Raiffeisen Bank International

fPortfolio 4.0 or the Rmetrics Reloaded

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useR! 2024, Salzburg, 9 July 2024

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Where do we come from?

A little bit of history about the Rmetrics packages and optimization in R

Where do we come from?

- Asset allocation and portfolio optimization problems are since decades a field of active research and has remained highly relevant for asset managers, banks and other financial institutions
- Related optimization problems are often easily solved via standard optimization tools readily available in R
- Additionally, several contributed packages on CRAN as well as other package repositories offer tools to carry out empirical and quantitative financial research with R (see e.g., Eddelbuettel 2023)
- Since two decades the Rmetrics suite of packages offers functionality for many different aspects of empirical and computational finance
- A couple of books describe the tools and its usage, among them to mention is Portfolio Optimization with R/Rmetrics (Würtz *et al.* 2015)
- However, the focus areas in quantitative finance are constantly evolving and changing (e.g., ESG, scalability, generative AI, etc.)

Package fPortfolio

According to Würtz *et al.* (2015), package **fPortfolio** relies on four pillars:

- Definition of the portfolio input, writing specifications, loading the data of the assets, and setting up the constraints.
- Optimization of the portfolio, including the computation of single portfolios such as feasible, efficient, tangency (max reward/risk) or minimum variance (global minimum risk) portfolios, and the evaluation of the entire efficient frontier.
- Generation of portfolio reports: printing, plotting and summarizing the results.
- Analysis of portfolio performance, including rolling analysis, back- testing and benchmarking.

Three S4 classes that describe the portfolio environment including

- the specification of all parameters describing the portfolio,
- the selection and description of the assets data set for which we want to optimize the portfolio, and
- to set the constraints under which the portfolio will be optimized.

Mathematical foundation

Mean-Variance Portfolio Optimization Markowitz (1952)

- Minimum Risk

$$\begin{aligned} \min_{w} \quad & w^\top \hat{\Sigma}\, w \\ s.t. \quad & \\ & Aw^\top \leq b \end{aligned}$$

- Maximum Return

$$\begin{aligned} \max_{w} \quad & w^\top \hat{\mu} \\ s.t. \quad & \\ & Aw \leq b \\ & w^\top \hat{\Sigma} w \leq \sigma \end{aligned}$$

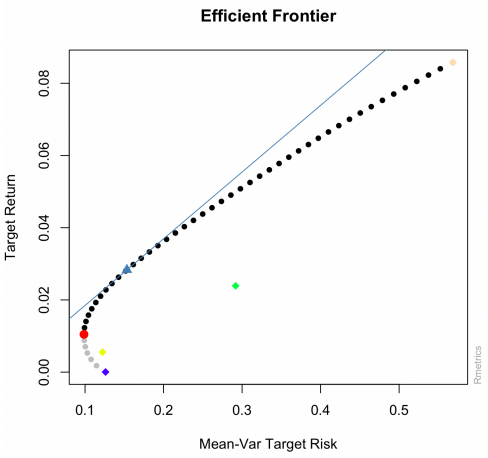
Solving minimum risk problem via fPortfolio I

Example from Würtz *et al.* (2015), Section 17.2:

```
> library("fPortfolio")
> data(LPP2005.RET)
> lppData <- 100 * LPP2005.RET[, 1:6]
> r <- mean(lppData)
> minriskSpec <- portfolioSpec()
> targetReturn <-  mean(lppData)
> setTargetReturn(minriskSpec) <- targetReturn
> minriskPortfolio <- efficientPortfolio(
+   data = lppData,
+   spec = minriskSpec,
+   constraints = "LongOnly")
```

Solving minimum risk problem via fPortfolio II

```
> minriskPortfolio

Title:
 MV Efficient Portfolio
 Estimator:         covEstimator
 Solver:            solveRquadprog
 Optimize:          minRisk
 Constraints:       LongOnly

Portfolio Weights:
   SBI    SPI    SII    LMI    MPI    ALT
0.0000 0.0086 0.2543 0.3358 0.0000 0.4013

Covariance Risk Budgets:
    SBI     SPI     SII     LMI     MPI     ALT
 0.0000  0.0184  0.1205 -0.0100  0.0000  0.8711

Target Returns and Risks:
  mean    Cov   CVaR    VaR
0.0431 0.2451 0.5303 0.3412

Description:
 Fri Jun 28 18:49:16 2024 by user:
```



Optimization problem solving I

Following Boyd and Vandenberghe (2004), a mathematical optimization problem, or just *optimization problem*, has the form

$$\begin{array}{ll} \text{minimize} & f_0(x) \\ \text{subject to} & f_i(x) \leq b_i, \quad i = 1, \ldots, m, \end{array} \tag{1}$$

where

- $x = (x_1, \ldots, x_n)$ is the *optimization variable* of the problem,
- the function $f_0 : \mathbb{R}^n \to \mathbb{R}$ is the *objective function*,
- the functions $f_i : \mathbb{R}^n \to \mathbb{R}$, $i = 1, \ldots, m$, are the (inequality) constraint functions, and the constants $b_1, \ldots, b_m$ are the limits, or bounds, for the constraints.

Optimization problem solving II

A vector x^* is called *optimal*, or a *solution* of the above problem, if it has

- the smallest *objective value* among all vectors that satisfy the constraints
- for any z with $f_1(z) \leq b_1, \ldots, f_m(z) \leq b_m$, we have $f_0(z) \geq f_0(x^*)$.

We generally consider families or *classes of optimization problems*, characterized by particular forms of the objective and constraint functions: linear programming, quadratic programming, conic programming and general nonlinear programming. A problem is called a mixed integer problem (MIP) if the (type) constraint $x_k \in \mathbb{Z}$ for at least one k is added.

Optimization problem solving III

R, as a general-purpose tool for data science,

- requires optimization and access to highly efficient solvers,
- already has access to many modern optimization solvers (see, e.g., the CRAN optimization and mathematical programming task view by Schwendinger and Borchers 2023),
- with many commonalities and differences, e.g., how optimization problems are to be formulated and solved using the respective solver.

However, it is still commonplace to develop highly sophisticated special purpose code (SPC) for many statistical problems.
Enablers for a more general optimization approach in R (see also Theußl *et al.* 2020):

1. *availability*, solvers have not been easily available in R,
2. *capability*, i.e., problems could not be solved due to a lack of adequate solvers, and
3. *efficiency*, i.e., SPC tended to be faster.

Package **fPortfolio** contains its own code to glue together the portfolio infrastructure with the solvers (R interface, AMPL, or remote access such as via the NEOS server).

Many solvers available in R

	GLPK	Rglpk	lp_solve	lpSolve	SYMPHONY	Rsymphony
aflow30a	1158.00	1158.00	1158.00	1158.00	1158.00	1159.00
air04	56137.00	56137.00	56137.00		56137.00	56137.00
air05	26374.00	26374.00	26374.00	26374.00	26374.00	26374.00
cap6000		−2451377	−2451380	−2451377	−2451377	−2451377
danoint		65.67	65.67	65.67	65.67	65.67
disctom		−5000.00			−5000.00	−5000.00
fiber	405935.18	405935.18			405935.18	405935.18
fixnet6					3983.00	3983.00
gesa2	25779856.37			24534703.78		25779856.37
manna81					−13164.00	−13164.00
mas76	40005.05	40005.05		40005.05	40005.05	40005.05
misc07	2810.00	2810.00	2810.00	2810.00	2810.00	2810.00
modglob			20740500.00	20740508.09	20740508.09	20740508.09
nw04	16862.00	16862.00	16862.00	16862.00	16862.00	16862.00
p2756					3124.00	3124.00
pk1	11.00	11.00	11.00	11.00	11.00	11.00
pp08aCUTS			7350.00	7380.00	7350.00	7350.00
qiu		−132.87	−132.87	−32.06	−132.87	−132.87
rout		1127.54	1077.56	1077.56		−Inf
vpm2	13.75	13.75	13.75	7.00	13.75	13.75

Table 1: Objective values, command line solvers and R interfaces. Source: Theußl (2008) (presentation at the 2nd R/Rmetrics conference)

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Where are we now?

fPortfolio and **ROI**

Where are we now?

	Version	License	Published	Maintainer
BLCOP	0.3.3	MIT + file LICENSE	2021-01-25	Joe Russell <jrussell@mango-solutions.com>
DistributionUtils	0.6-0	GPL (>= 2)	2018-11-27	David Scott <d.scott@auckland.ac.nz>
fAssets	4023.85	GPL (>= 2)	2023-04-24	Stefan Theussl <Stefan.Theussl@R-project.org>
fBasics	4022.94	GPL (>= 2)	2023-03-04	Georgi N. Boshnakov <georgi.boshnakov@manchester.ac.uk>
fBonds	3042.78	GPL (>= 2)	2017-11-15	Tobias Setz <tobias.setz@live.com>
fCopulae	4022.85	GPL (>= 2)	2023-01-07	Paul Smith <paul@waternumbers.co.uk>
fExtremes	4021.83	GPL (>= 2)	2022-08-06	Paul J. Northrop <p.northrop@ucl.ac.uk>
fGarch	4022.89	GPL (>= 2)	2022-11-05	Georgi N. Boshnakov <georgi.boshnakov@manchester.ac.uk>
fImport	4021.86	GPL (>= 2)	2022-07-21	Georgi N. Boshnakov <georgi.boshnakov@manchester.ac.uk>
FKF	0.2.4	GPL (>= 2)	2022-10-10	Paul Smith <paul@waternumbers.co.uk>
fMultivar	4021.83	GPL (>= 2)	2022-07-18	Stefan Theussl <Stefan.Theussl@R-Project.org>
fNonlinear	4021.81	GPL (>= 2)	2022-10-26	Paul Smith <paul@waternumbers.co.uk>
fPortfolio	4023.84	GPL (>= 2)	2023-04-25	Stefan Theussl <Stefan.Theussl@R-project.org>
fRegression	4021.83	GPL (>= 2)	2022-08-11	Paul J. Northrop <p.northrop@ucl.ac.uk>
fTrading	3042.79	GPL (>= 2)	2017-11-15	Tobias Setz <tobias.setz@live.com>
fUnitRoots	4021.80	GPL (>= 2)	2022-08-06	Georgi N. Boshnakov <georgi.boshnakov@manchester.ac.uk>
GeneralizedHyperbolic	0.8-4	GPL (>= 2)	2018-05-15	David Scott <d.scott@auckland.ac.nz>
ghyp	1.6.3	GPL (>= 2)	2022-11-02	Marc Weibel <marc.weibel@quantsulting.ch>
HyperbolicDist	0.6-4	GPL (>= 2)	2022-02-21	David Scott <d.scott@auckland.ac.nz>
NormalLaplace	0.3-0	GPL (>= 2)	2018-11-26	David Scott <d.scott@auckland.ac.nz>
randtoolbox	2.0.4	BSD_3_clause + file LICENSE	2023-01-28	Christophe Dutang <dutangc@gmail.com>
rngWELL	0.10-9	BSD_3_clause + file LICENSE	2023-01-16	Christophe Dutang <dutangc@gmail.com>
SkewHyperbolic	0.4-0	GPL (>= 2)	2018-11-29	David Scott <d.scott@auckland.ac.nz>
timeDate	4022.108	GPL (>= 2)	2023-01-07	Georgi N. Boshnakov <georgi.boshnakov@manchester.ac.uk>
timeSeries	4021.105	GPL (>= 2)	2022-10-16	Georgi N. Boshnakov <georgi.boshnakov@manchester.ac.uk>
VarianceGamma	0.4-0	GPL (>= 2)	2018-11-26	David Scott <d.scott@auckland.ac.nz>

Table 2: Rmetrics package maintainers as of 2023-05-08 (updated within last 5 years)

Available ROI solvers

Package **ROI** (Theußl *et al.* 2023) readily interfaces many solvers

Constraints	Objective: linear	Objective: quadratic	Objective: conic	Objective: functional
no				
box				**optimx**
linear	**clp***, **cbc**$^{*+}$, **glpk**$^{*+}$, **lpsolve**$^{*+}$, **msbinlp**$^{*+}$, **symphony**$^{*+}$	**ipop**, **quadprog***, **qpoases**		
quadratic		**cplex**$^{+}$, **gurobi**$^{*+}$, **mosek**$^{*+}$, **neos**$^{+}$		
conic			**ecos**$^{*+}$, **scs***	
functional				**alabama**, **deoptim**, **nlminb**, **nloptr**

Table 3: Available **ROI** plug-ins. * indicates that the solver is restricted to convex problems and $^{+}$ indicates that the solver can model integer constraints.

Portfolio optimization using ROI I

Same parameters as before

```
> library("ROI")
> foo <- Q_objective(Q = cov(lppData), L = rep(0, ncol(lppData)))
> full_invest <- L_constraint(rep(1, ncol(lppData)), "==", 1)
> target_return <- L_constraint(apply(lppData, 2, mean), "==", r)
> op <- OP(objective = foo, constraints = rbind(full_invest, target_return))
> op
ROI Optimization Problem:

Minimize a quadratic objective function of length 6 with
- 6 continuous objective variables,

subject to
- 2 constraints of type linear.
- 0 lower and 0 upper non-standard variable bounds.
```

Portfolio optimization using ROI II

Solve the portfolio optimization problem via `ROI_solve()`

```
> sol <- ROI_solve(op, solver = "cplex")
> w <- sol$solution
> round(w, 4)
[1] 0.0000 0.0086 0.2543 0.3358 0.0000 0.4013
> sqrt(t(w) %*% cov(lppData) %*% w)[,1]
[1] 0.2450869
> sol <- ROI_solve(op, solver = "quadprog")
> w <- sol$solution
> round(w, 4)
[1] 0.0000 0.0086 0.2543 0.3358 0.0000 0.4013
> sqrt(t(w) %*% cov(lppData) %*% w)[,1]
[1] 0.2450869
```

Portfolio optimization using ROI III

Solve the max-return portfolio optimization problem:

```
> sigma <- sqrt(t(w) %*% cov(lppData) %*% w)
> foo <- L_objective(L = colMeans(lppData))
> maxret_constr <- Q_constraint(Q = list(cov(lppData)*2, NULL), L = rbind(rep(0, ncol(lppData)),
+                                                                         +     rep(1, ncol(lppData))), c("<=", "<="), c(sigma^2, 1))
> op <- OP(objective = foo, constraints = maxret_constr, maximum = TRUE)
> op
ROI Optimization Problem:

Maximize a linear objective function of length 6 with
- 6 continuous objective variables,

subject to
- 2 constraints of type quadratic.
- 0 lower and 0 upper non-standard variable bounds.
> sol <- ROI_solve(op, solver = "cplex")
> w <- sol$solution
> round(w, 4)
[1] 0.0000 0.0086 0.2543 0.3358 0.0000 0.4013
> round(w %*% colMeans(lppData), 4)[,1]
[1] 0.0431
```

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What is next?

fPortfolio 4.0

What is next?

Expected service from financial research provider

Historical portfolio performance and volatility

Return 10y	Return 5y	Return 1y	Return ytd
5.3	3.85	-6.08	2.5
Sharpe Ratio 5y*	Vola 5y	Drawdown**	TTR**
0.49	7.83	-19.63	383

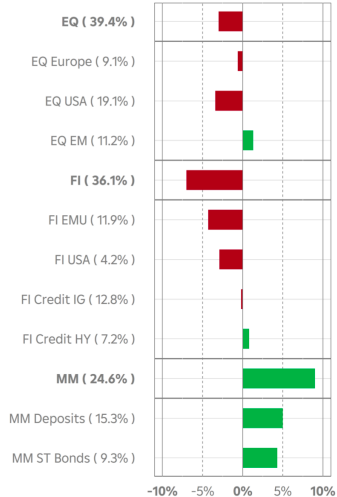
*As of 24 Mär 2023, in percent, total return, p.a., weekly return data. Based on the tactical allocation (since inception) using historical index data, quarterly rebalancing. * Using a risk-free rate of 0%; ** Time to recovery in days. Using the 95% quantile in a five year rolling window since 30 Sep 2004.*

Portfolio weightings and expected return

	Tactical	Strategic	Delta*	Exp ret**
EQ Europe	9.1	9.7	-0.6	8.6
EQ USA	19.1	22.5	-3.4	8.7
EQ EM	11.2	9.9	1.3	9.6
FI EMU	11.9	16.2	-4.3	1.3
FI USA	4.2	7.0	-2.9	-2.8
FI Credit IG	12.8	13.0	-0.2	2.6
FI Credit HY	7.2	6.4	0.8	6.9
MM Deposits	15.3	10.3	5.0	3.0
MM ST Bonds	9.3	5.0	4.3	2.1

*As of 24 Mär 2023, in percent, total return in EUR, p.a.; Sum of weights and deltas need not equal to 100 and 0, respectively, due to rounding differences; * In percentage points; ** Estimated performance (p.a.) over the next year.*

Expected annual portfolio return over the next one/ten years: 5 %/ 4.5 %.



Figures and numbers were taken from the latest financial analysis (Q2 23) published by Raiffeisen Research for Slovakian clients in March 2023.
Source: LSEG/Refinitiv, RBI/Raiffeisen RESEARCH

Structural Model Portfolio Set-Up

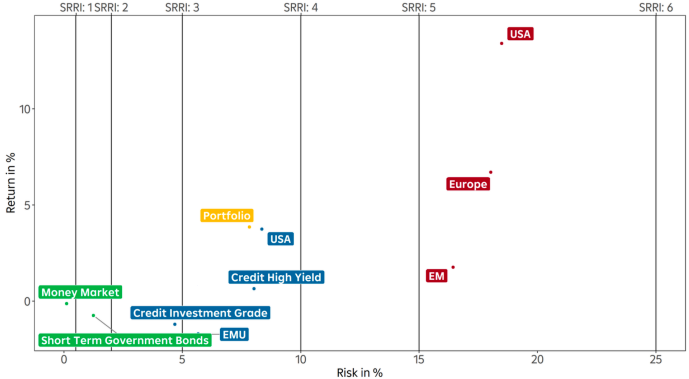
- Compliant to regulatory standards (in particular MiFID-II), e.g., ESMA Guideline 2012/387: "[..] the advice and portfolio management services provided to the client take account of an appropriate degree of risk diversification;"
- Clear definition of risk such as the Synthetic Risk/Reward Indicator (SRRI)
- Risk-return efficient
  - tactically re-allocated quarterly using our own and consensus forecasts (1y forward total return estimates)
  - strategically assessed annually (10y forward total return estimates)
  - diversification of sub-assets classes to reduce overall portfolio risk
- Tailor-made, i.e., coherent with local business requirements of each network banking unit (NWU)
  - Client risk profile
  - Home bias
  - Up to 5 risk profiles to account for different risk propensities of potential clients
  - Client portfolio steering in such away that risk lis ower or equal to model portfolio
- Structured into three main asset classes and sub-asset classes of:
  - Equity (EQ)
  - Fixed-income (FI)
  - Money market (MM)
- Implementation aims to be extensible/scalable

Implementation

- Data retrieval
- Data cleaning/transformation
- Generation of portfolio objects
  - Relevant pricedata
  - Structure metadata
  - Creation date
- Pre-loading of specific constraints
- Database retrieval of internal forecasts
- Apply model by Black and Litterman (1992)
- Currently, report generation is done via Sweave and a custom LaTeX template
- Process runs containerized in the cloud

Conclusion and Outlook I

Historical risk/return distribution



As of 24 Mar 2023, based on total return series in EUR, p.a. from weekly returns over the last five years. Asset classes: equities (red), fixed income (blue), and money market (green); tactical allocation (yellow).
Source: LSEG/Refinitiv, RBI/Raiffeisen RESEARCH

Conclusion and Outlook II

To sum up,

- **fPortfolio** implements concepts for carrying out portfolio optimization with R
- **ROI** has its strengths as a general infrastructure for solving optimization problems and through extensibility
- Next will be an evaluation of whether one can move to **ROI** as the primary optimization interface

Other interesting new aspects to be considered for **fPortfolio**

- Assetclass-specific modeling, e.g. via **fAssets**
- Automatic text generation for portfolio reports
- Dashboard using Shiny for enhanced usability
- What about easy re-use of **fPortfolio** in the cloud (documentation, images)?

For the Rmetrics packages in general we are open to increase the developer community even more. We use events such as the *International Conference on Data Science in Finance* for knowledge exchange (https://dsf.academy/conference). Any support welcome!

References

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for listening