PORTFOLIO CONSTRUCTION AND ANALYSIS WITH PYTHON

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1. INTRODUCTION AND METHODOLOGY

1.1. Objective

This report aims to analyse different portfolio construction strategies using historical data spanning over 10 years. The dataset includes 14 stocks, 3 bonds, and 3 funds. Our objective is to identify the strategy offering the best trade-off between risk and return.

1.2. Asset Selection

The selected assets are chosen to ensure optimal diversification, comprising of

- Stocks: 14 stocks from various economic sectors: Apple Inc. (AAPL), UnitedHealth Group Incorporated (UNH), Microsoft Corporation (MSFT), Alphabet Inc. (GOOGL), NVIDIA Corporation (NVDA), Pfizer Inc. (PFE), Oracle Corporation (ORCL), Citigroup Inc. (C), Exxon Mobil Corporation (XOM), JPMorgan Chase & Co. (JPM), Barclays PLC (BCS), British American Tobacco p.l.c. (BTI), NIKE, Inc. (NKE), Baker Hughes Company (BKR)

- Bonds: 3 sovereign bonds: Federated Hermes Corporate Bond A (FDBAX), iShares iBoxx $ High Yield Corporate Bond ETF (HYG), iShares 10+ Year Investment Grade Corporate Bond ETF (IGLB)
- Funds: 3 diversified index funds: Rydex NASDAQ-100 2x Strategy A (RYVLX), ProFunds Semiconductors UltraSector Inv (SMPIX), Causeway International Value Inv (CIVVX)

1.3. Data Collection

The historical data for the selected assets was collected from Yahoo Finance over a 10-year period from January 2010 to January 2020. Python code was used for data extraction and preprocessing, and EDHEC Risk Kit module was used for computations.

```
import yfinance as yf

start_date = '2010-01-01'

end_date = '2020-01-01'

ticker = ['AAPL', 'UNH', 'MSFT', 'GOOGL', 'NVDA', 'PFE',

'ORCL', 'C', 'XOM', 'JPM', 'BCS', 'BKR', 'BTI', 'NKE',

'RYVLX', 'SMPIX', 'CIVVX', 'FDBAX', 'HYG', 'IGLB']

data = yf.download(ticker, start_date, end_date)

print(data.tail()) # the most recent prices
```

1.4. Portfolio Strategies

The following strategies were developed and analysed:

1. Equal-Weighted Portfolio:

As its name suggests, EW assigns equal weights to all assets in the portfolio. Academic research found empirical evidence that this naïve approach is not inferior to more advanced models under certain market conditions [DeMiguel et.al (2009), Duchin and Levy (2009), and Kritzman et. al (2010)]. However, a naïve EW method underperformed most other risk models. The main reason for EW underperformance is the high allocation of risk to volatile assets. Given these high allocations, EW models tend to underperform during market crises.

2. CPPI Portfolio:

CPPI is a strategy designed to prevent the portfolio value from dropping below a pre-determined floor. The strategy achieves that goal by changing the allocation to the risky asset – increasing it when the performance of the asset is positive and decreasing exposure to the risky asset when the performance of the risky asset declines. When the level of assets reaches the pre-determined floor, the allocation is entirely to the risk-free asset, and it does not change further. This is often called a 'cash lock' or CPPI defeasance. The CPPI strategy is defined with the level of the Cushion ($C = P - B$) which is the difference between the portfolio value (P) and the pre-determined floor (B), and with the leverage Multiplier M (positive number greater than 1). The dollar allocation to the risky asset is given by the Multiplier times the Cushion ($M \times C$).

3. Mean Variance Optimization (MVO) portfolio leading to Maximum Sharpe ratio (MSR) portfolio:

MVO was first proposed by Markowitz (1952). The goal of the method is to produce a portfolio with the highest Sharpe ratio. Specifically, the method solves the portfolio optimization problem by

maximizing a simple utility function aiming for higher returns and lower risk. As a result, Mean Variance Optimization will result in an optimal portfolio with a maximum Sharpe ratio:

$$\lambda_p = \frac{\mathbb{E}(R_p) - R_f}{\sigma_p}$$

4. Global Minimum Variance (GMV) Portfolio:

Global Minimum Variance (GMV) is a special case of MVO where an investor has very high-risk aversion. In this case "risk avoidance" takes priority to "return maximization" and the optimization tries to find the weights that will result in a portfolio with the lowest possible volatility. The GMV approach is also equivalent to a special case of an MVO in which the investor simply assumes that the expected returns for all assets are equal. Thus, GMV may be an optimal approach for investors that are either highly risk averse, or don't have any differentiating view on the performance of individual assets.

1.5. Performance Metrics

The following metrics were used to evaluate portfolio performance:

1. Expected Return
2. Volatility (Standard Deviation)
3. Sharpe Ratio
4. Maximum Drawdown

2. RESULTS AND ANALYSIS

Strategy	Return	Volatility	Final Wealth	Sharpe Ratio	Maximum Drawdown
EW	0.000515	0.010209	3204.142806	0.763064	-0.235345
GMV	0.000058	0.002032	1150.543836	0.436184	-0.112859
MSR	0.000693	0.007390	5333.377589	1.55596	-0.185914
CPPI	NaN	NaN	1984.909316	[0.710596585573 6214]	-0.250000

Table 1. Results and Analysis of the 20 asset universe

The performance metrics presented in the table highlight the distinct advantages and limitations of each portfolio strategy, providing clear guidance for different investor profiles. Among the analysed options, the Maximum Sharpe Ratio (MSR) portfolio emerges as the strongest performer with a Sharpe ratio of 1.56 and a return of 0.069%. These metrics confirm that the MSR portfolio delivers the best risk-adjusted returns, making it particularly attractive for investors seeking an optimal balance between risk and reward. Its volatility of 0.7% reflects a moderate level of risk, supporting its suitability for investors willing to accept some risk for higher returns. Furthermore, its final wealth of $5333.38 is the highest among the strategies, reinforcing its growth potential. In contrast, the Global Minimum Volatility (GMV) portfolio prioritizes risk minimization, achieving the lowest volatility at 0.2%. This stability makes it ideal for risk-averse investors, but it comes at the expense of significantly lower returns (0.006%) and a reduced Sharpe ratio of 0.44. The final wealth for GMV stands at $1150.54, reflecting its conservative nature. Despite its lower growth potential, the GMV strategy offers strong downside protection, as evidenced by its minimal maximum drawdown of 11.2%. The Equally-Weighted (EW) portfolio strikes a middle ground, with a return of 0.052% and a volatility of 1.0%. While its Sharpe ratio of 0.76 falls short of the MSR portfolio, it benefits from simplicity and broad diversification. The final wealth of $3204.14 indicates a decent balance between growth and stability, though it lacks the optimization seen in the other strategies. Finally, the CPPI strategy, while dynamic and focused on preserving capital, shows a final wealth of $1984.91. Although the return and volatility metrics are not directly comparable due to the strategy's dynamic nature, its maximum drawdown of 25% underscores its ability to limit losses during market downturns. In conclusion, the MSR portfolio stands out for its superior risk-adjusted returns and growth potential. The GMV portfolio is an excellent choice for minimizing risk, while the EW portfolio offers a straightforward and balanced approach. Meanwhile, the CPPI strategy provides a unique dynamic option that combines growth participation with downside protection, making it well-suited for volatile markets. The choice ultimately depends on the investor's specific goals and risk tolerance.

2.1 Visualizations

Figure 1. Portfolio Value vs. Time for CPPI strategy

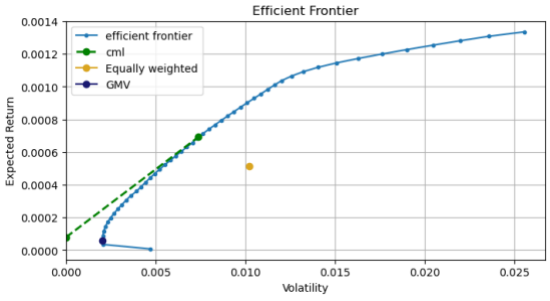

Figure 2. Efficient Frontier and Capital Market Line (CML) with EW and GMV portfolios plotted

The Efficient Frontier graph illustrates the relationship between risk (volatility) and expected return for our portfolios. The Global Minimum Variance Portfolio (GMV) (blue point) lies on the efficient frontier, confirming that it represents the portfolio with the lowest possible volatility for a given return. In contrast, the Equally Weighted Portfolio (yellow point) falls below the efficient frontier, indicating it is suboptimal in terms of risk-return trade-off. The Capital Market Line (CML) demonstrates that a portfolio combining a risk-free asset with the tangency portfolio (on the efficient frontier) achieves better risk-adjusted returns.

The CPPI Strategy graph displays the portfolio value evolution over time. The upward trend highlights its ability to protect a minimum capital level while participating in market growth. Drawdowns are limited due to the dynamic allocation strategy, and the upward movements reflect effective exposure to risky assets. This demonstrates the robustness of the CPPI approach in navigating volatile market conditions while preserving capital and seeking growth opportunities.

2.2 Performance Summary & Insights

The comparison of portfolio strategies highlights important differences in their performance metrics, providing insights into their suitability for various types of investors. Among the strategies analysed, the Maximum Sharpe Ratio (MSR) portfolio stands out with the highest Sharpe ratio of 1.556 and a solid return of 0.0006931. This indicates it offers the best balance between risk and reward, making it an attractive option for investors focused on maximizing returns for every unit of risk taken. However, it comes with a moderate level of volatility at 0.00739, which suggests a measured approach to risk without compromising returns.

On the other hand, the Global Minimum Volatility (GMV) portfolio delivers the lowest volatility at just 0.002032, making it ideal for risk-averse investors who prioritize stability. That said, this stability comes at a cost, as its return is notably lower at 0.00005783. This trade-off makes it a good choice for those seeking to preserve capital in uncertain market conditions, even if it means forgoing higher growth potential.

The Equally-Weighted (EW) portfolio, with a return of 0.0005153 and volatility of 0.010209, offers a straightforward approach that spreads investment equally across assets. While its Sharpe ratio of 0.763 doesn't match the MSR portfolio, it provides diversification without the need for complex calculations, making it a practical option for investors looking for simplicity and broad exposure.

In conclusion, the right strategy depends on the investor's objectives and risk tolerance. The MSR portfolio is ideal for those aiming for strong, risk-adjusted returns, the GMV portfolio is a safe bet for stability and minimal risk, while the EW portfolio provides a balanced and easy-to-implement alternative.

2.3 Limitations

While the analysis provides valuable insights into portfolio strategies, several limitations must be acknowledged. First, the historical price data from 2010 to 2019 may not fully capture extreme market conditions or structural shifts, limiting the applicability of results to future scenarios. Second, the strategies assume constant market conditions and ignore transaction costs, taxes, and other real-world frictions that could affect performance. For instance, CPPI assumes perfect execution of dynamic allocation, which may be impractical in highly volatile markets. Additionally, the reliance on past volatility and returns for GMV and MSR strategies assumes stability in asset behavior, which might not hold during unexpected events. Finally, the focus on daily prices may overlook intraday risks or long-term structural trends, potentially biasing the results toward short-term metrics.

3. CONCLUSION

This study analyzed four portfolio construction strategies: Equally Weighted (EW), Global Minimum Variance (GMV), Maximum Sharpe Ratio (MSR), and Constant Proportional Portfolio Insurance (CPPI), using a dataset of 20 assets over a 10-year period. Each strategy demonstrated distinct strengths and weaknesses, aligning with varying investor preferences and risk tolerances. The Maximum Sharpe Ratio (MSR) portfolio emerged as the top performer in terms of risk-adjusted returns, achieving the highest Sharpe ratio (1.56) and final wealth ($5333.38). This makes it particularly suitable for investors seeking an optimal balance between risk and return. In contrast, the Global Minimum Variance (GMV) portfolio achieved the lowest volatility (0.2%) and offered strong downside protection, making it an ideal choice for highly risk-averse investors. The Equally Weighted (EW) portfolio provided a simple and balanced approach but underperformed the optimized strategies, while the CPPI strategy demonstrated robust capital preservation during volatile periods but faced challenges in achieving higher returns. However, the findings must be interpreted with caution due to inherent limitations. These include the reliance on historical data that may not predict future market behavior, the exclusion of transaction costs and taxes, and the assumption of stable market conditions.

In conclusion, the choice of a portfolio strategy should align with an investor's specific goals, risk

appetite, and market outlook. By understanding the trade-offs between risk and return offered by each strategy, investors can make informed decisions to optimize their portfolios in various market conditions.