Package ‘parma’

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Type Package

Title Portfolio Allocation and Risk Management Applications

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Author Alexios Ghalanos and Bernhard Pfaff

Maintainer alexios ghalanos <alexios@dscape.com>

Description Portfolio Optimization

     p-Utility.R p-MILPR p-NLPR p-GNLPR p-LPR p-QPR p-SOCP.R

Depends R (>= 2.10), methods, nloptr

Imports slam, Rglpk, quadprog, FRAPo, corpcor, parallel

Suggests truncnorm, xts, Rsymphony

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The portfolio allocation and risk management applications (parma) package contains a unique set of methods and models for the optimal allocation of capital in financial portfolios. It uniquely represents certain discontinuous problems using their smooth approximation counterparts and implements fractional based programming for the direct optimization of risk-to-reward ratios. In combination with the rmgarch package, it enables the confident solution to scenario based optimization problems using such risk and deviation measures as Mean Absolute Deviation (MAD), Variance (EV), Minimax, Conditional Value at Risk (CVaR), Conditional Drawdown at Risk (CDaR) and Lower Partial Moments (LPM). In addition, it implements moment based optimization for use with the quadratic EV problem, and a higher moment CARA utility expansion using the coskewness and cokurtosis matrices generated from the GO-GARCH with affine GH or NIG distributions. Benchmark relative optimization (tracking error) is also implemented as are basic mixed integer cardinality constraints. Finally, for non-convex problem formulations such as the upper to lower partial moments function, global optimization methods using a penalty based method are available. The key functions in the package are parmaspec which defines the optimization setup, and parmasolve which solves the problem given a chosen representation and solver. A portfolio frontier function is implemented in parmafrentier, utility optimization in parmautility and a custom translation of
the cmaes global optimization solver of Hansen (2006) with full features is implemented in cmaes.

How to cite this package
Whenever using this package, please cite as

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License
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Author(s)
Alexios Ghalanos and Bernhard Pfaff

References
The Covariance Matrix Adaptation Evolution Strategy (cmaes) Solver

Description
The direct translation of the Hansen’s cmaes matlab code v3.60.

Usage
```
cmaes(pars, fun, lower = rep(0, length(pars)), upper = rep(1, length(pars)),
       insigma = 1, ctrl = cmaes.control(), ...)
```

```
cmaes.control(
    options = list(StopFitness = -Inf, MaxFunEvals = Inf,
                   MaxIter = '1e3*(N+5)^2/sqrt(popsise)', StopFunEvals = Inf,
                   StopIters = Inf, TolX = '1e-11*max(insigma)', TolUpX = '1e-3*max(insigma)',
                   TolFun = 1e-12, TolHistFun = 1e-13, StopOnStagnation = TRUE,
                   StopOnWarnings = TRUE, StopOnEqualFunctionValues = '2 + N/3',
                   DiffMaxChange = Inf, DiffMinChange = 0, WarnOnEqualFunctionValues = FALSE,
                   EvalParallel = FALSE, EvalInitialX = TRUE, Restarts = 0,
                   IncPopSize = 2, PopSize = '4 + floor(3*log(N))', ParentNumber = 'floor(popsise/2)',
                   RecombinationWeights = c("superlinear", "linear", "constant"),
                   DiagonalOnly = '0*(1+100*N/sqrt(popsise))+(N>=1000)',
                   CMA = TRUE, Seed = 'as.integer(Sys.time())', DispFinal = TRUE,
                   DispModulo = 100, Warns = FALSE),
    cma = list(cs = '(mueff+2)/(N+mueff+3)',
              damps = '1 + 2*max(0,sqrt((mueff-1)/(N+1))-1) + cs',
              ccum = '(4 + mueff/N) / (N+4 + 2*mueff/N)', cccov = '2 / ((N+1.3)^2+mueff)',
              cccovmu = '2 * (mueff-2/mueff) / ((N+2)^2+mueff)', active = 0))
```

Arguments
- **pars**: A numeric vector of starting parameters.
- **fun**: The user function to be minimized.
- **lower**: A vector the lower parameter bounds.
- **upper**: A vector with the upper parameter bounds.
- **insigma**: The initial coordinate wise standard deviations for the search.
- **ctrl**: A list with control parameters as returned from calling the `cmaes.control` function.
- **...**: Additional arguments passed to the user function.
- **options**: The main options in the cmaes.control which may be optionally strings which are evaluated on initialization of the solver.
- **CMA**: The options for the active CMA.
Details

This solver has been translated from the matlab version created by Nikolaus Hansen and available on his website http://www.lri.fr/~hansen/cmaes_inmatlab.html. There is also a cmaes on CRAN but this does not offer the same level of options and flexibility that the matlab version offers. For more details on what the options mean and generally how the cmaes solver works, consult the relevant website and literature.

Author(s)

Alexios Ghalanos

References


Examples

```r
## Not run:
ctrl = cmaes.control()
ctrl$options$StopOnWarnings = FALSE
ctrl$cma$active = 1
ctrl$options$TolFun = 1e-12
ctrl$options$DispModule = 100
ctrl$options$Restart = 0
ctrl$options$MaxIter = 3000
ctrl$options$TolUpX = 5
ctrl$options$PopSize = 300
test1 = cmaes(rnorm(10), fun = parma:::fsphere,
lower = -Inf, upper = Inf, insigma = 1, ctrl = ctrl)
test2 = cmaes(rnorm(10), fun = parma:::frosenbrock,
lower = -Inf, upper = Inf, insigma = 1, ctrl = ctrl)

ctrl = cmaes.control()
ctrl$options$StopOnWarnings = FALSE
ctrl$cma$active = 1
ctrl$options$TolFun = 1e-12
ctrl$options$DispModule = 100
ctrl$options$Restart = 0
ctrl$options$MaxIter = 3000
ctrl$options$PopSize = 400
test3 = cmaes(rep(1, 10), fun = parma:::frastrigin10,
lower = -50, upper = 50, insigma = 1, ctrl = ctrl)

## End(Not run)
```
## Constraints

### NLP Custom Constraint Functions

| Description | Provides a number of custom constraints and their jacobians for use with the NLP representation (both minimum risk and the fractional problem). |
| Usage | ineqfun.turnover.min(w, optvars, uservars) |
| | ineqjac.turnover.min(w, optvars, uservars) |
| | ineqfun.bsturnover.min(w, optvars, uservars) |
| | ineqjac.bsturnover.min(w, optvars, uservars) |
| | ineqfun.turnover.opt(w, optvars, uservars) |
| | ineqjac.turnover.opt(w, optvars, uservars) |
| | ineqfun.bsturnover.opt(w, optvars, uservars) |
| | ineqjac.bsturnover.opt(w, optvars, uservars) |
| | ineqfun.variance.opt(w, optvars, uservars) |
| | ineqjac.variance.opt(w, optvars, uservars) |
| | ineqfun.variance.min(w, optvars, uservars) |
| | ineqjac.variance.min(w, optvars, uservars) |

### Arguments

- **w**: The decision weight vector.
- **optvars**: Problem specific list (not for use by user).
- **uservars**: User specific list with some required parameters to be set (see details).

### Details

Functions preceded by “ineqfun” denote the functions which may be passed to the ineqfun option in the parmaspec function, while “eqfun” to the eqfun option. Functions which include “jac” in the first part of the name denote the jacobians of the equivalent constraints and should be passed to the ineqgrad or eqgrad options in parmaspec. Functions ending with “min” denote formulations for use with the minrisk type problems while functions ending with “opt” denote the fractional risk formulation.

For the simple turnover constraint, the uservars list must contain an entry called ‘wold’ denoting the previous vector of weights with which the comparison will be made. Additionally, an entry called ‘turnover’ is required which denotes the (positive) value for the maximum turnover.

For the buy and sell turnover constraint (bsturnover), there should instead be (positive) ‘buyturnover’ and ‘sellturnover’ entries in the uservars list. Finally note that when using this type of constraints in a fractional programming setup, care should be taken that the combination of bounds, turnover limits and the forecast return vector do not result in a negative expected return in which case the problem is not solvable.
The variance constraint allows the targeting of a maximum acceptable variance. The extra arguments which must be passed to the uservars list are ‘Cov’ for the asset covariance matrix and ‘varbound’ representing the maximum acceptable upper variance.

**Value**

Used internally by the NLP solver. The fun return a scalar, while the jac return a matrix with n.cols equal to the length of the decision vector (which may be greater than the length of the weights as in the fractional problem which contains the fractional multiplier as well as other formulations which have additional decision variables).

**Author(s)**

Alexios Ghalanos

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**Description**

The xts dataset consists of the adjusted daily closing prices of 15 iShare ETFs for the period 2003-05-28 to 2012-06-01 (2272 periods) representing a selection of US style and international equity benchmark. The iShare series are IWF (Russell 1000 Growth Index), IWD (Russell 1000 Value Index), IWO (Russell 2000 Growth Index), IWN (Russell 2000 Value Index), EEM (MSCI Emerging Markets Index), TLT (Barclays 20+ Year T-Bond), EWC (MSCI Canada Index), EWA (MSCI Australia Index), EWJ (MSCI Japan Index), EWG (MSCI Germany Index), EWL (MSCI Switzerland Index), EWQ (MSCI France Index), EWU (MSCI UK Index), EPP (MSCI Pacific ex-Japan), EZA (MSCI South Africa Index).

**Usage**

data(etfdata)

**Format**

An xts matrix containing 2272x15 observations.

**Source**

Yahoo Finance
Description

Solves for the portfolios on the efficient frontier given a specification object.

Usage

parmafrontier(spec, n.points = 100, miny = NULL, maxy = NULL, type = NULL, solver = NULL, solver.control = list(), parma.control = list(ubounds = 10000, mbounds = 1e+05, penalty = 10000), cluster = NULL)

Arguments

spec A parmaSpec object.
n.points The number of portfolios to solve for along the frontier.
miny (Optional) Minimum return from which to calculate the frontier. If not provided, will be calculated by a first pass optimization.
maxy (Optional) Maximum return for which to calculate the frontier. If not provided, will be based on the maximum forecast.
type The problem type to use (the show method on parmaSpec will indicate the available options).
solver For a GNLP type problem the choice of global solver, either "cmaes" or "crs" from the nloptr package.
solver.control A list with optional control parameters passed to the nloptr or cmaes solver.
parma.control Internal NLP tuning parameters, where 'ubounds' represents the symmetric unconstrained parameter bounds in the fractional problem, 'mbounds' the multiplier upper bounds in the fractional formulation, 'penalty' the GNLP penalty parameter.
cluster A precreated cluster object from the parallel package for the parallel evaluation of the frontier portfolios (see note).

Details

If using a cluster object, care should be taken since some of the LP based problems are quite memory intensive. Though some care some gone into using slam matrices and forcing garbage collection in intermediate setup steps of these problems, there is no guarantee that memory will not be quickly depleted for large problems using many cores/sockets.

Value

A matrix object with columns for the weights, risk, reward and termination status of the solver (not available for the QP solver), and n.points rows. The user should investigate the non-converged solutions as well as remove any NA based rows (non-converged with error).
parmaPort-class

Author(s)
Alexios Ghalanos

Description
The parma optimal portfolio class.

Objects from the Class
Objects can be created by calls to `parmasolve`.

Slots
- `solution`: Object of class "vector" The list with the optimal values.
- `model`: Object of class "vector" A list with details of the risk model.

Methods
- `show` signature(object = "parmaPort"): Summary.
- `weights` signature(object = "parmaPort"): Extracts the optimal weights.
- `tictoc` signature(object = "parmaPort"): Extracts the time elapsed to solve the problem.
- `checkarbitrage` signature(object = "parmaPort"): Extracts the arbitrage check on the scenario.
- `parmarisk` signature(object = "parmaPort"): Extracts the expected risk of the optimized portfolio.
- `parmareward` signature(object = "parmaPort"): Extracts the expected reward of the optimized portfolio.
- `parmastatus` signature(object = "parmaPort"): Solver termination code for the LP and NLP solvers.

Author(s)
Alexios Ghalanos

Examples
`showClass("parmaPort")`
parmasolve-methods  Portfolio Allocation Model Solver

Description
Solves for the optimal weights given parmaSpec defined model.

Usage
parmasolve(spec, type = NULL, solver = NULL, solver.control = list(), x0 = NULL, w0 = NULL, parma.control = list(ubounds = 1e4, mbounds = 1e5, penalty = 1e4, eqSlack = 1e-05), ...)

Arguments
spec A parmaSpec object.
type The problem type to use (the show method on parmaSpec will indicate the available options).
solver For a GNLP type problem the choice of global solver, either “cmaes” or “crs” from the nloptr package. For LP type problems, either glpk or symphony.
solver.control A list with optional control parameters passed to the nloptr or cmaes solver.
x0 Optional starting parameters for the NLP type problems. This may be of size greater than the number of assets depending on whether it takes extra optimization parameters (CVaR has VaR in position 1, whilst the fractional formulation has the multiplier in the last position).
w0 Optional starting parameters for only the asset weights.
parma.control Internal NLP tuning parameters, where ‘ubounds’ represents the symmetric unconstrained parameter bounds in the fractional problem, ‘mbounds’ the multiplier upper bounds in the fractional formulation, ‘penalty’ the GNLP penalty parameter and ‘eqSlack’ the slack value to use for converting equalities to inequalities in the SOCP formulation.
... Currently only the ‘verbose’ argument (logical) which is used and passed to the GLPK solver (similar to ‘trace’).

Details
In most of the cases, the intersection of objective and constraints will define whether a problem is LP, MILP, QP, MIQP, QCQP, NLP, MINLP or GNLP. However, there are cases when the problem can be solved by more than one type of solver so that the ‘type’ option allows the user to choose between the options. For the GNLP type, the ‘solver’ allows for a choice of “cmaes” or “crs”, while the LP type there is a choice of “glpk” or “symphony”. Future development will likely expand on these choices.

Value
A parmaPort object containing details of the PARMA optimized portfolio.
parmaSpec-class

Author(s)
Alexios Ghalanos

parmaSpec-class  Class "parmaSpec"

Description
Object returned from calling parmaspec.

Objects from the Class
Objects can be created by calls of the form new("parmaSpec").

Slots
model: A list with details of the risk and optimization model.
modeldata: A list with the data.
constraints: A list with details on the optimization constraints.

Methods
parmasolve signature(spec = "parmaSpec"): Solves for the optimal weights.
show signature(object = "parmaSpec"): Summary method.
parmaset< signature(object = "parmaSpec"): Set a specified ‘arg’ from the list of arguments defined in the parmaspec to some ‘value’ and return a modified specification.
parmaget signature(object = "parmaSpec"): Get a specified ‘arg’ from the list of arguments defined in the parmaspec.

Author(s)
Alexios Ghalanos

Examples
showClass("parmaSpec")
Description

Defines the type model and method for optimization using either a scenario or covariance matrix.

Usage

```
parmaspec(scenario = NULL, probability = NULL, S = NULL, Q = NULL, qB = NULL,
benchmark = NULL, benchmarkS = NULL, forecast = NULL, target = NULL,
targetType = c("inequality", "equality"),
risk = c("MAD", "MiniMax", "CVaR", "CDaR", "EV", "LPM", "LPMUPM"),
riskType = c("minrisk", "optimal", "maxreward"), riskB = NULL,
options = list(alpha = 0.05, threshold = 999, moment = 1, lmoment=1,
              umoment=1, uthreshold = -0.01, uthreshold = 0.01),
LB = NULL, UB = NULL, budget = 1, leverage = NULL,
ineqfun = NULL, ineqgrad = NULL, eqfun = NULL, eqgrad = NULL,
uservars = list(), ineq.mat = NULL, ineq.LB = NULL,
ineq.UB = NULL, eq.mat = NULL, eqB = NULL, max.pos = NULL,
asset.names = NULL, ...)
```

Arguments

- **scenario**: An n-by-m scenario matrix.
- **probability**: An optional n-by-1 vector of scenario probabilities which must sum to 1 (only currently used in LP problems). Default is to assign equal weights to each row of the scenario.
- **S**: An m-by-m positive definite covariance matrix.
- **Q**: A list of m-by-m positive definite matrices for QCQP type problems.
- **qB**: A vector of the same length as Q denoting the upper bound on Q.
- **benchmark**: A n-by-1 scenario benchmark matrix, used when scenario is not NULL.
- **benchmarkS**: An m+1 vector consisting of the benchmark variance (1) and covariances (m) with the other m assets, used when S is not NULL.
- **forecast**: A vector (m) of forecast values for the assets. If a benchmark is included, this should then be the active forecast over the benchmark.
- **target**: The target return required when riskType is minrisk. If a benchmark is used, then this is the active target over the benchmark (given the active forecasts above).
- **targetType**: Whether the target should be a hard equality or inequality.
- **risk**: The risk measure.
- **riskType**: The type of optimization to use, with a choice of minimizing the risk given the relevant constraints, on optimizing directly the risk to reward ratio using established fractional programming methods or maximizing the reward subject to a risk upper bound and other constraints (only currently supported by the SOCP solver for covariance matrix type problems).
For the case that riskType is “maxreward”, then riskB is the upper bound for the risk constraint.

A vector of optional parameters related to the tail risk measures CVaR, CDaR and LPM.

The lower bounds for the asset weights. If using a benchmark, this should be the maximum deviation below the benchmark weights.

The upper bounds for the asset weights. If using a benchmark, this should be the maximum deviation above the benchmark weights.

The investment constraint. If using a benchmark, this is usually set to zero so that weights represent the active bets on the benchmark.

The leverage constraint for Long/Short optimization.

A list of user inequality functions for use in an NLP type setup (see details).

A list of user inequality gradients if ineqfun was provided.

A list of user equality functions for use in an NLP type setup (see details).

A list of user equality gradients if eqfun was provided.

A list of any additional user required values to be used with user defined inequality and equality functions (for NLP).

A k-by-m inequality matrix (for LP and QP problems).

A vector (k) of the lower bounds for the ineq.mat.

A vector (k) of the upper bounds for the ineq.mat.

A l-by-m equality matrix (for LP and QP problems).

A vector (l) of equalities for the eq.mat.

Cardinality Constraints. The maximum assets to include in the solution, effectively making this a MILP, MIQP or MINLP problem.

An optional character vector of asset names.

Not used.

The parmaspec method is the entry point for specifying and solving portfolio problems in the parma package. Currently 7 measures of risk are supported, 3 based on tail measures: Conditional Value at Risk (CVaR), Conditional Drawdown at Risk (CDaR) and Lower Partial Moments (LPM), and 3 based on the Lp-Norm: Mean Absolute Deviation (L_1, MAD), Mean Variance (L_2, EV) and MiniMax (L_inf, Minimax). The LPMUPM measure is the ratio of lower to upper partial moments, a non convex measure discussed in Holthausen (1981). Additionally, the problems may be solved based on minimization of risk subject to a target return, else on the optimal risk-reward ratio using fractional programming (see references), thus avoiding the estimation of the entire frontier. Problems are classified and solved according to whether they can be formulated as Linear (LP), Mixed Integer LP (MILP), Quadratic (QP), Mixed Integer Quadratic (MIQP), Second Order Cone Programming (SOCP), Non-Linear (NLP), Mixed Integer NLP (MINLP) and Global NLP (GNLP). This in turn depends on the intersection of objectives and constraints. It is possible that a problem may be solved both as an LP and NLP (or QP and NLP), and this can be defined during the solver stage (parmasolve). Because all NLP models, make use of analytical derivatives, the results should
be the same for any formulation chosen, and considerations such as memory usage should guide
the choice of formulation (with some LP models being particularly expensive). Not all problem
types are supported, but this might change subject to the availability of solvers in R which can deal
with these specific types e.g. MINLP and MIQP. The parmaspec also allows the input of a bench-
mark so that benchmark relative optimization is carried out. User defined equality and inequality
functions for NLP problems need to be properly defined to be accepted by the model, and their
analytic gradients also provided, unless the problem is solved as a GNLP in which case a derivative
free penalty function is used. These custom constraint functions should be provided in a list, and
should take as arguments the vector of decision variables ‘w’, an argument called ‘optvars’ which is
used by the program internally, and an argument called ‘uservars’ which is a list with optional user
defined values for the constraints. The examples in the inst folder provide some guidance, and the
user is left to his own devices to study the underlying workings of the program to understand how
to supply these. Finally, the NLP functions which are known to be discontinuous because of the
presence of functions such as the min and max, have been re-written to take advantage of smooth
approximations to such functions, details of which may be founds in the vignette. The package
support for GNLP is based on a choice of the cmaes solver of the cmaes package (which is not
production level) or the crs solver of the nloptr package which may be defined in solver.control
option of the parmasolve method with named argument ‘solver’. High quality GNLP solvers are
not available in R and as such support for these types of problems is experimental at best and your
mileage will vary. The problems which must be solved as GNLP include the ‘LPMUPM’ measure,
all problems with risk type ‘optimal’ AND cardinality constraints (‘max.pos’), and all problems
with custom NLP constraints without derivatives, non-convex inequalities or non-affine equalities.

Value

A parmaSpec object containing details of the PARMA specification.

Author(s)

Alexios Ghalanos

parmautility-methods

Utility Based Optimization

Description

Utility based portfolio optimization using either Taylor series expansion of utility function with
moments or scenario based.

Usage

parmautility(U = c("CARA", "Power"), method = c("moment", "scenario"),
scenario = NULL, M1 = NULL, M2 = NULL, M3 = NULL, M4 = NULL, RA = 1,
budget = 1, LB = rep(0, length(M1)), UB = rep(1, length(M1)))
 riskfun

Arguments

- U: The utility function (only CARA currently implemented).
- method: Whether to use moment or scenario based optimization (only moment currently implemented).
- scenario: A n-by-m scenario matrix.
- M1: A vector (m) of forecasts.
- M2: An m-by-m positive definite covariance matrix.
- M3: An m-by-m^2 third co-moment matrix.
- M4: An m-by-m^3 fourth co-moment matrix.
- RA: Risk Aversion Coefficient for CARA.
- budget: The investment constraint.
- LB: The lower bounds for the asset weights (positive).
- UB: The upper bounds for the asset weights.

Details

The function currently only implements the CARA moment based approach, but will be expanded in the future. The moment approach can take as inputs either M1 and M2 (2-moment approximation), or M1, M2, M3 and M4 (4-moment approximation). Not many models generate M3 and M4, but the “gogarch” model with manig or magh distribution will.

Value

A `parmaPort` object containing details of the PARMA optimized portfolio.

Author(s)

Alexios Ghalanos

References


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riskfun

Portfolio Risk Measures

Description

Calculates a given portfolio risk/deviation measure given a set of weights and matrix of returns, possible representing a forecast scenario.
Usage

riskfun(weights, Data, risk = c("mad", "ev", "minimax", "cvar", "cdar", "lpm"),
benchmark = NULL, alpha = 0.05, moment = 1, threshold = 0, VaR = NULL, DaR = NULL)

Arguments

weights vector of weights.
Data Matrix of returns.
risk Choice of measure.
benchmark (Optional) vector of benchmark returns with same number of rows as Data.
alpha The lower quantile for the “cvar” and “cdar” measures.
moment The “lpm” measure moment.
threshold The “lpm” measure threshold. A value of 999 will subtract the portfolio mean.
VaR (Optional) The pre-calculated VaR for the “cvar” measure.
DaR (Optional) The pre-calculated DaR for the “cdar” measure.

Details

A simple utility function for the calculation and understanding of some of the risk and deviation measures implemented in the package.

Value

A numeric value representing the risk/deviation measure.

Author(s)

Alexios Ghalanos
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