Contemporary Portfolio Optimization Modeling

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Contents

Portfolio Optimization

- General outline and problem formulation.
- Use Cases: Strategic Asset Allocation, (Really) Smart Beta, Trading Strategy Selection

Portfolio Optimization Modeling with R

- An overview of various approaches and packages

A Contemporary Portfolio Optimization Modeling approach (AML)

Portfolio Optimization

General outline and problem formulation

Consider a set of underlying assets **A** (various asset classes)

We want to compute an optimal investment strategy **x**

Ground-breaking: H. Markowitz seminal work in 1952 (Mean-Variance)

```
Minimize Variance(x)
Subject to Mean(x) ≥ mu
```

Issue: Only the Covariance matrix of the assets under consideration as well as a vector of expected returns is used as input → severe loss of information, difficult to estimate.

Stochastic Portfolio Optimization

With knowledge from the scientific area of Stochastic Optimization, a generalized version of the portfolio optimization problem can be formulated.

Data is provided as a scenario matrix (asset returns) with a certain number of scenarios. Each column of the scenario matrix represents an asset and each row one possible scenario.

Multiplying the scenario matrix with any portfolio vector computes the loss distribution of the specific portfolio. Using this loss distribution approach, we generalize the problem and are free to specify new risk measures and complex constraints based on the loss distribution easily.

Portfolio Optimization - Use Cases

Various Use Cases

- Strategic Asset Allocation
- (Really) Smart Beta
- Trading Strategy Selection
- ...

Each of these cases requires a completely different approach to model the underlying optimization problem. Still, most of the time only a classical Markowitz model is applied - only sometimes replaced with CVaR/ES (Conditional Value at Risk/Expected Shortfall) models.

Use Case: Strategic Asset Allocation

Pension funds, endowments, family offices, ...

- Number of assets: low, i.e. 10-25.
- Asset categories: International Stocks, National Stocks, Bonds, Alternative Assets - 3 to 5 assets per category.
- Risk Objective: minimize Drawdown, minimize Volatility, ...
- Constraints: Regulatory, Life-cycle, Liability-driven, ...

Use Case: (Really) Smart Beta

Nowadays, many smart beta tools are factor-based - most often computed without sophisticated optimization approaches.

- Idea: Cheap, outperform an index passively, outperform active managers.
- Assets: All stocks from a respective index, which should be outperformed.
- Risk objective: Index-tracking, Omega risk measure.
- Constraints: Deviation from index, outperformance lower limit.

Use Case: Trading Strategy Selection

Smart combination of TTR strategies and stochastic portfolio optimization:

1. Using a set of assets, e.g. all stocks from an index.
2. Computing various (and numerous) TTR (technical trading rule) strategies for all the assets.
3. Preselecting the best Asset/TTR combinations into the scenario matrix (e.g. those with the highest Sharpe ratio) used for the subsequent portfolio optimization.
4. Using Stochastic Portfolio Optimization not only to select the optimal asset investment strategy, but also the optimal Asset/TTR combination strategy.

Portfolio Optimization - Use Cases

Each of these cases requires a completely different approach to the modeling of the underlying optimization problem.

Still, most of the time classical Markowitz models are applied - only sometimes replaced with CVaR/ES (Conditional Value at Risk/Expected Shortfall) models.

Other contemporary risk measures and complex constraints are often found in obscure settings only.

Solution: Generalized Stochastic Portfolio Optimization approach as well as a simplified portfolio optimization modeling language.

Portfolio Optimization Modeling with R

Basic Setup - Software and Data

Software

- **R**
  https://cran.r-project.org/
- **RStudio Preview**
  https://www.rstudio.com/products/rstudio/download/preview/

Slides, Data and Packages

- http://www.finance-r.com/cpom/

Everything free and open-source!

Portfolio Optimization Package Overview

There are many different portfolio optimization packages for R.

Besides considering a plain optimization modeling approach, we will take a closer look at the following packages:

- `tSeries`
- `fPortfolio`
- `PortfolioAnalytics`
- `FRAPO`
- `scenportopt`

Apologies to all package authors whose package is not included in this list!

A simple, yet useful approach

Package: `tseries`

Provides a simple and useful Markowitz optimization function `portfolio.optim()` using a return scenario set as input and providing basic customization.

Manually create basic portfolio optimization tasks easily in a few lines of code:

- Backtesting portfolio performance.
- Efficient frontiers.

Colorful Efficient Frontiers with fPortfolio

Package: `fPortfolio`

Create colorful efficient frontiers as well various other graphs to depict portfolio compositions given different levels of risk aversion. These graphs can be used to brighten up your reports.

The optimization is mainly based on Markowitz and CVaR/ES models. Furthermore, the syntax to add specific constraints takes getting used to.

Plain Optimization (Matrix-based)

Of course, it is always possible to do all the underlying optimization modeling manually, i.e. setting up the optimization model on a low level (matrix-based).

Markowitz (QP). Consider the Markowitz portfolio optimization model, which can be formulated as a standard quadratic programming (QP) model.

We apply the package `modopt.matlab`, which provides a simple interface to LP and QP solvers with the well-known MatLab functional way to specify optimization model matrices. A good alternative is the package `ROI`.

CVaR (LP). CVaR/ES portfolio models can be formulated as a linear programming (LP) model. The creation would fill an entire Webinar.

PortfolioAnalytics

Package: `PortfolioAnalytics`

`PortfolioAnalytics` is a widely used and well-designed package for optimizing portfolios.

The package provides functionality to conduct risk-parity optimization as well as adding non-convex objectives and constraints to solve the final portfolio models using various optimization heuristics (applying `DEoptim`).

FRAPO

Package: FRAPO

FRAPO is the package accompanying the book *Financial Risk Modelling and Portfolio Optimisation with R* (Wiley) by Bernhard Pfaff.

- Notable additions are ready to use portfolio optimization functions with a minimum conditional drawdown at risk objective as well as average/maximum drawdown constraints.
- Furthermore, robust optimization models are provided and solved using second-order cone programming (SOCP).

Functional portfolio optimization

Package: `scenportopt`

The package `scenportopt` has been designed to streamline the creation of optimal portfolios in a functional programming style opposed to the classical procedural way. Thus it naturally fits into the R scope, especially in combination with the `magrittr` pipe operator.

Other notable features include the simple and easy creation of active extension portfolios (“130/30”) with different risk measures.

A Contemporary Portfolio Optimization Modeling approach

Contemporary Portfolio Optimization Modeling

Problem: Many packages provide nice models/constraint combinations and visualizations. However: restricted, hard to learn & difficult to extend.

Solution: The contemporary AML approach!

1. Build a general AML (algebraic modeling language) for any optimization model in R.
2. Add portfolio optimization specifics to this AML (separate packages).

This idea has been presented at R/Finance 2014 and its implementation made its debut at R/Finance 2016: http://finance-r.com/portfolio/

More information & applications online

Quantitative Finance & Financial Engineering with R

http://finance-r.com

Upcoming Online Book & Video Tutorials “Become a ~~Billionaire~~ Quant with R”

http://quant-r.com

Further questions, comments, remarks, complaints always welcome:

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