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PORTFOLIO OPTIMIZATION ANALYSIS

Comparing Minimum Variance and Maximum Sharpe Ratio Strategies

This report presents our portfolio optimization analysis using Modern Portfolio Theory (MPT). We analyzed eight assets across tech, defensive, financial, and bond categories to construct two optimal portfolios with distinct investment goals.

Our main takeaway: the same set of assets can produce dramatically different portfolios depending on the optimization target. The Minimum Variance Portfolio (MVP) allocated 86.9% to bonds for safety, while the Maximum Sharpe Ratio Portfolio (MSRP) concentrated entirely in high-growth stocks (JPM and NVDA) for stronger risk-adjusted returns.

The power of optimization lies in how assets interact. Our MVP achieved lower volatility (6.3%) than any single bond, showing how smart combinations can outperform individual holdings through diversification and negative correlation benefits.

OUR APPROACH

We selected eight assets representing key market segments:

- Tech Growth: AAPL (Apple), MSFT (Microsoft), NVDA (NVIDIA)
- Defensive: NEE (NextEra Energy), PG (Procter & Gamble)
- Financials: JPM (JPMorgan Chase)
- Bonds: AGG (Aggregate Bond ETF), TLT (Treasury Bond ETF)

We used five years of historical data (December 14, 2020 – December 12, 2025), encompassing diverse market regimes—COVID recovery, rising rates, and recent volatility.

We built two optimization models:

- Minimum Variance Portfolio (MVP): Minimizes risk regardless of return. Ideal for risk-averse investors prioritizing capital preservation.
- Maximum Sharpe Ratio Portfolio (MSRP): Maximizes return per unit of risk. Best suited for growth-focused investors seeking efficiency.

Parameters included a 4% risk-free rate (current Treasury yield), long-only weights, full investment (sum = 100%), and a five-year horizon.

METHODOLOGY

Following the MPT framework:

1. Calculated daily returns: $(\text{Price_today} - \text{Price_yesterday}) / \text{Price_yesterday}$
2. Estimated annualized returns: $\text{average daily return} \times 252 \text{ trading days}$

3. Computed the covariance matrix using Ledoit-Wolf shrinkage for more stable estimates
4. Optimized portfolio weights to either minimize variance or maximize the Sharpe ratio

We used PyPortfolioOpt, a Python library for efficient frontier analysis. The MVP algorithm minimized total portfolio variance, while the MSRP maximized excess return relative to volatility.

RESULTS

Minimum Variance Portfolio (MVP)

- AGG (Aggregate Bonds): 86.9%
- JPM (JPMorgan): 6.8%
- PG (Procter & Gamble): 6.1%
- MSFT (Microsoft): 0.1%
- Others: 0%

Performance: Expected Return = 1.6%, Volatility = 6.3%, Sharpe Ratio = 0.25

Maximum Sharpe Ratio Portfolio (MSRP)

- JPM (JPMorgan): 52.0%
- NVDA (NVIDIA): 48.0%
- Others: 0%

Performance: Expected Return = 45.7%, Volatility = 31.2%, Sharpe Ratio = 1.33

Individual Asset Stats:

- *Expected Returns:* NVDA 67.9%, JPM 25.2%, AAPL 18.7%, MSFT 18.5%, NEE 4.8%, PG 3.6%, AGG -0.4%, TLT -8.5%
 - *Volatilities:* NVDA 51.9%, AAPL 28.0%, NEE 27.1%, MSFT 25.8%, JPM 24.4%, PG 17.4%, TLT 9.4%, AGG 6.7%
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WHY THESE RESULTS MAKE SENSE

Minimum Variance Portfolio:

The optimizer favored bonds due to their low volatility—AGG had the lowest at 6.7%. But the portfolio achieved even lower volatility (6.3%) by mixing small allocations of JPM and PG. This occurs because weakly or negatively correlated assets offset each other's movements.

A 100% AGG portfolio would have 6.7% volatility. But 86.9% AGG + 6.8% JPM + 6.1% PG produced 6.3% volatility—less risky than holding only bonds. High-volatility tech stocks like NVDA and AAPL were excluded because their risk outweighed their return contribution.

Maximum Sharpe Portfolio:

The optimizer selected JPM and NVDA for their combination of return potential and diversification. JPM offered high returns (25.2%) with moderate risk (24.4%), while NVDA had exceptional returns (67.9%) despite higher volatility (51.9%). Their correlation (0.31) provided valuable diversification.

MSFT, while strong, was excluded because JPM had higher returns, lower volatility, and a better diversification effect with NVDA. Bonds were excluded entirely because their negative or near-zero returns would have dragged down the Sharpe ratio.

INVESTOR RECOMMENDATIONS

- Minimum Variance Portfolio: Suitable for conservative investors nearing retirement, those focused on preserving capital, or those with shorter horizons (<5 years).
- Maximum Sharpe Portfolio: Appropriate for long-term investors seeking growth and comfortable with volatility (30%+ swings).

Ultimately, the “best” portfolio depends on the investor’s risk tolerance, goals, and time horizon—not a universal definition of performance.

LIMITATIONS

This analysis relies on simplifying assumptions: that past performance predicts future trends, there are no taxes or transaction costs, returns are normally distributed, and correlations remain stable. In reality, correlations often spike during crises, reducing diversification benefits. Further, there are nearly infinite firm- and macro-level attributes beyond expected return and covariance that will impact the appropriate weights.

Professional managers enhance MPT by adding forward-looking insights, stress testing, tax efficiency, and active rebalancing strategies.

FUTURE INQUIRY

We only used a limited number of functions within PyPortfolioOpt and primarily focused on following Markowitz's theory of optimal portfolio allocation. This library is capable of a wide range of classical portfolio optimizations, including Black-Litterman and hierarchical risk parity.

It might also be possible for us to create our own portfolio allocation algorithm. The MSRP and MVP optimize Sharpe Ratio and variance, but other attributes such as book to market ratio have proven to influence investor sentiment and thus valuation. Seeing that hedge funds have fine tuned their own algorithms based on a variety and combination of chosen variables, it would be worthwhile for us to conduct our own

CONCLUSION

This analysis highlights how mathematical optimization can create vastly different outcomes using the same assets.

- The Minimum Variance Portfolio emphasized safety (86.9% bonds) with 6.3% volatility—lower than any individual holding.
- The Maximum Sharpe Portfolio concentrated in two equities, achieving a Sharpe ratio of 1.33.

The key insight: portfolio construction isn't about picking the "best" stocks—it's about finding the right combination that aligns with an investor's objectives.

There's no universally perfect portfolio. The right one depends entirely on your risk appetite, time horizon, and goals.

All figures are based on market data from December 14, 2020 through December 12, 2025 (5 years). Results will vary with changing market conditions.

All data and portfolio statistics are based on market data as of December 12, 2025. Due to daily price updates from Yahoo Finance, running this analysis on different dates will produce slightly different results.

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