t &= \alpha y_t + (1-\alpha)(\ell_{t-1} + b_{t-1}), \\ b_t &= \beta(\ell_t - \ell_{t-1}) + (1-\beta) b_{t-1}, \\ \hat{y}_{t+1} &= \ell_t + b_t, \end{aligned}$$

where y_t is realized volatility, and α, β represent smoothing parameters. The one-step-ahead forecast represents expected 30-day volatility.

3.4 Value-at-Risk via Monte Carlo Simulation

We simulate future returns using a normal distribution calibrated from historical returns:

$$r_t \sim N(\mu, \sigma)$$

Cumulative 30-day returns are computed for 10,000 scenarios. VaR is defined as:

$$\text{VaR}_p = -Q_p(R_{\text{sim}}),$$

where Q_p is the p-th quantile.

4 Results

4.1 Diversification Impact

Sector diversification significantly reduces portfolio volatility. The annualized volatility of the diversified portfolio is 21.77%. Sector-only portfolios exhibit substantially higher volatilities:

- Entertainment: 45.32%
- Healthcare: 36.25%
- Natural Resources: 35.14%
- Telecommunications, Engineering, Agriculture: 27–29%

The average sector-only volatility is 29.23%, yielding a risk reduction of 25.5% when diversified across sectors. This confirms the risk mitigation benefits of diversification.

4.2 Crisis Risk: COVID-19

The 30-day annualized volatility exhibits a dramatic spike during the COVID-19 crash in early 2020, reaching 56.39%, up from typical pre-crisis values below 20–25%. A comparison with the S&P 500 shows strong synchronization with market-wide volatility. After the crisis, the portfolio gradually reverted toward normal levels but remained elevated for several months.

4.3 Volatility Forecasting

Holt's model fits the realized volatility series with parameters:

$$\alpha = 0.95, \qquad \beta = 0.21.$$

The model captures the spike during COVID-19 and the subsequent decline. The forecasted next 30-day annualized volatility is:

$$\hat{\sigma}_{30d} = 16.84\%.$$

4.4 Simulated Value-at-Risk

Using 10,000 Monte Carlo simulations:

- 30-day VaR (95%): 10.00% loss
- 30-day VaR (99%): 14.63% loss
- 1-day VaR (95%): 2.18% loss
- 1-day VaR (99%): 3.15% loss

These values provide a forward-looking measure of extreme losses and complement the volatility forecast.

5 Discussion

Three main insights emerge:

1. **Diversification substantially reduces portfolio risk** by smoothing sector-specific shocks.
2. **Crisis periods produce sharp volatility spikes**, reflecting elevated systemic risk.
3. **Holt forecasting and simulated VaR provide forward-looking risk estimates** that are interpretable and grounded in statistical methods.

These insights reinforce the value of combining realized volatility, exponential smoothing, and Monte Carlo simulation in portfolio risk analysis.

6 Conclusion

This study successfully assesses portfolio risk through diversification analysis, crisis risk evaluation, Holt-based volatility forecasting, and simulation-driven VaR estimation. Diversification reduces risk by 25.5%, volatility spiked dramatically during COVID-19, Holt's method forecasts moderate near-term volatility, and simulated VaR quantifies worst-case losses. Together, these methods form a comprehensive risk management toolkit aligned with the project's objectives.