Final Project Report: Portfolio Risk Analysis

**Abstract**

This project aims to analyze and compare the risk and return characteristics of three portfolios: Value, Growth, and Industrial. Multiple Value-at-Risk (VaR) methodologies and additional risk metrics are applied to assess downside risk and overall portfolio performance.

**Portfolios Selected**

Value Portfolio: JNJ, PG, KO, PEP, WMT, XOM, IBM, MCD, MMM, CVX.

Growth Portfolio: AAPL, MSFT, AMZN, GOOGL, NFLX, NVDA, ADBE, CRM, META, TSLA.

Industrial ETF Portfolio: XLI, IYJ, VIS, ITA, FXR, PIL, IGV, SOXX, PPA, FTEC.

Each portfolio is equally weighted.

**Data Source and Preprocessing**

Source: Yahoo Finance via *yfinance* package.

Period: 5 years of historical daily data to 03/20/2025.

Returns Computed As:

**VaR Methodologies and Assumptions**

1. Parametric Normal VaR: Assumes returns are normally distributed.

2. Historical Simulation: Uses historical returns.

3. Monte Carlo Simulation: Simulates returns under normal distribution.

4. GPD (Extreme Value Theory): Models tail losses using Generalized Pareto Distribution.

5. Filtered Historical Simulation (FHS): Uses GARCH to filter volatility and simulate returns.

6. GARCH-Based VaR: Conditional volatility from GARCH model.

7. Cornish-Fisher Expansion: Adjusts normal quantile for skew and kurtosis.

8. Bootstrapping: Resamples returns with replacement.

9. Kernel Density Estimation (KDE): Estimates return density non-parametrically.

10. Parametric t-Distribution: Assumes fat tails modeled with Student's t-distribution.

**Statistical Tests**

Statistical assumptions were evaluated to verify the suitability of VaR methodologies for each portfolio.

Normality Tests: Shapiro-Wilk and Kolmogorov-Smirnov tests indicated that none of the portfolios followed a normal distribution (p-values < 0.05). This supports the use of non-parametric and tail-sensitive VaR methods like KDE, Historical Simulation, and EVT.

Autocorrelation & Stationarity: Ljung-Box tests on lag-10 autocorrelation revealed significant autocorrelation in returns, especially for the Value and Industrial portfolios. This suggests that returns may not be i.i.d., validating the use of GARCH and Filtered Historical Simulation methods.

Tail Behavior: Anderson-Darling test results confirmed the presence of heavy tails in all portfolios, particularly in the Growth portfolio. This reinforces the appropriateness of using models like GPD and t-distribution-based VaR.

**Coherence Property Checks**

Each method is evaluated against four coherence properties:

Monotonicity: Worse outcomes result in higher VaR.

Sub-additivity: Diversification reduces risk.

Positive Homogeneity: Scaling the portfolio scales VaR.

Translation Invariance: Adding a risk-free asset reduces VaR accordingly.

Conclusion: Most methods satisfy these properties (Cornish-Fisher does not satisfy Monotonicity); and Historical, KDE, and GPD are slightly more sensitive.

**Expected Shortfall (Conditional VaR)**

Defined as:

Calculated for each method and portfolio using tail returns beyond the VaR threshold.

**Additional Risk Metrics**

Standard Deviation: Measures volatility.

Sharpe Ratio: , using daily T-Bill as .

Sortino Ratio: Like Sharpe but uses downside deviation.

Maximum Drawdown (MDD): Largest peak-to-trough decline.

Conditional Drawdown at Risk (CDaR): Average of drawdowns beyond a threshold.

**Visual Analysis**

Return Distributions: Growth is most volatile, Value is most stable.

Drawdowns: Growth exhibits deepest drawdowns.

VaR Comparison: Growth consistently shows highest VaR across methods.

Rolling Metrics: Show volatility and Sharpe dynamics over time.

**Conclusions**

**Value Portfolio:** Demonstrated the most conservative risk profile. It exhibited the lowest standard deviation, smallest maximum drawdown, and the best Sharpe and Sortino ratios across most risk measures. This makes it suitable for conservative investors seeking steady, risk-adjusted performance.

**Growth Portfolio:** Showed the highest volatility and deepest drawdowns. It consistently produced the highest VaR and Expected Shortfall values across all methods. While it has higher return potential, it is best suited for risk-tolerant investors focused on long-term capital appreciation.

**Industrial Portfolio:** Presented a moderate risk-return profile, with volatility and risk metrics between Value and Growth portfolios. It benefits from economic cycles and may offer diversification benefits when combined with either Value or Growth strategies.

Overall, the Value portfolio proved to be the most robust under stress scenarios, while the Growth portfolio carried significantly more tail risk. Methodologically, models like Historical Simulation and KDE captured non-normal tail behavior better, whereas Parametric methods offered consistency under distributional assumptions.

**Future Enhancements**

**Dynamic Portfolio Weighting:** Implement time-varying weights based on volatility, momentum, or fundamental factors.

**Multiple Confidence Levels:** Evaluate risk under 99% and 90% VaR/ES thresholds.

**Out-of-Sample Validation:** Backtest model performance and stability using walk-forward or cross-validation.

**Interactive Dashboard:** Build a Streamlit or Plotly dashboard for real-time visualization and scenario testing.