Riskfolio-Lib

Quantitative Strategic Asset Allocation with Python

Dany Cajas - February 2026

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How asset managers build a Portfolio?

Asset managers have a wide universe of assets and models to choose:

- **Cash** → Cash; T-bills, etc.
- **Fixed Income** → Gov. Bonds; Corp. Bonds, etc.
- **Equities** → Stocks; ETFs
- **Commodities** → Oil; Gold; Wheat, etc.
- **Alternatives** → Hedge Funds; Private Equity; Real State, etc.

How to find the best combination of assets?

Heuristics

- 60 Equity / 40 Fixed Income
- 1/N Portfolio
- 100 - age in Equities
- Endowment model

Quant Approach

- Portfolio Optimization

Riskfolio-Lib

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What is Portfolio Optimization?

Portfolio optimization is the process to select the best possible combination of assets according to a set of desired objectives and constraints using mathematical techniques.

Advantages	Disadvantages
Diversification, reduce of idiosyncratic risk.	Risk of over-diversification, too many assets increase cost of rebalancing.
Lead to more efficient portfolios in a risk-return sense.	More appropriate for frictionless markets and liquid assets.
Allows to build custom portfolios designed to meet investor's needs.	Complex mathematical models. Some models are hard to implement and solve.

Riskfolio-Lib

Riskfolio-Lib is a library for portfolio optimization in Python made in Peru 🇵🇪. It has 3,781 Github ⭐ and more than 1.2M downloads. It is built on top of CVXPY and closely integrated with Pandas data structures. I started its development in 2018 with CVXPY 0.4 and the first version was released in March 2, 2020.

It allows users to solve two types of portfolio optimization models:

- Convex Portfolio Optimization.
- Machine Learning Asset Allocation (based on hierarchical clustering algorithms).

Convex Portfolio Optimization

Risk-Return Trade Off

Risk Minimization

$$
\begin{aligned}
\min_{x} \quad & \phi_0(x) \\
\text{s.t.} \quad & \phi_i(x) \leq \overline{\phi}_i, \;\; i = 1, \ldots, m \\
& x \in \mathcal{X}
\end{aligned}
$$

Return Maximization

$$
\begin{aligned}
\max_{x} \quad & R(x) \\
\text{s.t.} \quad & \phi_i(x) \leq \overline{\phi}_i, \;\; i = 0, \ldots, m \\
& x \in \mathcal{X}
\end{aligned}
$$

Utility Maximization

$$
\begin{aligned}
\max_{x} \quad & R(x) - \lambda \phi_0(x) \\
\text{s.t.} \quad & \phi_i(x) \leq \overline{\phi}_i, \;\; i = 1, \ldots, m \\
& x \in \mathcal{X}
\end{aligned}
$$

Return/Risk Maximization

$$
\begin{aligned}
\max_{x} \quad & \frac{R(x)}{\phi_0(x)} \\
\text{s.t.} \quad & \phi_i(x) \leq \overline{\phi}_i, \;\; i = 1, \ldots, m \\
& x \in \mathcal{X}
\end{aligned}
$$

Risk Parity

Least Squares Approach

$$
\begin{aligned}
\min_{x} \quad & \sum_{i=1}^{n} \left(\frac{x_i (\Sigma x)_i}{x^T \Sigma x} - \mathbf{b}_i \right)^2 \\
\text{s.t.} \quad & \mathbf{1}' x = 1 \\
& x \geq 0
\end{aligned}
$$

Risk Budgeting Approach

$$
\begin{aligned}
\min_{y, t} \quad & \phi(y) \\
\text{s.t.} \quad & \mathbf{b}' \ln(y) \geq c \\
& \mathbf{1}' y = t \\
& y, t \geq 0
\end{aligned}
$$

Semidefinite Approach

$$
\begin{aligned}
\min_{x, X} \quad & \text{Tr}(\Sigma X) \\
\text{s.t.} \quad & \begin{bmatrix} X & x \\ x' & 1 \end{bmatrix} \succeq 0 \\
& A \, \text{diag}\, (\Sigma X) \leq \mathbf{b} \, \text{Tr}(\Sigma X) \\
& X \in \mathbf{S}^n \\
& x \in \mathcal{X}
\end{aligned}
$$

Convex Portfolio Optimization

Worst Case Optimization

Robust Variance Minimization

$$\begin{aligned} \min_{x} \quad & \max_{\Sigma \in U_{\Sigma}} x'\Sigma x \\ \text{s.t.} \quad & x \in \mathcal{X} \end{aligned}$$

Robust Return Maximization

$$\begin{aligned} \max_{x} \quad & \min_{\mu \in U_{\mu}} \mu' x \\ \text{s.t.} \quad & x \in \mathcal{X} \end{aligned}$$

Robust Utility Maximization

$$\begin{aligned} \max_{x} \quad & \min_{\mu \in U_{\mu}} \mu' x - \lambda \max_{\Sigma \in U_{\Sigma}} x'\Sigma x \\ \text{s.t.} \quad & x \in \mathcal{X} \end{aligned}$$

Robust Return/Standard Deviation Maximization

$$\begin{aligned} \max_{x} \quad & \frac{\displaystyle\min_{\mu \in U_{\mu}} \mu' x - r_f}{\displaystyle\max_{\Sigma \in U_{\Sigma}} \sqrt{x'\Sigma x}} \\ \text{s.t.} \quad & x \in \mathcal{X} \end{aligned}$$

Mean Variance with Factor Risk Contribution Constraints

Semidefinite Approach

$$\begin{aligned} \min_{x_f, X_F} \quad & \text{Tr}\left(\bar{\Sigma} X_F\right) \\ \text{s.t.} \quad & \begin{bmatrix} X_F & x_F \\ x_F' & 1 \end{bmatrix} \succeq 0 \\ & \bar{\Sigma} = \left((B')^{+}\right)' \Sigma (B')^{+} \\ & x = (B')^{+} x_F \\ & \text{Adiag}\left(\bar{\Sigma} X_F\right) \leq b \, \text{Tr}\left(\bar{\Sigma} W_F\right) \\ & X_F \in \mathbf{S}^{m} \\ & x \in \mathcal{X} \end{aligned}$$

Ordered Weighted Average

Risk Minimization

$$\begin{aligned} \min_{x} \quad & \sum_{i=1}^{T} w_{[i]} y_{[i]} \\ \text{s.t.} \quad & y = rx \\ & R(x) \geq \bar{\mu} \\ & x \in \mathcal{X} \end{aligned}$$

Convex Portfolio Optimization

Risk Measure	LP	QP	SOCP	SDP	EXP	POW
Variance (MV)			X	X*		
Mean Absolute Deviation (MAD)	X					
Gini Mean Difference (GMD)						X**
Semi Variance (MSV)			X			
Kurtosis (KT)				X		
Semi Kurtosis (SKT)				X		
First Lower Partial Moment (FLPM)	X					
Second Lower Partial Moment (SLPM)			X			
Conditional Value at Risk (CVaR)	X					
Tail Gini (TG)						X**
Entropic Value at Risk (EVaR)					X**	
Relativistic Value at Risk (RLVaR)						X**

Risk Measure	LP	QP	SOCP	SDP	EXP	POW
Worst Realization (WR)	X					
CVaR Range (CVRG)	X					
Tail Gini Range (TGRG)						X**
EVaR Range (EVRG)					X**	
RLVaR Range (RVRG)						X**
Range (RG)	X					
Average Drawdown (ADD)	X					
Ulcer Index (UCI)			X			
Conditional Drawdown at Risk (CDaR)	X					
Entropic Drawdown at Risk (EDaR)					X**	
Relativistic Drawdown at Risk (RLDaR)						X**
Maximum Drawdown (MDD)	X					

(*) When SDP graph theory constraints or risk contribution constraints are included. In the case integer programming graph theory constraints are included, the model assume the SOCP formulation.

(**) For these models is highly recommended to use MOSEK as solver, due to in some cases CLARABEL cannot find a solution and SCS takes too much time to solve them.

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Convex Portfolio Optimization

In addition convex optimization allows Riskfolio-Lib to incorporate to incorporate additional features such as:

- Use logarithmic returns instead of arithmetic returns.
- Include constraints on asset classes.
- Include tracking error constraints.
- Create long-short portfolios.
- Add constraints on risk measures, among other investor's needs.

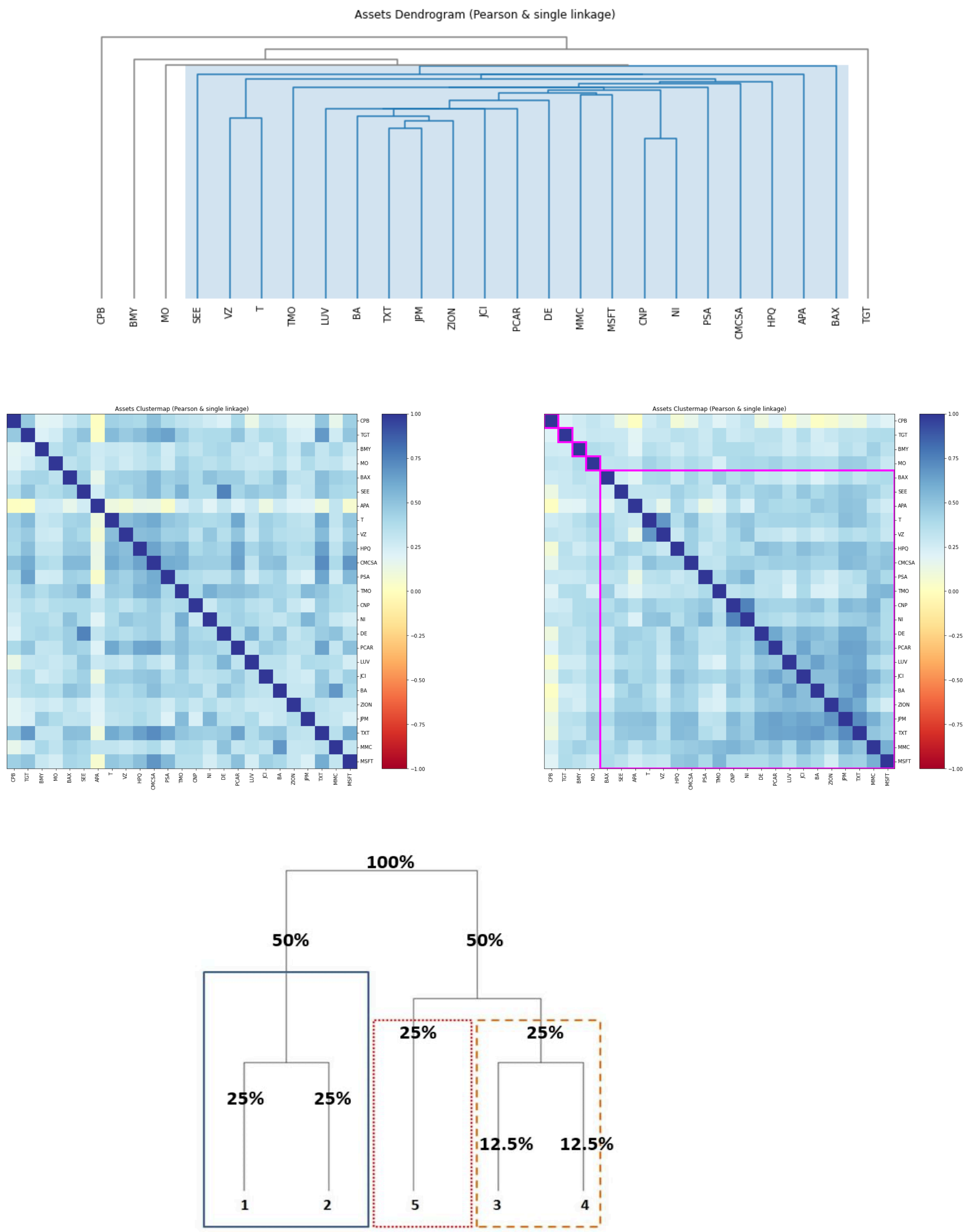
Integer Optimization Constraints

For some special cases, convex optimization is not enough. Integer optimization allows Riskfolio-Lib to incorporate special constraints such as:

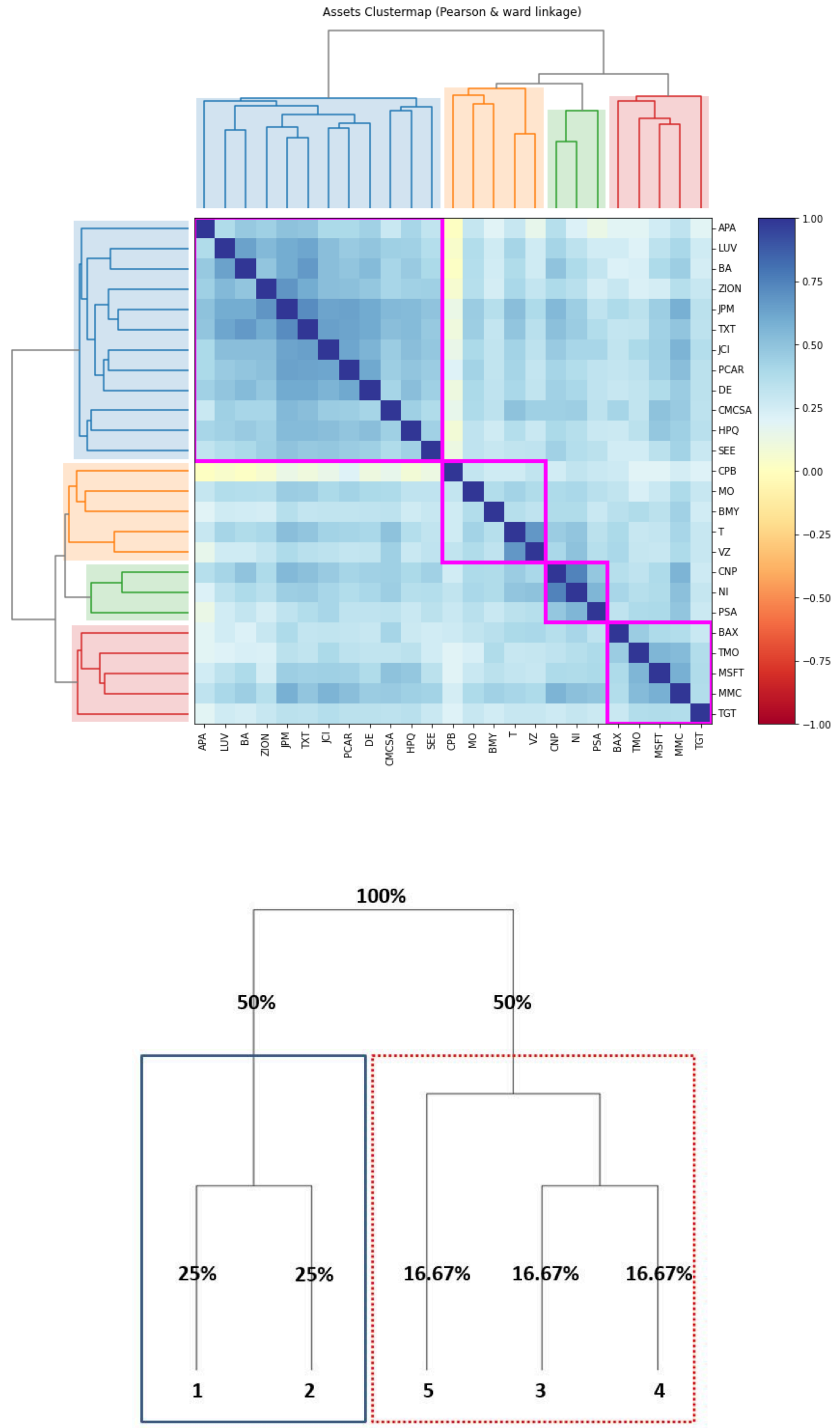
- Cardinality constraints on assets.
- Cardinality constraints on sets or asset classes.
- Mutually exclusive constraints.
- Join Investment Constraints.
- Neighborhood constraints and clusters constraints.

Machine Learning Asset Allocation

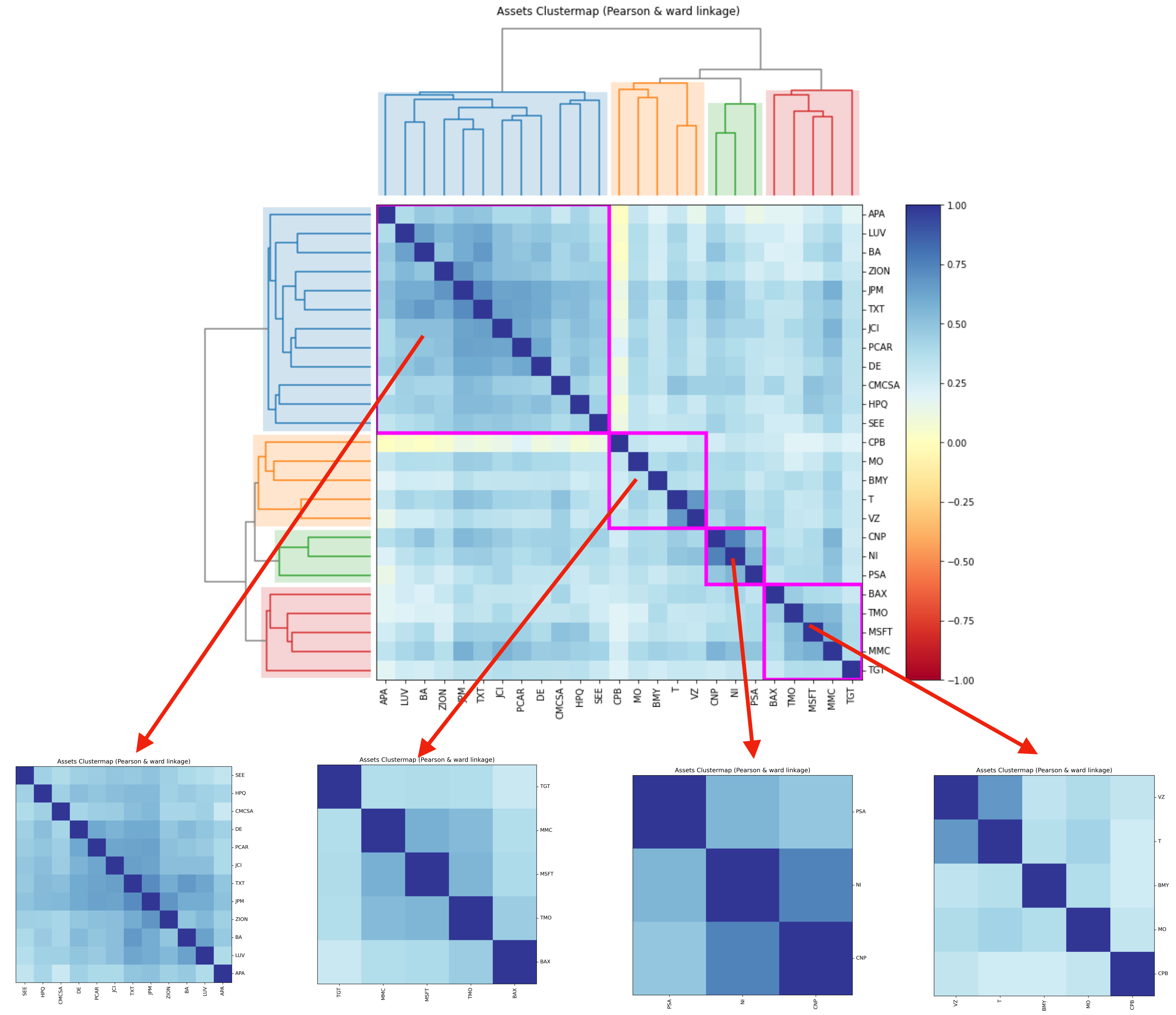
Hierarchical Risk Parity



Hierarchical Equal Risk Contribution



Nested Clustered Optimization



Intra-Cluster Asset Allocation

$\min_{x_{C_1}} \Phi(x_{C_1})$ $\min_{x_{C_2}} \Phi(x_{C_2})$ $\min_{x_{C_3}} \Phi(x_{C_3})$ $\min_{x_{C_4}} \Phi(x_{C_4})$

Inter-Cluster Asset Allocation

$$\min_{[C_1, C_2, C_3, C_4]} \Phi([C_1, C_2, C_3, C_4])$$

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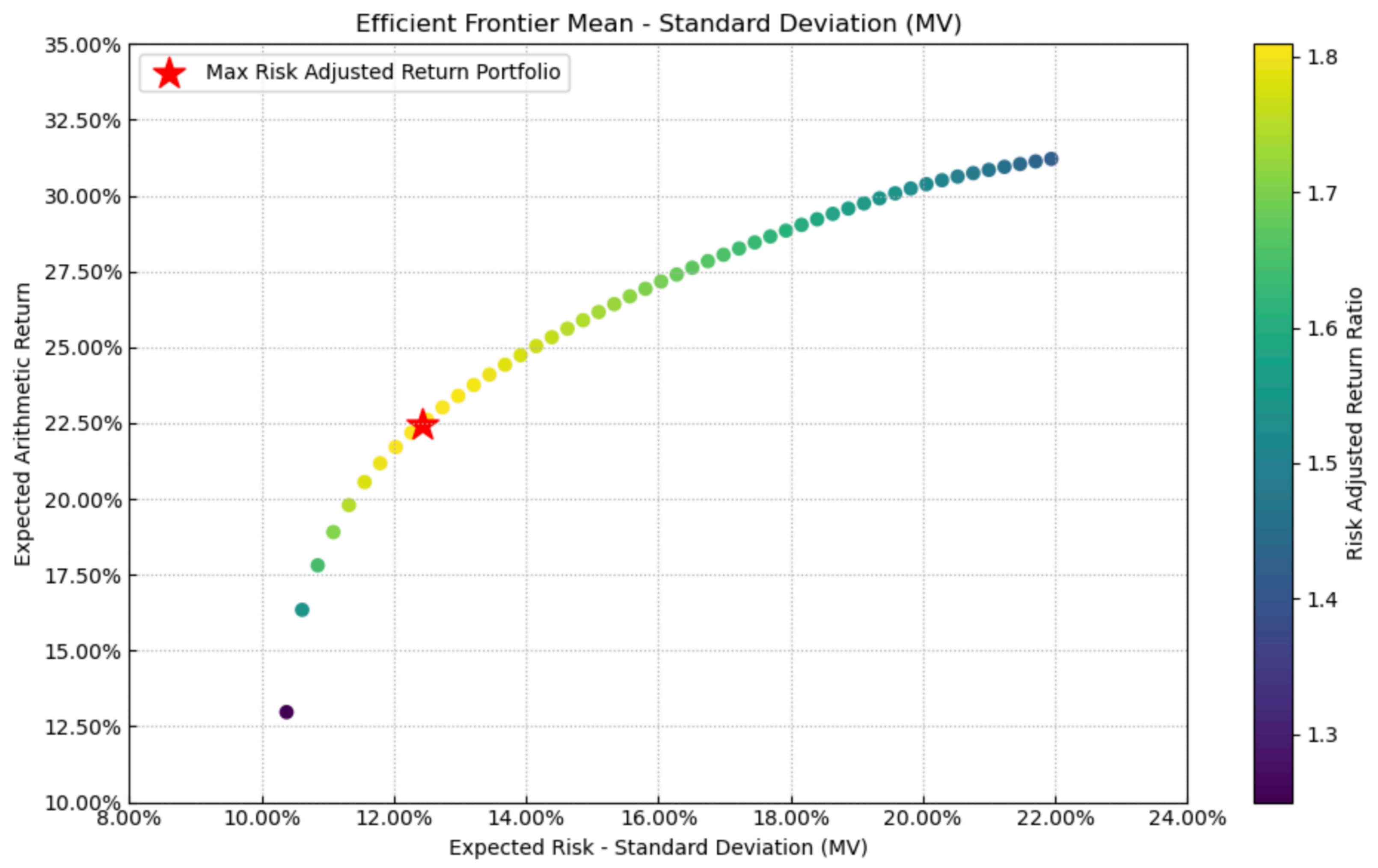
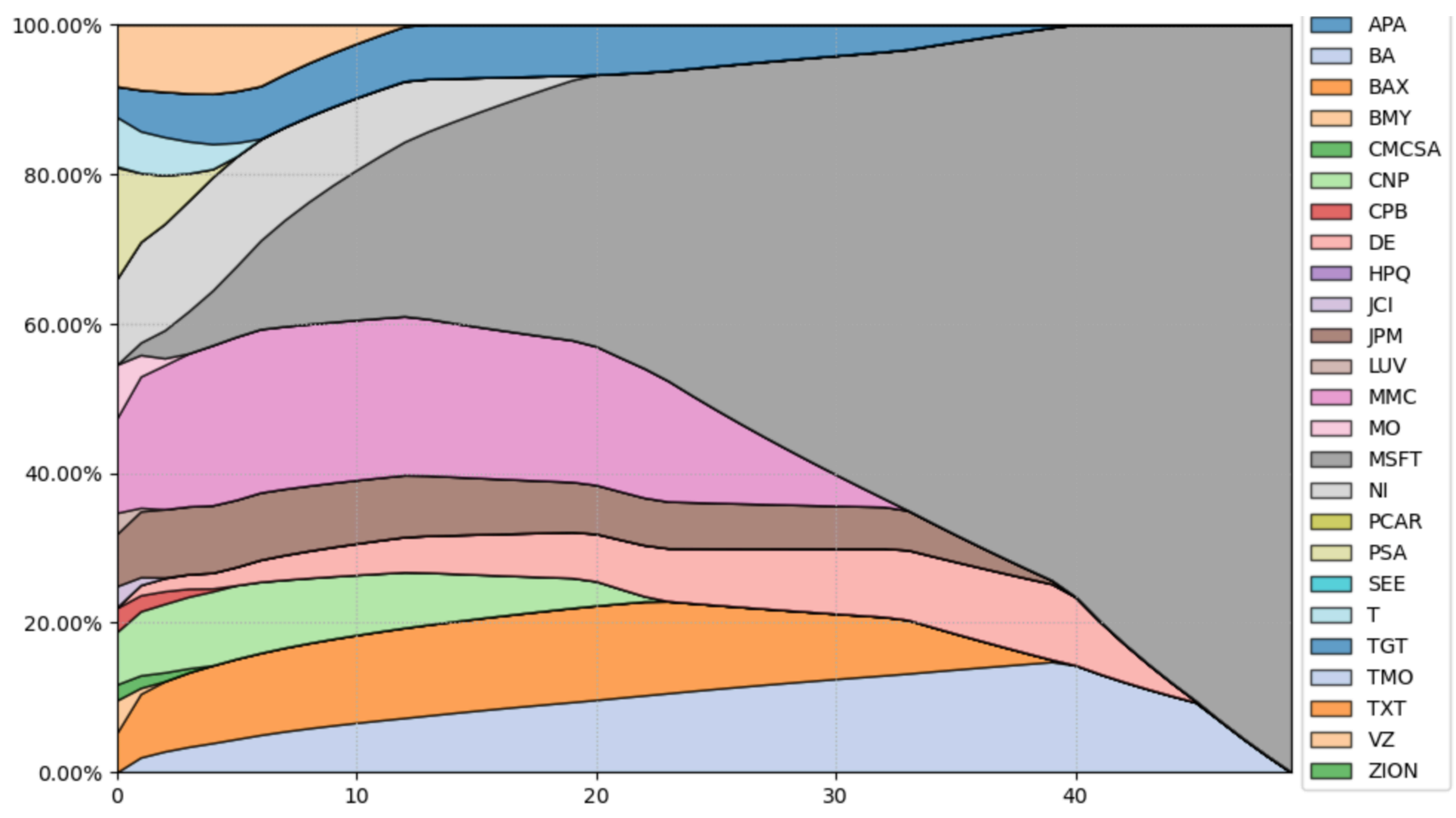
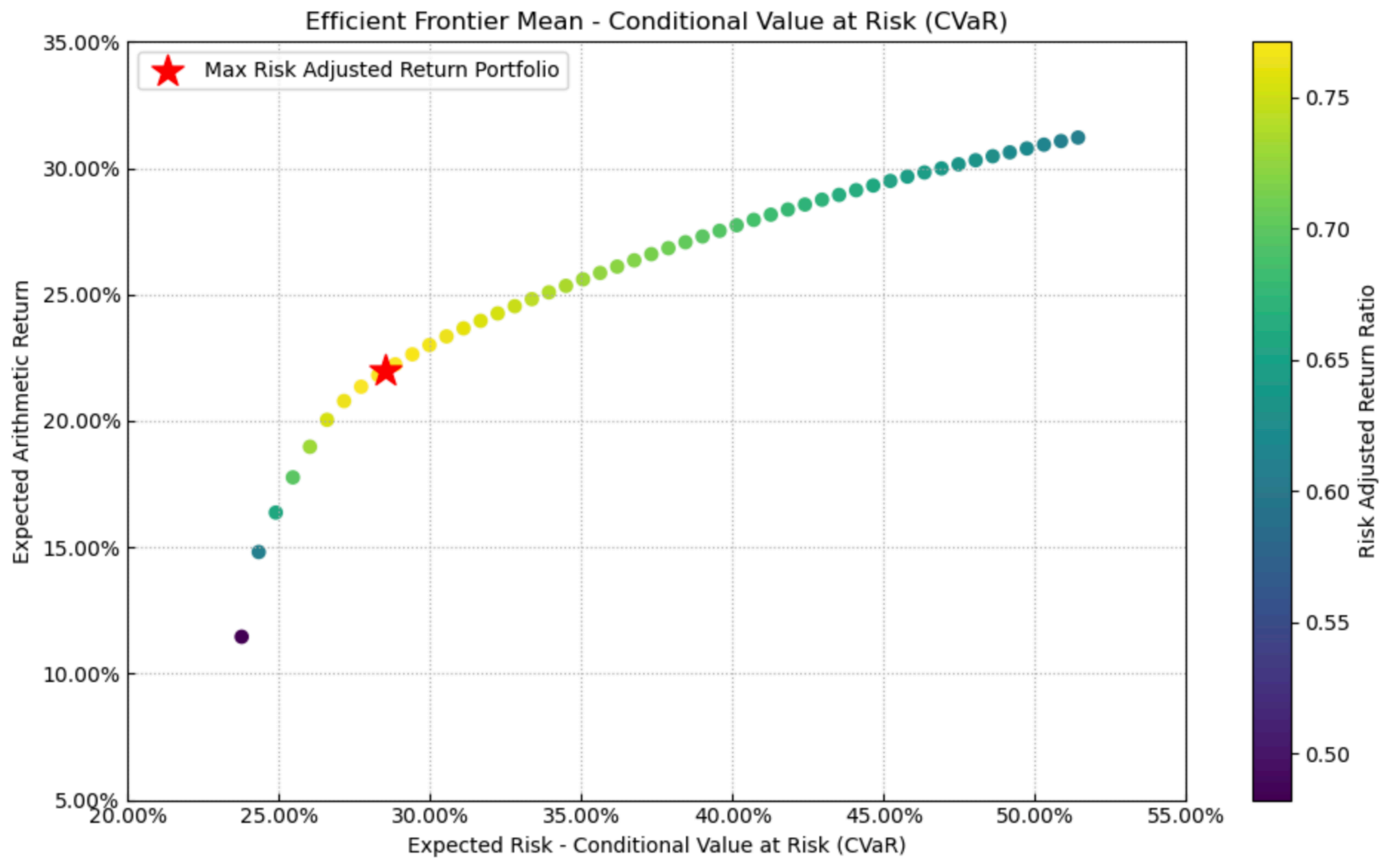
More Riskfolio-Lib Features

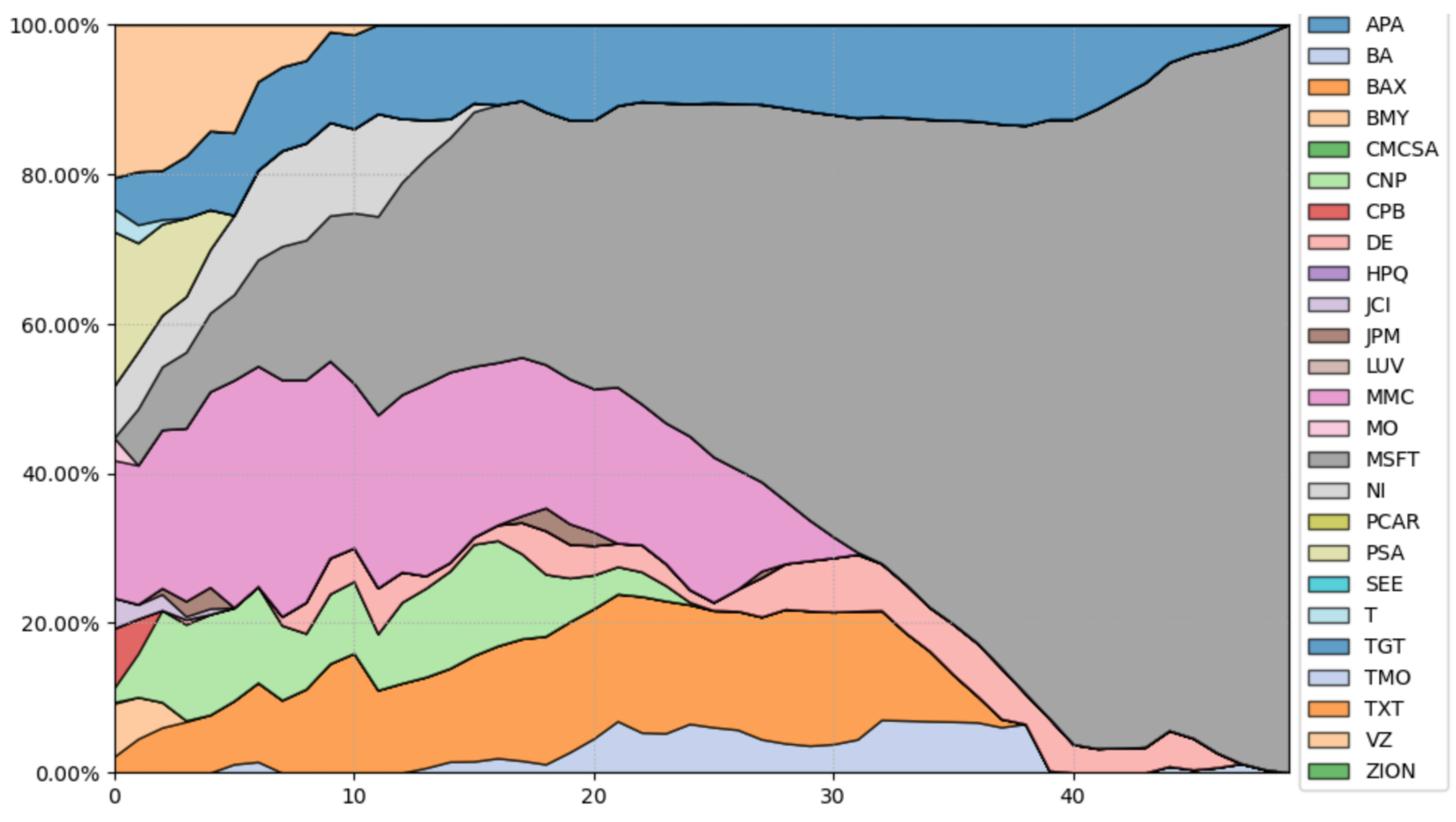
Efficient Frontier Mean-Standard Deviation





Efficient Frontier Mean-CVaR





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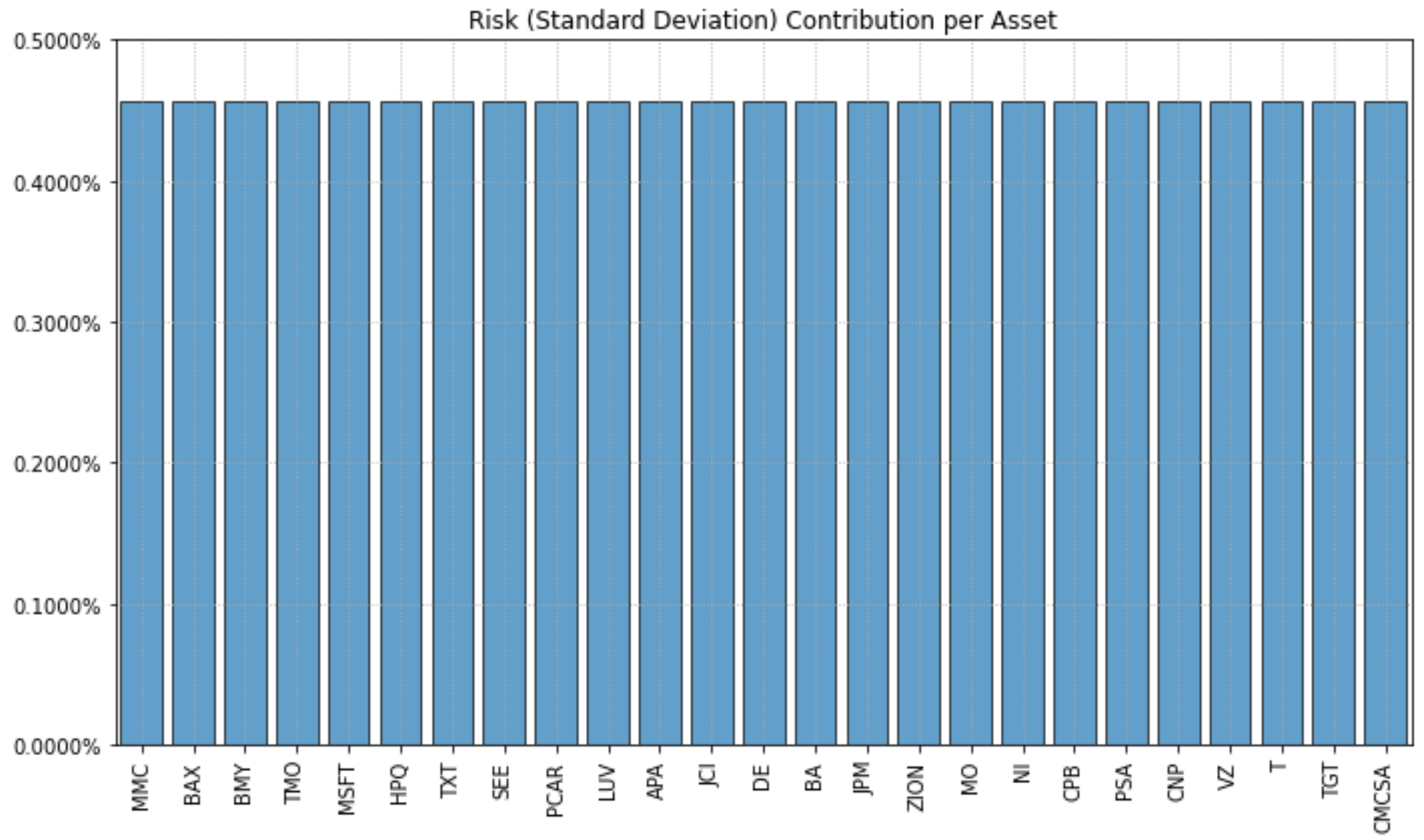
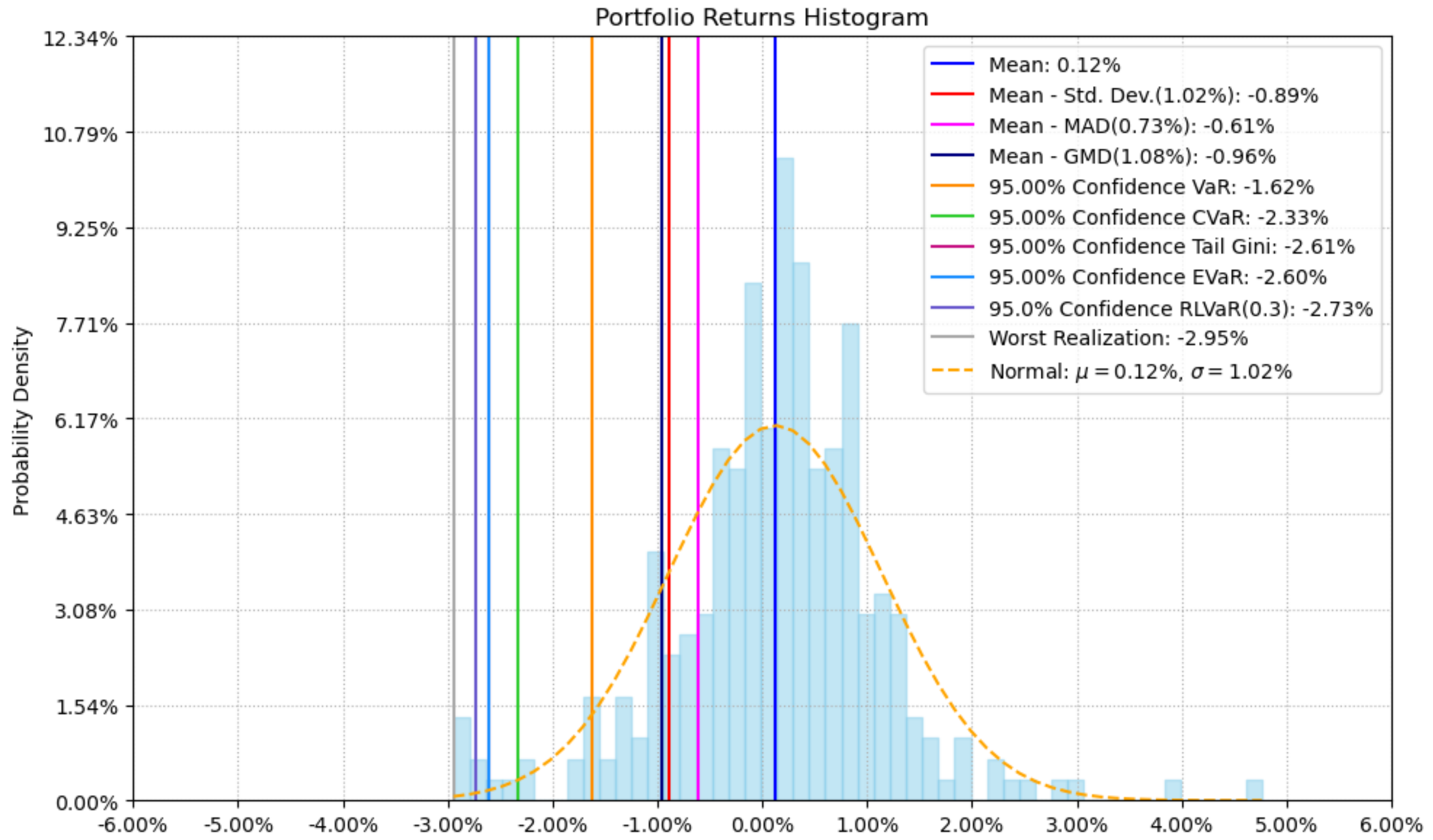
More Riskfolio-Lib Features

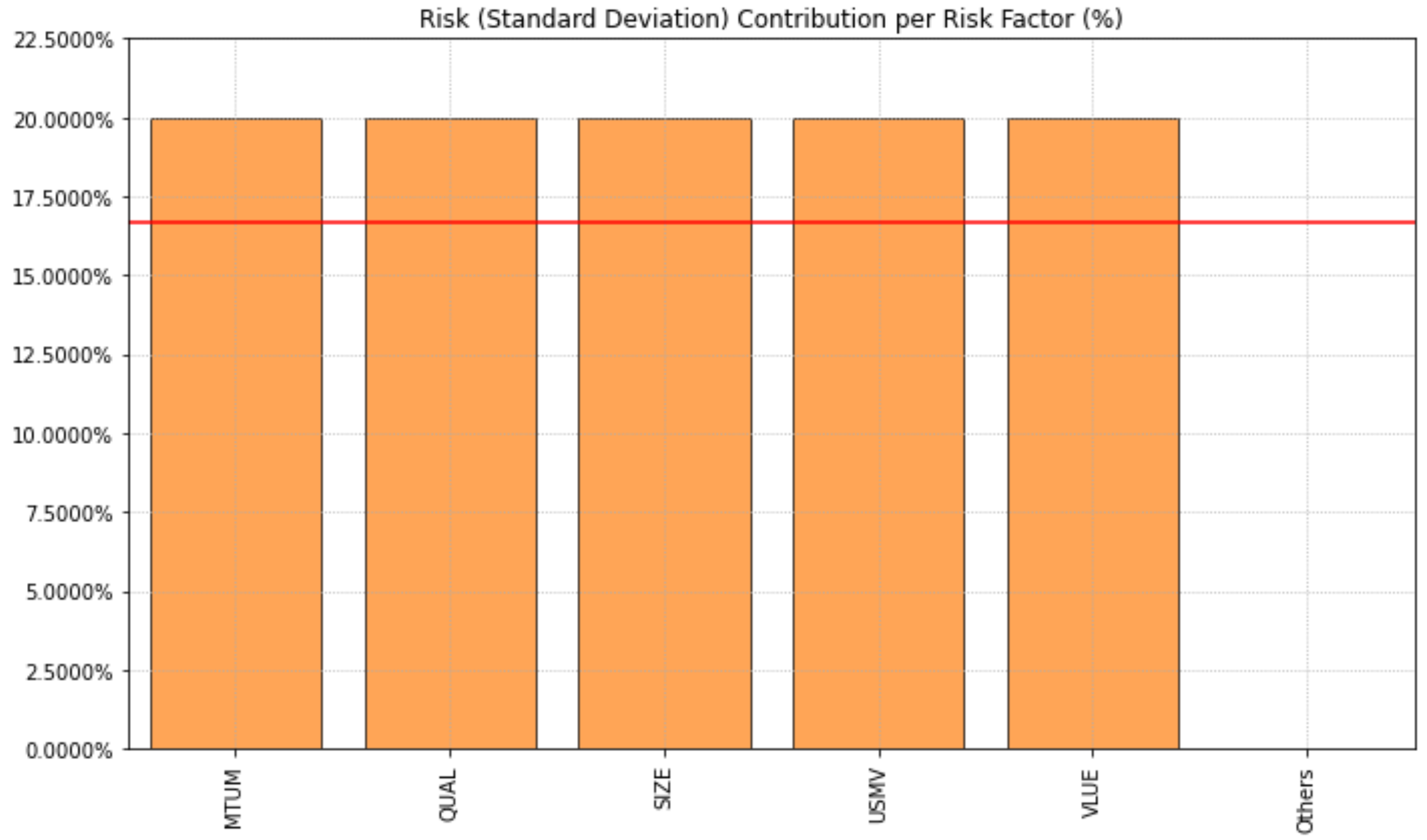
Risk Contribution per Asset



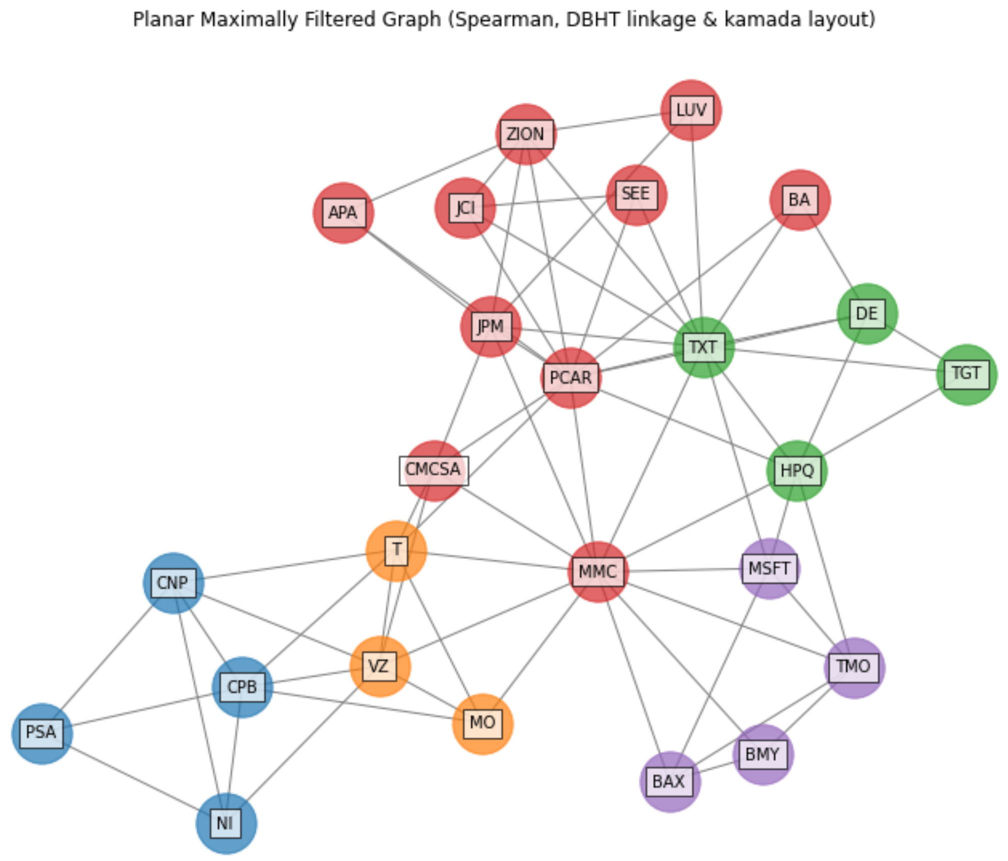
Portfolio Return's Histogram



Risk Contribution per Risk Factor



Assets Cluster's Network



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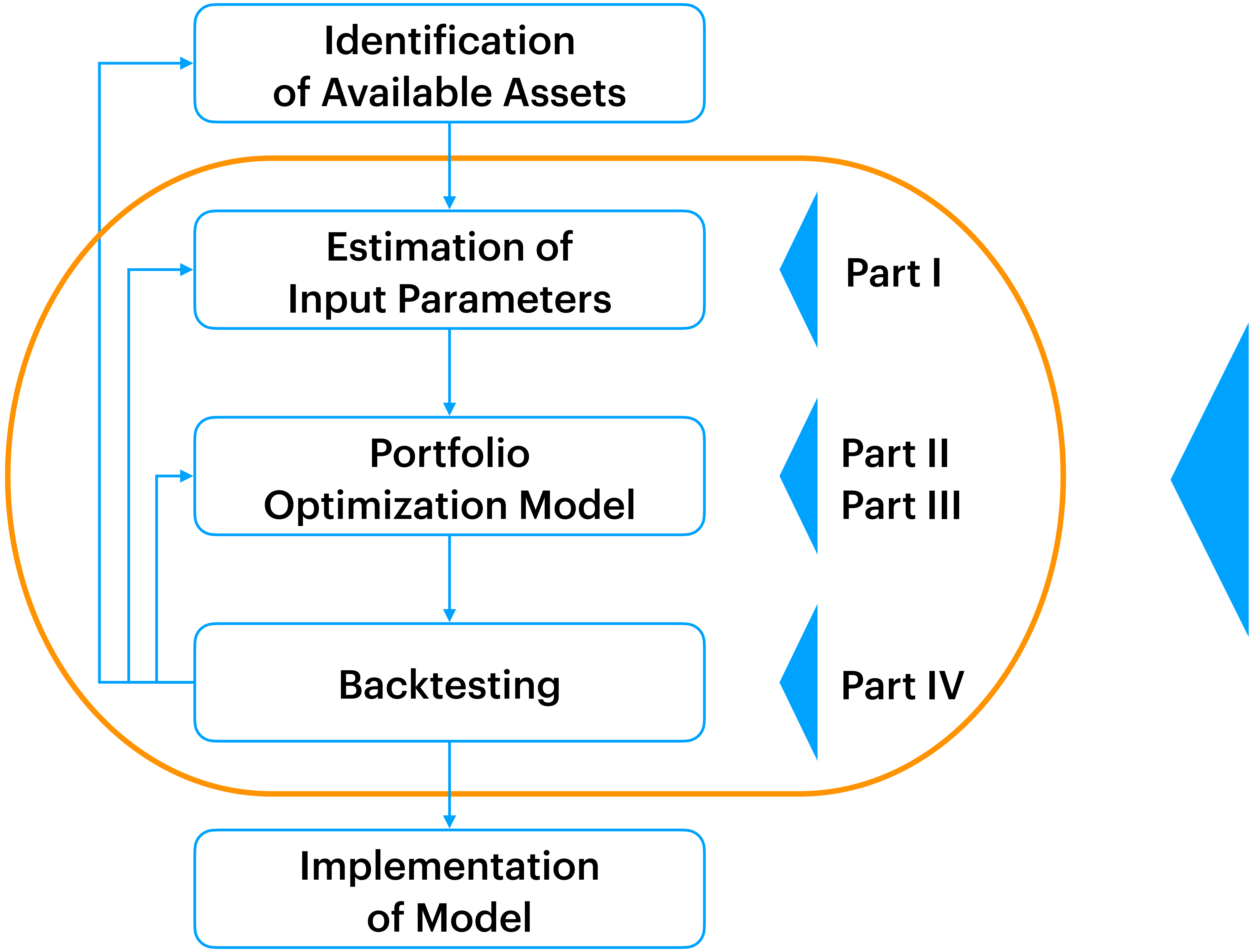
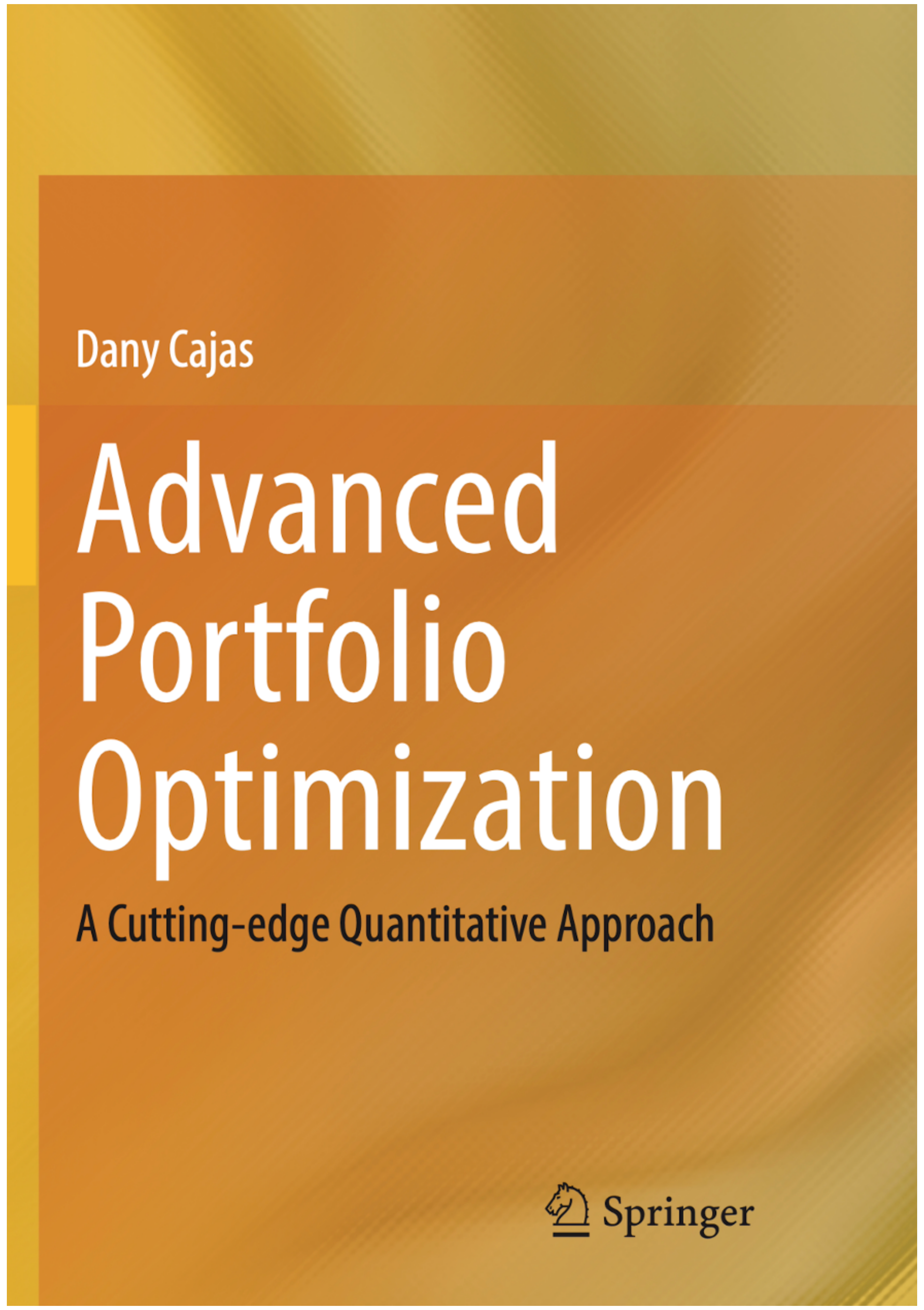
Riskfolio-Lib Links

- Source code is available at https://github.com/dcajasn/Riskfolio-Lib
- Documentation is available at https://riskfolio-lib.readthedocs.io/
- Examples are available at https://riskfolio-lib.readthedocs.io/en/latest/examples.html
- Pypi page for installation is available at https://pypi.org/project/Riskfolio-Lib/
- Support this project (Donations):
  - https://github.com/sponsors/dcajasn
  - https://ko-fi.com/riskfolio

Portfolio Optimization Process





[Book Link]

Riskfolio-Lib Tutorial

Classic Mean Risk Optimization

1. Downloading the data:

```
[ ]: import numpy as np
import pandas as pd
import yfinance as yf
import warnings

warnings.filterwarnings("ignore")
pd.options.display.float_format = '{:.4%}'.format

# Date range
start = '2020-01-01'
end = '2025-12-30'

# Tickers of assets
asset_classes = pd.read_excel('asset_classes.xlsx')
asset_classes = asset_classes.sort_values(by=['Assets'])

assets = asset_classes['Assets'].tolist()
assets.sort()

# Downloading data
data = yf.download(assets, start = start, end = end, auto_adjust=False)
data = data.loc[:,('Adj Close', slice(None))]
data.columns = assets
```

Thanks

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