■ Stock Returns & Volatility Analysis

Complete Technical Report

Project Analysis: AAPL, GOOGL, MSFT

Analysis Period: January 2023 - January 2025

Report Generated: September 18, 2025

■ Stock Returns & Volatility Analysis - Complete Technical Report

■ Executive Summary

This project implements a comprehensive financial analysis system for calculating stock returns, volatility, and risk metrics using modern Python data science tools. The system analyzes major technology stocks (Apple, Google, Microsoft) over a 2-year period, implementing advanced financial models including EWMA volatility calculations, correlation analysis, and risk-adjusted performance metrics.

Project Duration: September 18, 2025 **Analysis Period:** January 2023 - January 2025 (2 years)
Stocks Analyzed: AAPL, GOOGL, MSFT **Total Data Points:** 1,506 daily observations per stock

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■■ Project Architecture

Directory Structure*

```
STOCK ANALYSIS/ ■■■ .venv/ # Python virtual environment ■■■ src/ # Core application
modules ■ ■■■ __init__.py # Package initialization ■ ■■■ stock_analyzer.py # Main
analysis engine ■ ■■■ plotting.py # Visualization framework ■■■ notebooks/ #
Jupyter analysis notebooks ■ ■■■ stock_analysis.ipynb # Main analysis workflow ■
■■■ tableau_exports/ # CSV exports for visualization ■ ■■■
01_daily_stock_prices.csv ■ ■■■ 02_daily_returns.csv ■ ■■■
03_cumulative_returns.csv ■ ■■■ 04_volatility_analysis.csv ■ ■■■
05_summary_statistics.csv ■ ■■■ 06_correlation_analysis.csv ■ ■■■
07_monthly_performance.csv ■ ■■■ 08_risk_metrics.csv ■ ■■■
09_performance_comparison.csv ■ ■■■ 10_data_dictionary.csv ■■■ examples/ # Usage
examples ■■■ data/ # Raw data storage
```

■■ Technology Stack

Core Technologies*

Component	Technology	Version	Purpose
Language	Python	3.13.2	Primary development language

Environment	Virtual Environment	Built-in venv	Dependency isolation
IDE	VS Code	Latest	Development environment
Notebook	Jupyter	1.0.0+	Interactive analysis

Data Science Libraries*

Library	Version	Primary Use Case
pandas	≥2.0.0	Data manipulation and analysis
numpy	≥1.24.0	Numerical computations
yfinance	≥0.2.18	Yahoo Finance API integration
matplotlib	≥3.7.0	Static visualizations
seaborn	≥0.12.0	Statistical visualizations
scipy	≥1.10.0	Statistical functions

Financial Analysis Components*

• **EWMA Volatility Model** with λ=0.94 decay factor

• **Simple & Log Returns** calculations

• **Sharpe Ratio** risk-adjusted performance

• **Value-at-Risk (VaR)** at 95% and 99% confidence levels

• **Maximum Drawdown** analysis

• **Rolling Correlation** with 60-day window

■ Implementation Workflow

Phase 1: Project Initialization*

Step 1.1: Workspace Creation

```
bash
```

Created project directory structure

mkdir -p "STOCK ANALYSIS"/{src,notebooks,examples,data} cd "STOCK ANALYSIS" ```

Step 1.2: Python Environment Setup

```
bash
```

Virtual environment creation and activation

python3 -m venv .venv source .venv/bin/activate # macOS/Linux ```

Step 1.3: Dependency Installation

```
bash
```

Core financial analysis libraries

pip install yfinance>=0.2.18 pip install pandas>=2.0.0 pip install numpy>=1.24.0 pip install matplotlib>=3.7.0 pip install seaborn>=0.12.0 pip install jupyter>=1.0.0 pip install scipy>=1.10.0 ```

Phase 2: Core Module Development

Step 2.1: StockAnalyzer Class (`src/stock_analyzer.py`)

Purpose: Central engine for financial data operations

Key Methods: ``python class StockAnalyzer: def **init**(self, symbols, start*date, end*date) def fetch*stock*data() # Yahoo Finance API integration def calculate_returns() # Simple & log returns def calculate*ewma*volatility() # EWMA model implementation def calculate_correlation() # Rolling correlation analysis def get*summary*statistics() # Performance metrics aggregation ``

Technical Implementation: - **Data Source:** Yahoo Finance API via yfinance library - **Return Calculations:** - Simple Returns: (P*t* / *P*{t-1}) - 1 - Log Returns: ln(P*t* / *P*{t-1}) - **EWMA Volatility:** σ²*t* = λσ²{t-1} + (1-λ)r²_{t-1} where λ=0.94 - **Error Handling:** Comprehensive exception management for API failures

Step 2.2: StockPlotter Class (`src/plotting.py`)

Purpose: Advanced visualization framework

Key Methods: ``python class StockPlotter: def **init**(self, data, returns*data, volatility*data) def plot*price*analysis() # OHLC and volume charts def plot*returns*analysis() # Return distribution analysis def plot*volatility*analysis() # Volatility time series def plot*correlation*analysis() # Rolling correlation heatmaps def plot*risk*return_scatter() # Risk-return optimization ``

Visualization Features: - **Subplots:** Multi-panel layouts for comprehensive analysis - **Styling:** Professional financial chart aesthetics - **Interactivity:** Zoom, pan, and hover capabilities - **Export:** High-resolution PNG output

Phase 3: Interactive Analysis Development

Step 3.1: Jupyter Notebook Creation (`notebooks/stock_analysis.ipynb`)

Structure: 24 cells with comprehensive workflow

Cell Organization: 1. **Cells 1-3:** Environment setup and imports 2. **Cells 4-6:** Data fetching and initial exploration 3. **Cells 7-9:** Returns calculation and analysis 4. **Cells 10-12:** EWMA volatility implementation 5. **Cells 13-15:** Risk-return analysis 6. **Cells 16-18:** Correlation analysis 7. **Cells 19-21:** Statistical analysis and normality testing 8. **Cells 22-24:** Tableau data export

Step 3.2: Data Processing Pipeline

Data Flow: `` Yahoo Finance API → Raw OHLCV Data → Returns Calculation → Volatility Analysis → Risk Metrics → Correlation Analysis → Statistical Tests → Tableau Export ``

Processing Steps: 1. **Data Fetching:** 2-year daily data for AAPL, GOOGL, MSFT 2. **Data Cleaning:** Missing value handling, outlier detection 3. **Feature Engineering:** Return calculations, moving averages 4. **Statistical Analysis:** Distribution testing, normality checks 5. **Risk Analysis:** VaR, maximum drawdown, Sharpe ratios

Phase 4: Advanced Analytics Implementation

Step 4.1: EWMA Volatility Model

Mathematical Foundation: - **Decay Factor:** $\lambda = 0.94$ (industry standard) - **Formula:** $\sigma^2t = \lambda\sigma^2\{t-1\} + (1-\lambda)r^2\_\{t-1\}$ - **Annualization:** $\sigma annual = \sigma daily \times \sqrt{252}$

Implementation Benefits: - **Responsiveness:** Recent observations weighted more heavily - **Smoothing:** Reduces noise in volatility estimates - **Industry Standard:** Widely accepted in risk management

Step 4.2: Risk Metrics Calculation

Value-at-Risk (VaR): - **95% VaR:** Daily loss exceeded 5% of the time - **99% VaR:** Daily loss exceeded 1% of the time - **Implementation:** Historical simulation method

Maximum Drawdown: - **Calculation:** Peak-to-trough decline in cumulative returns - **Formula:** `MDD = min((Cumulativet - RunningMaxt) / RunningMax_t)`

Sharpe Ratio: - **Formula:** `(AnnualReturn - RiskFreeRate) / AnnualVolatility` - **Risk-Free Rate:** Assumed 0% for comparative analysis

Step 4.3: Correlation Analysis

Rolling Correlation: - **Window Size:** 60 trading days - **Frequency:** Daily updates - **Pairs:** AAPL-GOOGL, AAPL-MSFT, GOOGL-MSFT

Statistical Testing: - **Jarque-Bera Test:** Normality testing for return distributions - **Significance Level:** $\alpha = 0.05$

Phase 5: Tableau Integration

Step 5.1: Data Export Architecture

Export Strategy: - **File Format:** CSV for Tableau compatibility - **Structure:** Normalized tables for optimal Tableau performance - **Documentation:** Complete data dictionary for field definitions

Step 5.2: CSV File Specifications

File	Rows	Purpose	Key Fields
01_daily_stock_prices.csv	1,506	OHLCV data	Date, Symbol, OHLC, Volume
02_daily_returns.csv	1,503	Daily returns	Simple_Return, Return_Category
03_cumulative_returns.csv	1,503	Performance tracking	Cumulative_Return_Simple_Pct
04_volatility_analysis.csv	1,503	Risk metrics	EWMA_Volatility, Volatility_Level
05_summary_statistics.csv	3	Key metrics	Total_Return, Sharpe_Ratio
06_correlation_analysis.csv	2,646	Correlation data	Correlation, Pair_Name
07_monthly_performance.csv	75	Monthly aggregation	Monthly_Return, Trading_Days
08_risk_metrics.csv	4,716	Risk analysis	VaR_95, Max_Drawdown
09_performance_comparison.csv	6	Stock comparisons	Winner_Risk_Adjusted
10_data_dictionary.csv	32	Field documentation	Field descriptions

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■ Key Results & Findings

Performance Summary (2-Year Analysis)*

Stock	Total Return	Annual Return	Annual Volatility	Sharpe Ratio	Performance Rank
GOOGL	+81.8%	+35.2%	27.1%	1.30	1st (Highest Return)
MSFT	+57.3%	+25.1%	16.5%	1.52	1st (Best Risk-Adj.)
AAPL	+35.6%	+16.4%	23.8%	0.69	3rd

Risk Analysis Results*

Volatility Rankings: 1. **MSFT:** Lowest volatility (16.5% annual) 2. **AAPL:** Medium volatility (23.8% annual) 3. **GOOGL:** Highest volatility (27.1% annual)

Value-at-Risk (95% confidence): - **MSFT:** -2.1% daily VaR - **AAPL:** -2.8% daily VaR - **GOOGL:** -3.2% daily VaR

Correlation Analysis*

Average Correlations (60-day rolling): - **AAPL-MSFT:** 0.72 (High positive correlation) - **AAPL-GOOGL:** 0.68 (High positive correlation) - **GOOGL-MSFT:** 0.65 (Moderate-high correlation)

■ Technical Challenges & Solutions

Challenge 1: Data Quality & API Reliability*

Problem: Yahoo Finance API occasional failures and data gaps

Solution Implemented: ``python def fetch*stock*data(self): try: # Robust error handling with retries for attempt in range(3): data = yf.download(symbols, start=start*date, end=end*date) if not data.empty: return data time.sleep(1) # Brief pause between attempts except Exception as e: logger.error(f"Data fetch failed: {e}") return None ``

Challenge 2: DateTime Index Alignment*

Problem: Correlation plotting errors due to misaligned datetime indices

Solution Implemented: ```python

Ensure proper datetime index handling

correlation*data* = *rolling*corr.reset_index() correlation*data['Date']* = *correlation*data['Date'].dt.strftime('%Y-%m-%d') ```

Challenge 3: Large Dataset Memory Management

Problem: Memory constraints with multiple stocks and long time series

Solution Implemented: - **Chunked Processing:** Process data in smaller time windows - **Efficient Data Types:** Use appropriate pandas dtypes - **Memory Cleanup:** Explicit garbage collection after large operations

Challenge 4: EWMA Volatility Implementation

Problem: Correct implementation of exponentially weighted moving average

Solution Implemented: ``python def calculate*ewma*volatility(self, decay=0.94): ewma_vol = returns.ewm(alpha=1-decay, adjust=False).var() annualized*vol* = *np.sqrt(ewma*vol * 252) return annualized_vol ``

■ Code Quality & Best Practices

Object-Oriented Design

• **Modular Architecture:** Separate classes for analysis and visualization

• **Encapsulation:** Private methods for internal calculations

• **Inheritance:** Base classes for extensibility

Error Handling

• **Try-Catch Blocks:** Comprehensive exception management

• **Input Validation:** Parameter checking and sanitization

• **Graceful Degradation:** Fallback options for failed operations

Documentation Standards*

• **Docstrings:** Comprehensive function and class documentation

• **Type Hints:** Modern Python typing for better code clarity

• **Comments:** Inline explanations for complex financial calculations

Performance Optimization*

• **Vectorized Operations:** NumPy and pandas optimizations

• **Efficient Data Structures:** Appropriate data types for memory efficiency

• **Caching:** Memoization for expensive calculations

■ Business Value & Applications

Risk Management Applications*

• **Portfolio Optimization:** Risk-return analysis for asset allocation

• **Volatility Forecasting:** EWMA models for risk prediction

• **Stress Testing:** VaR calculations for downside risk assessment

Investment Decision Support*

• **Performance Comparison:** Objective stock ranking metrics

• **Correlation Analysis:** Diversification opportunity identification

• **Trend Analysis:** Time-series patterns for timing decisions

Regulatory Compliance*

• **Risk Reporting:** Standardized risk metrics calculation

• **Audit Trail:** Comprehensive calculation documentation

• **Stress Testing:** Regulatory capital requirement support

■ Future Enhancements

Technical Improvements*

Real-Time Data Integration: WebSocket connections for live data

Machine Learning Models: LSTM networks for volatility prediction

Alternative Data Sources: Multiple API integration for robustness

Cloud Deployment: AWS/Azure infrastructure for scalability

Analysis Enhancements*

GARCH Models: Advanced volatility modeling

Monte Carlo Simulation: Scenario analysis capabilities

Options Pricing: Black-Scholes implementation

Factor Models: Fama-French multi-factor analysis

Visualization Improvements*

Interactive Dashboards: Plotly/Dash implementation

Real-Time Charts: Live updating visualizations

Mobile Optimization: Responsive design for mobile devices

Custom Indicators: Technical analysis tool integration

■ References & Resources

Financial Theory*

• **Modern Portfolio Theory:** Markowitz optimization framework

• **EWMA Models:** RiskMetrics methodology (J.P. Morgan, 1996)

• **Value-at-Risk:** Historical simulation approach

Technical Documentation

• **Yahoo Finance API:** yfinance library documentation

• **Pandas Financial Analysis:** Time series analysis best practices

• **Matplotlib Visualization:** Professional chart design principles

Industry Standards

• **Basel III:** International banking risk management framework

• **GICS Classification:** Global Industry Classification Standard

• **Risk Management Standards:** CFA Institute guidelines

■ Conclusion

This project successfully implements a comprehensive financial analysis system that combines modern Python data science tools with rigorous financial theory. The modular architecture enables easy extension and modification, while the Tableau integration provides powerful visualization capabilities for business users.

Key Achievements: - ■ **Robust Data Pipeline:** Reliable data fetching and processing - ■ **Advanced Analytics:** EWMA volatility and risk metrics - ■ **Professional Visualizations:** Publication-quality charts - ■ **Business Intelligence Integration:** Tableau-ready datasets - ■ **Comprehensive Documentation:** Full technical specification

The system provides valuable insights into technology stock performance, demonstrating that Microsoft offers the best risk-adjusted returns despite Google's higher absolute returns. The correlation analysis reveals significant interdependence among technology stocks, important for portfolio diversification strategies.

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