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Stochastic Factor-Neutral Equity Trading Strategy for S&P 500 Stocks

Factor Model with Principal Components

- We propose a beta-neutral factor trading strategy for stocks in the S&P 500, where the factors f are the first K = 5, principal components of a sample of 50 component stocks.

$$r_{excess,i} = \alpha_i + \sum_{j=1}^{K} \beta_{ij} f_j + \epsilon_i$$

- We calculate the βs of all S&P stocks with the endogenous factors and use a numerical optimizer to calculate weights such that the *net* portfolio β is 0.

- We backtest the strategy from Oct'15 to Sept'23, recalibrating the βs and rebalancing the portfolio monthly. The strategy outperforms a simple *long-only* strategy on the S&P 500 index with an excess Sharpe Ratio of 0.3188

02-Oct-2015 To 30-Sep-2023				
Annualised Metrics	**Return**	**Volatility**	**Sharpe Ratio**	**Sortino Ratio**
Strategy vs S&P 500	**5.48%**	**17.18%**	**0.3188**	**0.5225**
Strategy Excess	**15.70%**	**20.47%**	**0.7670**	**1.2139**
S&P 500 Excess	**10.22%**	**18.70%**	**0.5467**	**0.8365**

Out of Sample Strategy Betas		
Alpha	**Stock Beta (S&P 500)**	**US Bond Beta (AGG)**
0.0004	**0.6612**	**0.5868**

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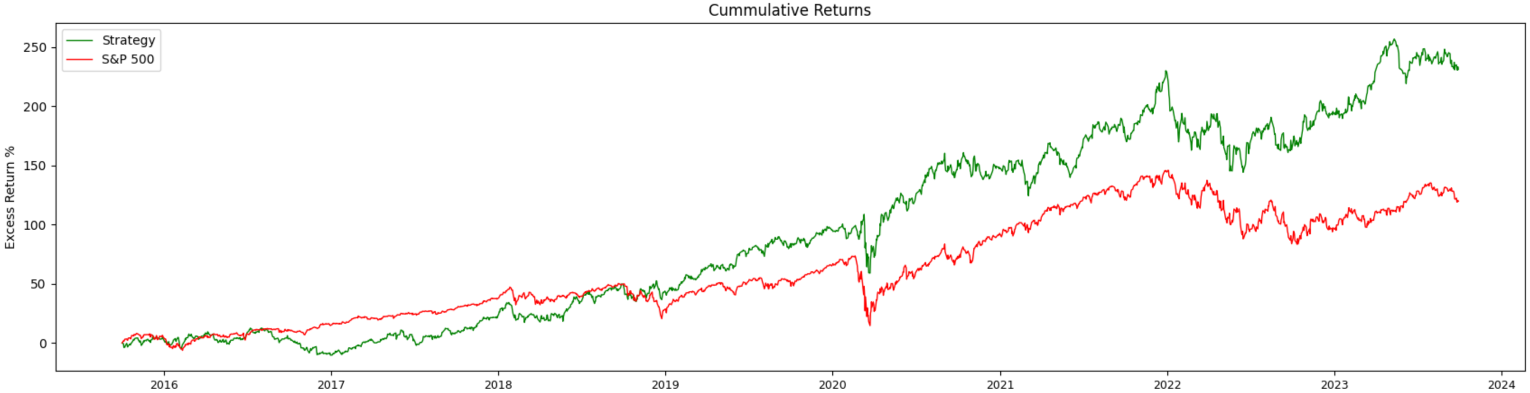
Strategy Backtesting Results



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Sample Covariance Matrix

- Factor model variance-covariance matrix $\Sigma = \beta\Omega_f\beta' + \Psi_\epsilon$
- If invertible, the expected value of its inverse is a biased estimator for the theoretical inverse*.

$$E(S^{-1}) = \frac{T}{T - N - 2}\Sigma^{-1}$$

- The sample covariance can be volatile in the sense that the constructed weights for the beta neutral portfolios may give rise to high turnover rates over time.
- To tackle these issues, we select a set of 50 representative stocks proportional to their industry weights in the S&P 500. We calculate the factors using the subset of 50 stocks.

GICS Sector	Number of Stocks	Percentage
Communication Services	23	5%
Consumer Discretionary	52	10%
Consumer Staples	38	8%
Energy	23	5%
Financials	72	14%
Health Care	65	13%
Industrials	76	15%
Information Technology	64	13%
Materials	29	6%
Real Estate	31	6%
Utilities	30	6%
Total	503	100%

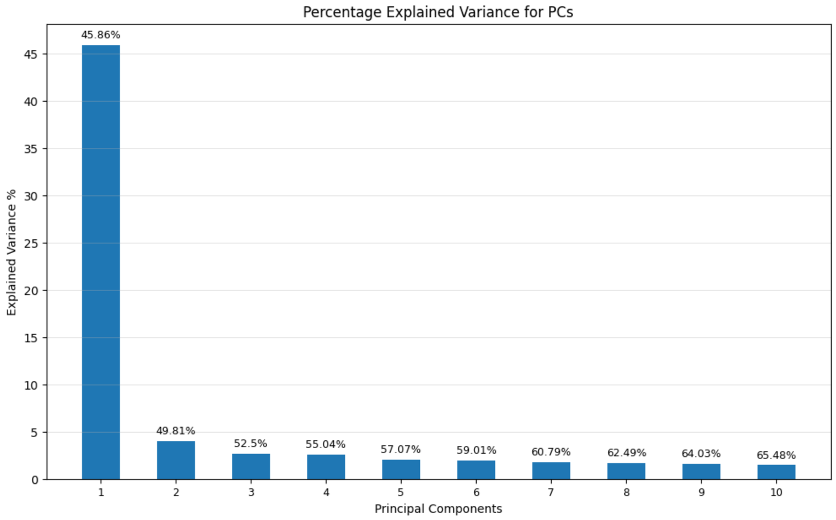
*While the sample covariance S is unbiased for Σ, S^{-1} is highly biased for Σ^{-1}

Principal Component Factors

- For n distinct eigenvalues, we calculate a set of n eigenvectors, ordered by most-to-least explained variance. Transforming the returns matrix by multiplication with the eigenvectors returns the stochastic factors for our model a.k.a principal components.

- We select the first $k = 5$ principal components using PCA decomposition with a cumulative explained variance of 57.07%

$$r_{excess,i} = \alpha_i + \sum_{j=1}^{K} \beta_{ij} f_j + \epsilon_i$$



Factor-Neutral Strategy

- We omit stocks with missing data from our dataset, reducing our universe to 390 stocks. We perform a linear regression for each stock against the stochastic factors to calculate their factor loadings i.e., $\boldsymbol{\beta}$.
- Initializing the portfolio weight vector $\boldsymbol{w_0}$ with equal weights, we optimize the portfolio weights to minimize the portfolio beta exposure subject to a net zero long/short strategy i.e., $\sum_1^N w_i = 0$

$$\underset{\boldsymbol{w}}{\operatorname{argmin}}\left(\sum_{i=1}^{N}\sum_{j=1}^{5} w_i \beta_{ij}\right)^2$$

- We use SciPy's numerical optimizer with a sequential least squares programming optimization method with constraints to calculate the beta-neutral weight vector $\boldsymbol{w}$.

Backtesting

- We perform PCA decomposition on stock returns from 01-October-2003 to 30-September-2015 and select the first 5 principal components as our factors with a cumulative explained variance ratio of 57%.

- We backtest our strategy from 02-October-2015 to 30-September-2023. The betas and portfolio weights are recalibrated monthly by sliding the PCA window forward by 1 month. The portfolio is rebalanced on the first business day of every month.

- We use the daily yield on the 1-year T-bill as the risk-free rate to calculate excess returns

- We assume zero transaction costs, unlimited leverage and that trades are executed immediately at the EOD close price with no slippage. There is also a tracking error with the benchmark used due to the omission of stocks with missing data.

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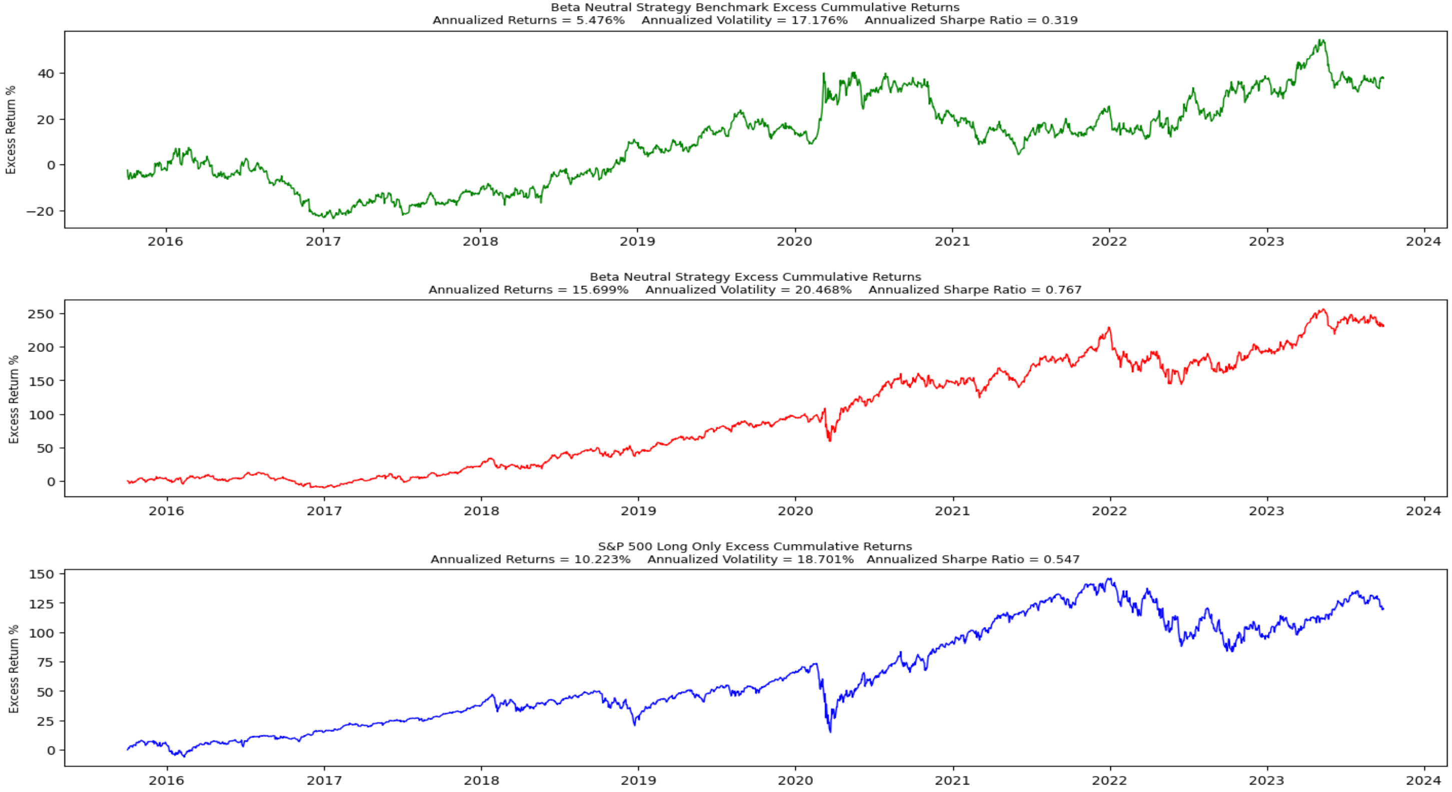
Backtesting



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Appendix

- Jupyter Notebook - [Github Repo]

*The list of S&P 500 stocks is retrieved dynamically from Wikipedia.

*The price dataset is downloaded from Yahoo Finance using an API call within the Jupyter Notebook