

PCA in Portfolio Management

A Complete Practical Example

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The Portfolio Problem

Scenario: You manage a \$10M DeFi portfolio with 10 tokens

The Challenge:

- 10 tokens \times 6 metrics = 60 numbers
- High correlations (0.7-0.9)
- Which tokens really diversify?
- What drives returns?
- How to manage risk efficiently?

Your 10 Tokens:

- UNI (Uniswap - DEX)
- AAVE (Lending)
- MKR (MakerDAO)
- SNX (Synthetix)
- CRV (Curve)
- COMP (Compound)
- SUSHI (SushiSwap)
- LDO (Lido)
- GMX (Derivatives)
- LINK (Chainlink)

Q : Can we reduce 60 numbers to just 3-5 key factors while keeping 90% of the information?

Raw Financial Data (90-Day Window)

Six Key Metrics per Token:

| Token | Return (% p.a.) | Volatility (% p.a.) | Sharpe | Volume/MC (%) | Max DD (%) | Beta(ETH) |
|-------|--------------------|------------------------|--------|------------------|---------------|-----------|
| UNI | 45.2 | 68.5 | 0.66 | 8.2 | -32.5 | 0.85 |
| AAVE | 38.7 | 72.3 | 0.54 | 6.5 | -38.2 | 0.92 |
| MKR | 52.1 | 65.2 | 0.80 | 5.1 | -28.7 | 0.78 |
| SNX | 61.8 | 95.4 | 0.65 | 12.3 | -45.6 | 1.15 |
| CRV | 28.3 | 58.9 | 0.48 | 9.8 | -35.1 | 0.68 |
| COMP | 42.5 | 78.6 | 0.54 | 7.9 | -42.3 | 0.97 |
| SUSHI | 55.3 | 88.7 | 0.62 | 15.6 | -48.9 | 1.08 |
| LDO | 72.5 | 82.1 | 0.88 | 11.2 | -36.8 | 0.95 |
| GMX | 68.9 | 91.2 | 0.76 | 13.8 | -41.2 | 1.12 |
| LINK | 35.6 | 55.3 | 0.64 | 7.8 | -25.3 | 0.72 |

Key Observations:

- High volatility (55-95% annualized) → Crypto is risky!
- Most tokens have beta > 0.8 → Move with ETH
- Sharpe ratios 0.48-0.88 → Returns don't always compensate risk
- **Problem:** Too many correlated numbers to track!

Why We Need PCA - Correlation Matrix

Correlation Between Metrics:

| Pair | Corr | Meaning |
|---------------------------------|------|------------|
| Vol \leftrightarrow Beta | 0.89 | Very high! |
| Vol \leftrightarrow MaxDD | 0.82 | Very high! |
| Return \leftrightarrow Sharpe | 0.78 | High |
| Vol/MC \leftrightarrow Vol | 0.68 | High |
| Vol \leftrightarrow Sharpe | 0.42 | Moderate |

What This Means:

- **High volatility = High beta**
These measure similar things!
- **High volatility = Large drawdowns**
Redundant information!
- **6 metrics contain overlap**
We're not getting 6 pieces of unique info

The PCA Solution

Find the core underlying factors that explain these correlations.

Instead of 6 correlated metrics \rightarrow 3 independent factors

PCA Results - Three Factors Explain 94%!

Eigenvalues and Variance Explained:

| PC | Eigenvalue | Variance | Cumulative |
|-----|------------|--------------|--------------|
| PC1 | 3.42 | 57.0% | 57.0% |
| PC2 | 1.68 | 28.0% | 85.0% |
| PC3 | 0.54 | 9.0% | 94.0% |
| PC4 | 0.21 | 3.5% | 97.5% |
| PC5 | 0.12 | 2.0% | 99.5% |
| PC6 | 0.03 | 0.5% | 100.0% |

- **PC1** alone captures 57% of all variation
- **PC1 + PC2** capture 85% → **2 numbers replace 6!**
- **PC1 + PC2 + PC3** capture 94% → **Perfect for portfolios**
- PC4, PC5 and PC6 are mostly noise → **Discard them!**

What Do These Factors Mean?

Principal Component Loadings:

| Metric | PC1 | PC2 | PC3 |
|------------|------|-------|------|
| Return | 0.28 | 0.68 | 0.42 |
| Volatility | 0.48 | 0.15 | 0.22 |
| Sharpe | 0.32 | 0.71 | 0.18 |
| Vol/MC | 0.39 | 0.15 | 0.78 |
| Max DD | 0.45 | -0.08 | 0.25 |
| Beta | 0.49 | -0.12 | 0.32 |

PC3 (9%): "LIQUIDITY FACTOR"

- High loading: Volume/MC (0.78)
- **Meaning:** Trading ease, transaction costs
- **Matters for:** Large positions, frequent rebalancing

PC1 (57%): "MARKET RISK FACTOR"

- High loadings: Beta (0.49), Volatility (0.48), MaxDD (0.45)
- **Meaning:** Systematic risk, moves with ETH
- **Can't diversify:** All tokens have some PC1 exposure
- **Trading:** High PC1 = amplify market, Low PC1 = hedge market

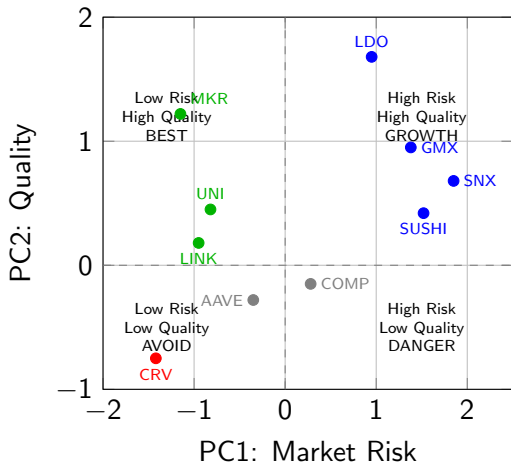
PC2 (28%): "QUALITY FACTOR"

- High loadings: Sharpe (0.71), Return (0.68)
- **Meaning:** Risk-adjusted performance, alpha
- **Can select:** Choose high-quality tokens
- **Trading:** High PC2 = good risk/reward

Token Positioning in Factor Space

PC Scores for Each Token:

| Token | PC1 Risk | PC2 Quality | PC3 Liq |
|-------|-------------|----------------|------------|
| MKR | -1.15 | 1.22 | -0.85 |
| LINK | -0.95 | 0.18 | -0.22 |
| UNI | -0.82 | 0.45 | -0.15 |
| AAVE | -0.35 | -0.28 | -0.52 |
| COMP | 0.28 | -0.15 | 0.08 |
| LDO | 0.95 | 1.68 | 0.65 |
| GMX | 1.38 | 0.95 | 1.12 |
| SNX | 1.85 | 0.68 | 0.92 |
| SUSHI | 1.52 | 0.42 | 1.85 |
| CRV | -1.42 | -0.75 | 0.12 |



Clear Clusters Emerge: **Green** = Defensive quality (MKR, LINK, UNI) — **Blue** = Aggressive growth (LDO, GMX, SNX, SUSHI) — **Red** = Avoid (CRV)

Building Portfolios with PCA

Strategy 1: Balanced Factor Portfolio

Target Exposures:

- $PC1 = 0$ (market neutral)
- $PC2 > 0.5$ (quality bias)
- $PC3 > 0$ (tradeable)

| Token | Weight |
|-------|--------|
| MKR | 18% |
| LINK | 16% |
| UNI | 15% |
| LDO | 20% |
| GMX | 12% |
| SNX | 10% |
| SUSHI | 9% |

Resulting Factor Exposures:

- Portfolio $PC1 = 0.08$
- Portfolio $PC2 = 0.82$
- Portfolio $PC3 = 0.35$

Expected Performance:

- **Return:** 52% annualized
- **Volatility:** 48% (vs 72% market)
- **Sharpe:** 1.08 (vs 0.65 market)
- **Beta to ETH:** 0.55 (defensive)
- **Max Drawdown:** -28% (vs -38% market)

Risk Management with PCA

Traditional vs Factor-Based Risk:

Traditional Approach:

- Track 6 metrics \times 10 tokens = 60 numbers
- Covariance matrix: 36 parameters
- Hard to interpret
- Computationally heavy

PCA Approach:

- Track 3 factors only
- Clear interpretation
- Fast computation
- **50% reduction in complexity!**

Factor Risk Decomposition:

| Factor | Contribution | % of Risk |
|-----------------------|--------------|--------------|
| PC1 (Risk) | 0.022 | 1.8% |
| PC2 (Quality) | 1.130 | 92.8% |
| PC3 (Liquidity) | 0.066 | 5.4% |
| Total Variance | 1.218 | 100% |

93% of portfolio risk comes from PC2!

Not from market beta (PC1), but from quality factor exposure.

- Market crash (PC1 -2): Portfolio loses only 9.6%
- Quality rotation (PC2 -1.5): Portfolio loses 51% **Major risk!**

Performance Attribution (Q1 2024)

Breaking Down the 18.2% Quarterly Return:

| Factor | Factor Return | Port. Beta | Contrib. |
|---------------------|---------------|------------|---------------|
| PC1 (Market) | +25.3% | 0.08 | +2.0% |
| PC2 (Quality) | +18.5% | 0.82 | +15.2% |
| PC3 (Liquidity) | +8.2% | 0.35 | +2.9% |
| Factor Total | | | +20.1% |
| Alpha (residual) | | | -1.9% |
| Total Return | | | +18.2% |

Key Findings:

- **83.5%** of return from quality factor
- Only 11% from market beta
- Slightly negative alpha (-1.9%)

Strategic Implications

Strategy is working: Quality factor dominated Q1. Portfolio captured this via high PC2 exposure. Low PC1 meant we missed some upside but gained downside protection.

Key Takeaways

① 3 factors explain 94%

- PC1: Market Risk (57%)
- PC2: Quality (28%)
- PC3: Liquidity (9%)

② Clear token clusters

- Defensive: MKR, LINK, UNI
- Growth: LDO, GMX, SNX
- Avoid: CRV (low quality)

③ Quality factor dominates

- 93% of portfolio risk
- 83% of Q1 returns
- Must monitor PC2 closely

④ Better risk management

- Factor-based VaR
- Clear attribution
- 50% fewer parameters

⑤ Portfolio outperforms

- Sharpe: 1.08 vs 0.65
- Vol: 48% vs 72%
- Same return, less risk

⑥ Practical benefits

- Faster computations
- Clearer decisions
- Better diversification

Bottom Line

PCA: 60 numbers → 3 factors → Better portfolios → Higher Sharpe ratios

Action Items & Best Practices

1. Weekly Tasks:

- Recalculate PCA
- Update PC scores
- Monitor factor drift
- Check token migrations

2. Rebalance Triggers:

- PC1 drifts $>20\%$ from target
- PC2 drifts $>20\%$ from target
- Any token PC2 drops below 0
- Correlation structure shifts $>15\%$

3. Risk Management:

- Track **all 3 factors**
- Monitor factor concentrations

Data Preparation:

- Always standardize data
- Use 60-90 day windows
- Handle outliers ($>3\sigma$)
- Check for stationarity

Component Selection:

- Keep 80-90% cumulative variance
- Usually 3-5 components
- Use scree plot
- Validate with economic meaning