Portfolio Strategy Analysis Using PCA and Risk Parity

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Abstract

This study compares portfolio construction strategies, including Equal Weight, Risk Parity (RP), PCA-based weighting, and Diversified Risk Parity (DRP), using historical stock data from the Hong Kong Stock Exchange. The analysis incorporates Principal Component Analysis (PCA) and Risk Parity for better risk diversification and return optimization. Key findings highlight the superior performance of DRP in both risk-adjusted returns and resilience during market fluctuations.

1 Introduction

Portfolio construction aims to optimize returns while managing risk. Traditional approaches like Equal Weight and Risk Parity offer simplicity, while advanced methods such as PCA identify underlying factors influencing returns. This study integrates PCA with Risk Parity to assess portfolio strategies and compare their performance, utilizing data from the Hong Kong Stock Exchange and Hang Seng Index (HSI).

2 Literature Review

2.1 Portfolio Construction Techniques

The foundation of portfolio construction lies in Modern Portfolio Theory (MPT) introduced by Markowitz (1952), which emphasizes the trade-off between risk and return. Subsequent advancements have introduced various strategies to optimize this balance, including Equal Weight and Risk Parity.

2.2 Equal Weight Strategy

The Equal Weight (EW) strategy assigns equal proportions to each asset within a portfolio. While simplistic, EW offers inherent diversification benefits by mitigating the impact of any single asset's performance. Studies such as Hsu and Chen (2005) have demonstrated the effectiveness of EW in reducing unsystematic risk without the need for complex optimization.

2.3 Risk Parity Approach

Risk Parity (RP) allocates portfolio weights based on the inverse of each asset's risk, typically measured by volatility. Maillard, Roncalli, and Teiletche (2010) highlighted that RP ensures balanced risk contributions, potentially leading to more stable portfolio performance compared to traditional mean-variance optimization. RP is particularly advantageous in volatile markets, where risk balance can prevent disproportionate losses.

2.4 Principal Component Analysis in Finance

PCA is a statistical technique used to reduce the dimensionality of data by transforming original variables into a set of uncorrelated principal components. In finance, PCA helps identify latent factors driving asset returns, facilitating more informed investment decisions. Jorion (2003) emphasized PCA's utility in risk management and portfolio construction, where it aids in understanding the underlying drivers of market movements.

2.5 Integration of PCA and Risk Parity

Combining PCA with RP offers a nuanced approach to portfolio construction. By identifying key principal components, investors can align their portfolios with the dominant factors influencing market dynamics, while RP ensures balanced risk exposure. This integration aims to enhance diversification and resilience, particularly in complex and multifaceted markets.

3 Theory

PCA reduces data dimensionality by identifying principal components that explain the most variance in asset returns. Combined with Risk Parity, which balances risk contributions across assets, this methodology aims to create diversified, low-risk portfolios. Detailed derivations and the PCA procedure are provided in the appendix.

4 Results

4.1 Performance Comparison

Portfolio strategies were evaluated using metrics such as total return, annualized volatility, and Beta coefficient. Key results:

- **Equal Weight (EW):** Moderate returns with low volatility, offering broad diversification.
- **Risk Parity (RP):** Reduced volatility by balancing risk contributions, leading to stable performance.
- **PCA-based Strategies (EW-PCA, DRP):** Enhanced returns with controlled risk, with DRP outperforming other strategies by integrating PCA and RP.

4.2 Risk Metrics

- **Beta Analysis:** RP and EW strategies had Beta values close to 1, while PCA-based strategies exhibited lower Betas, indicating reduced sensitivity to market fluctuations.
- **Cumulative Portfolio Value:** DRP consistently demonstrated superior cumulative growth over the analysis period.

5 Conclusion

This study demonstrates that integrating PCA with Risk Parity leads to better diversification and performance. The DRP strategy outperformed traditional methods by achieving higher risk-adjusted returns and reduced market sensitivity. Future work could explore dynamic weighting schemes and expand the analysis to other markets.

6 References

References

[1] Markowitz, H. (1952). *Portfolio Selection. The Journal of Finance*, 7(1), 77-91.

[2] Maillard, S., Roncalli, T., & Teiletche, J. (2010). *The properties of minimum risk factor portfolios. Journal of Banking & Finance*, 34(12), 3162-3182.

[3] Jorion, P. (2003). *Portfolio Optimization with the Black-Litterman Model. Financial Analysts Journal*, 59(5), 36-51.

[4] Yfinance Documentation. `https://pypi.org/project/yfinance/`

A Figures and Tables

Additional figures and performance data can be found here, including detailed plots of eigenvalues, variance, and cumulative returns.

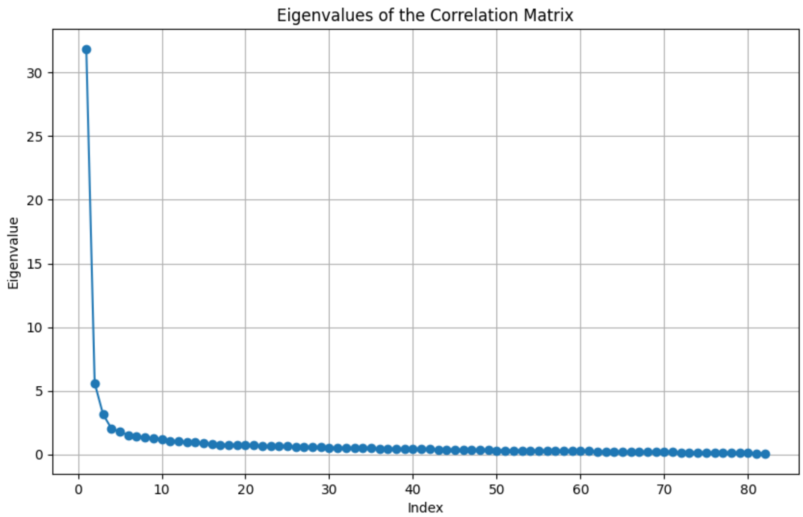

Figure 1: Eigenvalues of the Correlation Matrix

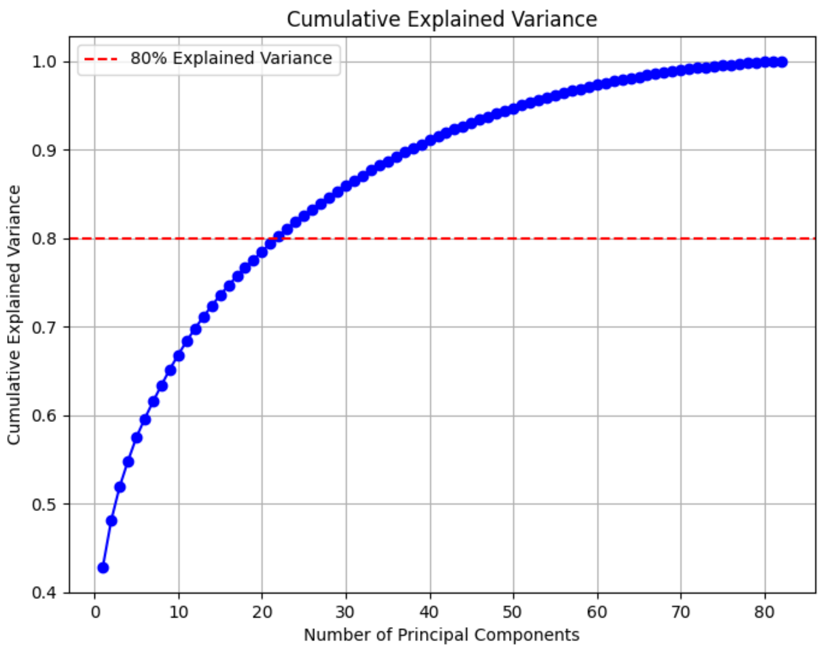

Figure 2: Cumulative Explained Variance

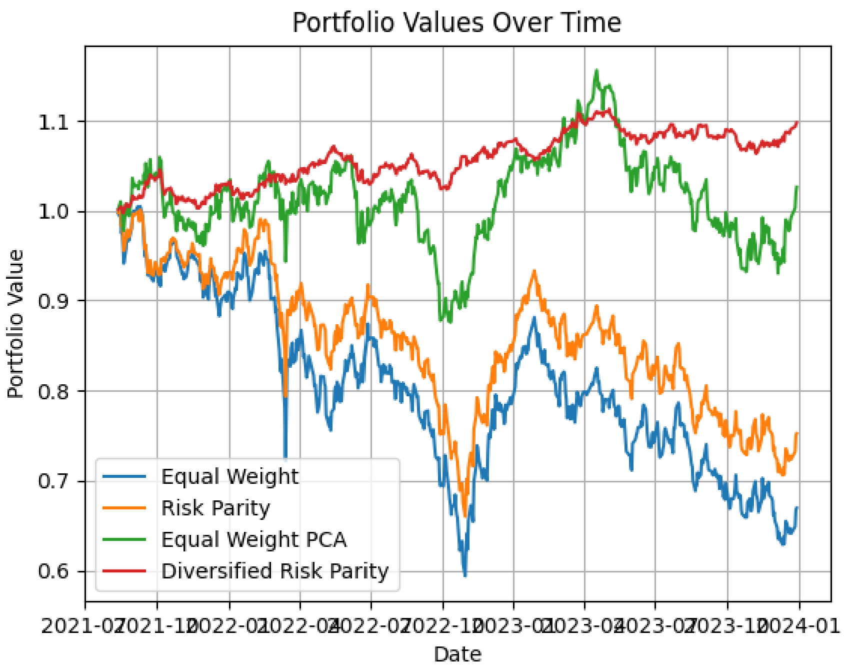

Figure 3: Portfolio Values Over Time