INTERMEDIATE PORTFOLIO ANALYSIS IN R

Introduction to Moments

Optimization Inputs

Portfolio optimization problem inputs:

- Assets
- Constraints
- Objectives
- Moments of asset returns

Asset Return Moments

- First Moment: expected returns vector
- Second Moment: variance-covariance matrix
- Third Moment: coskewness matrix
- Fourth Moment: cokurtosis matrix

Asset Return Moments

Moments to estimate are determined by **objectives** and **constraints:**

- Mean - Variance
  - Expected returns vector
  - Covariance matrix
- Minimum Variance
  - Covariance matrix

Asset Return Moment Estimates

Ledoit and Wolf (2003): *"The central message of this paper is that nobody should be using the sample covariance matrix for the purpose of portfolio optimization."*

Methods:

- Sample
- Shrinkage Estimators
- Factor Model
- Expressing Views
- Robust Statistics

20 Asset Portfolio		
Method	Sample	k = 3 factors
# of parameters	210	86

Calculating Moments in PortfolioAnalytics

```
set.portfolio.moments(R,
                      portfolio,
                      method = c("sample", "boudt", "black_litterman", "meucci"),
                      ...)
```

`set.portfolio.moments()` supports several methods:

- Sample
- Boudt
- Black-Litterman
- Meucci

Example: Moments in PortfolioAnalytics

```
# Sample vs Boudt
> sample_moments <- set.portfolio.moments(R = asset_returns,
                                          portfolio = port_spec)

> boudt_moments <- set.portfolio.moments(R = asset_returns,
                                         portfolio = port_spec,
                                         method = "boudt",
                                         k = 1)
```

Example: Moments in PortfolioAnalytics

```
> round(sample_moments$sigma, 6)
          [,1]      [,2]      [,3]      [,4]
[1,]  0.000402 -0.000034  0.000262  0.000429
[2,] -0.000034  0.000632 -0.000037 -0.000010
[3,]  0.000262 -0.000037  0.000337  0.000568
[4,]  0.000429 -0.000010  0.000568  0.001488

> round(boudt_moments$sigma, 6)
          [,1]      [,2]      [,3]      [,4]
[1,]  0.000403 -0.000016  0.000224  0.000523
[2,] -0.000016  0.000636 -0.000019 -0.000044
[3,]  0.000224 -0.000019  0.000337  0.000614
[4,]  0.000523 -0.000044  0.000614  0.001488
```

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Let’s practice!

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Custom Moment Functions

Custom Moment Functions

A custom moment function is a user defined function.

- Arguments
  - `R` for asset returns
  - `portfolio` for the portfolio specification object
- Return a named list where the elements represent the moments
  - `mu`: Expected returns vector
  - `sigma`: Variance-covariance matrix
  - `m3`: Coskewness matrix
  - `m4`: Cokurtosis matrix

Example: Custom Moment Function

```
> library(MASS)

> custom_fun <- function(R, portfolio, rob_method = "mcd"){
    out <- list()
    out$sigma <- cov.rob(R, method = rob_method)
    return(out)
}

# Passing the rob_method argument to custom_fun
> optimize.portfolio(R, portfolio, momentFUN = custom_fun,
                     rob_method = "mcd")
> optimize.portfolio(R, portfolio, momentFUN = custom_fun,
                     rob_method = "mve")
```

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Objective Functions

Objective Functions

Objective functions compute the objective value. In `PortfolioAnalytics`, objective functions can be any valid R function.

- Common portfolio risk measures
  - standard deviation, expected shortfall, value at risk, component contribution to risk, maximum drawdown, Sharpe Ratio
- Common benchmark relative performance measures
  - information ratio, tracking error, excess return, maximum relative drawdown

Custom Objective Functions

User defined functions as objective functions.

- Argument naming
  - `R` for asset returns
  - `weights` for the portfolio weights
  - `mu, sigma, m3, m4` for the moments
- Returns a single value

Example: Custom Objective Function

```
> # Annualized sharpe ratio
> sr_annualized <- function(R, weights, sigma, scale, rfr){

    # Geometric annualized return
    r <- Return.annualized(Return.portfolio(R, weights),
                           scale = scale)
    # Annual excess return
    re <- r - rfr

    # Annualized portfolio standard deviation
    pasd <- sqrt(as.numeric(t(weights) %*%
                 sigma %*% weights)) * sqrt(scale)

    return(re / pasd)
}
```

Example: Custom Objective Function

```
> data(edhec)
> asset_returns <- edhec[,1:4]

> # Setup spec and add constraints
> port_spec <- portfolio.spec(assets = colnames(asset_returns))
> port_spec <- add.constraint(portfolio = port_spec,
                              type = "full_investment")
> port_spec <- add.constraint(portfolio = port_spec,
                              type = "long_only")

> # Add custom objective function
> port_spec <- add.objective(portfolio = port_spec,
                      type = "return", name = "sr_annualized",
                      arguments = list(scale = 12,
                                       rfr = 0.02))
```

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