Adaptive PCA-Based Portfolio Construction Using Global Index Strategies (Apr 2024 – Mar 2025)

Rohan Biswas

1. Dataset Overview

The analysis includes 9 real-world indices representing 8 distinct weighting methodologies:

Weighting Scheme	Index Symbol
Market Cap (US)	ĜSPC
Market Cap (India)	N̂SEI
Equal Weighted	RSP
Price Weighted	D̂JI
Fundamental Weighted	PRF
Volatility Weighted	SPLV
Risk Parity Proxy	ACWV
Factor Momentum	MTUM
ESG Weighted	SUSA

2. Summary Statistics

Mean Returns and Volatility (Daily)

Weighting Scheme	Index Symbol	Region	Mean Return	Std Dev
Market Cap	ĜSPC	US	0.000349	0.008796
Market Cap	N̂SEI	India	0.000270	0.009029
Equal Weighted	RSP	US	0.000132	0.007583
Price Weighted	D̂JI	US	0.000169	0.007952
Fundamental Weighted	PRF	US	0.000220	0.007555
Volatility Weighted	SPLV	US	**0.000537**	0.006451
Risk Parity Proxy	ACWV	Global	0.000480	**0.005037**
Factor Weighted (Momentum)	MTUM	US	0.000322	**0.012793**
ESG Weighted	SUSA	US	0.000303	0.008647

Table 1: Real Index Strategies with Mean Daily Returns and Volatility (Apr 2024 - Mar 2025)

SPLV and ACWV showed smooth returns; MTUM had high volatility.

3. Time Series Observations

- Worst log return: **N̂SEI** on June 4, 2024: −6.112%
- Best log return: **MTUM** on Aug 8, 2024: +3.774%

4. Correlation Heatmap Highlights

- Highest correlation: SUSA vs ĜSPC = **0.98**
- PRF vs RSP = 0.97
- Lowest correlation: N̂SEI vs SPLV = **0.04**

5. PCA Findings

Cumulative Explained Variance

PC1: 69.7%, PC1 + PC2: 82.7%, PC1–PC5: $> 97\%$

Interpretations

- **PC1:** Market-wide factor; high in PRF (0.3858), low in NSEI (0.0745)
- **PC2:** Defensive vs Aggressive tilt:
  - Volatility Weighted (SPLV): +0.57
  - Factor Weighted (MTUM): −0.46
- **PC3:** Emerging Market Effect
  - N̂SEI loading: +0.95

6. KMeans Clustering on PCA Loadings

- **Cluster 0:** Price Weighted, Equal Weighted, PRF, SPLV, ACWV - stable core group
- **Cluster 1:** N̂SEI - region-specific outlier
- **Cluster 2:** ĜSPC, MTUM, SUSA - high-beta, thematic tilts

7. Synthetic Factor Portfolios

Correlation with Original Strategies

Portfolio	Positive Correlation	Negative Correlation
PC1 Portfolio	RSP, PRF, ESG, GSPC (0.94–0.95)	-
PC2 Portfolio	SPLV (+0.26)	MTUM (−0.80), ESG (−0.64), GSPC (−0.68)

Interpretation:

- **PC1 Portfolio** exhibits strong alignment with diversified US strategies, including Market Cap, Equal Weighted, Fundamental, ESG, and Price Weighted. It captures the dominant *market beta*.
- **PC2 Portfolio** shows inverse exposure to high-beta or thematic strategies such as Momentum, ESG, and Market Cap US. It positively correlates with Volatility Weighted (SPLV), suggesting a *defensive or hedging tilt*.
- **PC1 and PC2** are moderately negatively correlated (-0.47), reflecting orthogonal exposure and structural diversification.

Cumulative Return Extremes

- PC1: max = 1.5084 (Feb 13), min = 0.9134 (Apr 19)
- PC2: max = 1.2010 (Feb 19), min = 0.9613 (Apr 19)
- PC3: max = 1.0400 (Mar 10), min = 0.8881 (Dec 16)

8. Sharpe Ratio Comparison (Annualized)

Portfolio	Mean Return	Volatility	Sharpe
PC1 Portfolio	0.000869	0.02041	0.6761
PC2 Portfolio	0.000118	0.00981	0.1916
Market Cap (US)	0.000349	0.00879	0.6303

9. Rolling PCA Insights

- PC1 explained variance peaked: **0.7784** on Nov 4, 2024
- Mean rolling variance: 0.7166
- Factor rotation observed: MTUM gain mid-year, SPLV fade late-year

10. Adaptive PCA Portfolio (Regime-aware)

Strategy

Reallocation between PC1 and PC2 portfolios based on rolling PC1 dominance. If PC1 explained variance is high $\rightarrow$ more PC1 exposure; if low $\rightarrow$ shift to PC2.

Performance

Portfolio	Daily Mean	Volatility	Sharpe
Adaptive PCA	**0.001749**	0.01131	**2.455**
PC1 Portfolio	0.000258	0.02190	0.187
PC2 Portfolio	0.000570	0.00986	0.917
Market Cap (US)	0.000031	0.00953	0.052

Conclusion

- Adaptive PCA portfolio delivered high return with low volatility
- Outperformed all static and benchmark strategies in Sharpe ratio
- Validates that tracking latent market structure adaptively is superior to static allocation

Note: All visuals (PCA plots, heatmaps, cumulative returns) are available in the accompanying Jupyter Notebook.