Package ‘quarks’

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Type Package

Title Simple Methods for Calculating and Backtesting Value at Risk and Expected Shortfall

Version 1.1.4

Description Enables the user to calculate Value at Risk (VaR) and Expected Shortfall (ES) by means of various types of historical simulation. Currently plain-, age-, volatility-weighted- and filtered historical simulation are implemented in this package. Volatility weighting can be carried out via an exponentially weighted moving average model (EWMA) or other GARCH-type models. The performance can be assessed via Traffic Light Test, Coverage Tests and Loss Functions. The methods of the package are described in Gurrola-Perez, P. and Murphy, D. (2015) <https://EconPapers.repec.org/RePEc:boe:boeewp:0525> as well as McNeil, J., Frey, R., and Embrechts, P. (2015) <https://ideas.repec.org/b/pup/pbooks/10496.html>.

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Author Sebastian Letmathe [aut, cre]

Maintainer Sebastian Letmathe <sebastian.let@t-online.de>

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Contents

`cvgtest` *Unconditional and Conditional Coverage Tests, Independence Test*

Description

The conditional (Kupiec, 1995), the unconditional coverage test (Christoffersen, 1998) and the independence test (Christoffersen, 1998) of the Value-at-Risk (VaR) are applied.

Usage

```
cvgtest(obj = list(loss = NULL, VaR = NULL, p = NULL), conflvl = 0.95)
```

Arguments

`obj` a list that contains the following elements:

- `loss` a numeric vector that contains the values of a loss series ordered from past to present; is set to `NULL` by default.
- `VaR` a numeric vector that contains the estimated values of the VaR for the same time points of the loss series `loss`; is set to `NULL` by default.
- `p` a numeric vector with one element; defines the probability p stated in the null hypotheses of the coverage tests (see the section `Details` for more information); is set to `NULL` by default.

`conflvl` a numeric vector with one element; the significance level at which the null hypotheses are evaluated; is set to `0.95` by default. Please note that a list returned by the `rollcast` function can be directly passed to `cvgtest`.

Details

With this function, the conditional and the unconditional coverage tests introduced by Kupiec (1995) and Christoffersen (1998) can be applied. Given a return series r_t with n observations, divide the series into $n - K$ in-sample and K out-of-sample observations, fit a model to the in-sample data and obtain rolling one-step forecasts of the VaR for the out-of-sample time points.

Define

$$I_t = 1,$$

if $-r_t > \widehat{VaR}_t(\alpha)$ or

$$I_t = 0,$$

otherwise,

for $t = n+1, n+2, ..., n+K$ as the hit sequence, where α is the confidence level for the VaR (often $\alpha = 0.95$ or $\alpha = 0.99$). Furthermore, denote $p = \alpha$ and let w be the actual covered proportion of losses in the data.

1. Unconditional coverage test:

$$H_{0,uc} : p = w$$

Let K_1 be the number of ones in I_t and analogously K_0 the number of zeros (all conditional on the first observation). Also calculate $\hat{w} = K_0/(K - 1)$. Obtain

$$L(I_t, p) = p^{K_0}(1 - p)^{K_1}$$

and

$$L(I_t, \hat{w}) = \hat{w}^{K_0}(1 - \hat{w})^{K_1}$$

and subsequently the test statistic

$$LR_{uc} = -2 * \ln\{L(I_t, p)/L(I_t, \hat{w})\}.$$

LR_{uc} now asymptotically follows a chi-square-distribution with one degree of freedom.

2. Conditional coverage test:

The conditional coverage test combines the unconditional coverage test with a test on independence. Denote by w_{ij} the probability of an i on day $t - 1$ being followed by a j on day t, where i and j correspond to the value of I_t on the respective day.

$$H_{0,cc} : w_{00} = w10 = p$$

with $i = 0, 1$ and $j = 0, 1$.

Let K_{ij} be the number of observations, where the values on two following days follow the pattern ij. Calculate

$$L(I_t, \hat{w}_{00}, \hat{w}_{10}) = \hat{w}_{00}^{K_{00}}(1-\hat{w}_{00})^{K_{01}} * \hat{w}_{10})^{K_{10}}(1-\hat{w}_{10})^{K_{11}},$$

where $\hat{w}_{00} = K_{00}/K_0$ and $\hat{w}_{10} = K_{10}/K_1$. The test statistic is then given by

$$LR_{cc} = -2 * \ln\{L(I_t, p)/L(I_t, \hat{w}_{00}, \hat{w}_{10})\},$$

which asymptotically follows a chi-square-distribution with two degrees of freedom.

3. Independence test:

$$H_{0,ind} : w_{00} = w_{10}$$

The asymptotically chi-square-distributed test statistic (one degree of freedom) is given by

$$LR_{ind} = -2 * \ln\{L(I_t, \hat{w}_{00}, \hat{w}_{10})/L(I_t, \hat{w})\}.$$

The function needs four inputs: the out-of-sample loss series `obj$loss`, the corresponding estimated VaR series `obj$VaR`, the coverage level `obj$p`, for which the VaR has been calculated and the significance level `conflvl`, at which the null hypotheses are evaluated. If an object returned by this function is entered into the R console, a detailed overview of the test results is printed.

Value

A list of class `quarks` with the following four elements:

p probability p stated in the null hypotheses of the coverage tests

p.uc the p-value of the unconditional coverage test

p.cc the p-value of the conditional coverage test

p.ind the p-value of the independence test

conflvl the significance level at which the null hypotheses are evaluated

model selected model for estimation; only available if a list returned by the `rollcast` function is passed to `cvgtest`

method selected method for estimation; only available if a list returned by the `rollcast`) function is passed to `cvgtest`

References

Christoffersen, P. F. (1998). Evaluating interval forecasts. International economic review, pp. 841-862.

Kupiec, P. (1995). Techniques for verifying the accuracy of risk measurement models. The J. of Derivatives, 3(2).

Examples

```
prices <- DAX$price_close
returns <- diff(log(prices))
n <- length(returns)
nout <- 250 # number of obs. for out-of-sample forecasting
nwin <- 500 # window size for rolling forecasts
results <- rollcast(x = returns, p = 0.975, method = 'age', nout = nout,
                    nwin = nwin)
cvgtest(results)
```

DAX *German Stock Market Index (DAX) Financial Time Series Data*

Description

A dataset that contains the daily financial data of the DAX from 2000 to December 2023 (currency in EUR).

Usage

```
DAX
```

Format

A data frame with 6094 rows and 11 variables:

ticker id of the stock

ref_date date in format YY-MM-DD

price_open opening price (daily)

price_high highest price (daily)

price_low lowest price (daily)

price_close closing price (daily)

volume trading volume

price_adjusted adjusted closing price (daily)

ret_adjusted_prices returns obtained from the adj. closing prices

ret_closing_prices returns obtained from the closing prices

cumret_adjusted_prices accumulated arithmetic/log return for the period

Source

The data was obtained from Yahoo Finance.

DJI *Dow Jones Industrial Average (DJI) Financial Time Series Data*

Description

A dataset that contains the daily financial data of the DJI from 2000 to December 2023 (currency in USD).

Usage

```
DJI
```

Format

A data frame with 6037 rows and 11 variables:

ticker id of the stock

ref_date date in format YY-MM-DD

price_open opening price (daily)

price_high highest price (daily)

price_low lowest price (daily)

price_close closing price (daily)

volume trading volume

price_adjusted adjusted closing price (daily)

ret_adjusted_prices returns obtained from the adj. closing prices

ret_closing_prices returns obtained from the closing prices

cumret_adjusted_prices accumulated arithmetic/log return for the period

Source

The data was obtained from Yahoo Finance.

ewma *Exponentially weighted moving average*

Description

Estimates volatility of a return series by means of an exponentially weighted moving average.

Usage

```
ewma(x, lambda = 0.94)
```

Arguments

x	a numeric vector of asset returns
lambda	decay factor for the calculation of weights; default is 0.94

Value

Returns a numerical vector vol that contains the computed volatility.

Examples

```
prices <- DAX$price_close
returns <- diff(log(prices))
date <- DAX$ref_date[-1]
cvar <- ewma(x = returns, lambda = 0.94)
csig <- sqrt(cvar)
plot(date, csig, type = 'l',
     main = 'conditional standard deviations for the DAX30 return series')
```

---

fhs *Filtered historical simulation*

Description

Calculates univariate Value at Risk and Expected Shortfall (Conditional Value at Risk) by means of filtered historical simulation. Volatility can be estimated with an exponentially weighted moving average or a GARCH-type model.

Usage

```
fhs(x, p = 0.975, model = c("EWMA", "GARCH"), lambda = 0.94, nboot = NULL, ...)
```

Arguments

x	a numeric vector of asset returns
p	confidence level for VaR calculation; default is 0.975
model	model for estimating conditional volatility; options are 'EWMA' and 'GARCH'; if model = 'GARCH', additional arguments can be adjusted via ...; default is 'EWMA'
lambda	decay factor for the calculation of weights; default is 0.94
nboot	size of bootstrap sample; must be a single non-NA integer value with nboot > 0; default is NULL
...	additional arguments of the ugarchspec function from the rugarch-package; only applied if model = 'GARCH'; default settings for the arguments variance.model and mean.model are: variance.model = list(model = 'sGARCH', garchOrder = c(1, 1)) mean.model = list(armaOrder = c(0, 0))

Value

Returns a list with the following elements:

VaR Calculated Value at Risk

ES Calculated Expected Shortfall (Conditional Value at Risk)

p Confidence level for VaR calculation

garchmod The model fit. Is the respective GARCH fit for `model = "GARCH"` (see `rugarch` documentation) and `'EWMA'` for `model = "EWMA"`

Examples

```
prices <- DAX$price_close
returns <- diff(log(prices))
# volatility weighting via EWMA
ewma <- fhs(x = returns, p = 0.975, model = "EWMA", lambda = 0.94,
            nboot = 10000)
ewma
# volatility weighting via GARCH
garch <- fhs(x = returns, p = 0.975, model = "GARCH", variance.model =
list(model = "sGARCH"), nboot = 10000)
garch
```

`FTSE100` *Financial Times Stock Exchange Index (FTSE) Financial Time Series Data*

Description

A dataset that contains the daily financial data of the FTSE from 2000 to December 2023 (currency in EUR).

Usage

```
FTSE100
```

Format

A data frame with 6060 rows and 11 variables:

ticker id of the stock

ref_date date in format YY-MM-DD

price_open opening price (daily)

price_high highest price (daily)

price_low lowest price (daily)

price_close closing price (daily)

volume trading volume

price_adjusted adjusted closing price (daily)

ret_adjusted_prices returns obtained from the adj. closing prices

ret_closing_prices returns obtained from the closing prices

cumret_adjusted_prices accumulated arithmetic/log return for the period

Source

The data was obtained from Yahoo Finance.

`hs` *Nonparametric calculation of univariate Value at Risk and Expected Shortfall*

Description

Computes Value at Risk and Expected Shortfall (Conditional Value at Risk) by means of plain and age-weighted historical simulation.

Usage

```
hs(x, p = 0.975, method = c("age", "plain"), lambda = 0.98)
```

Arguments

`x`	a numeric vector of asset returns
`p`	confidence level for VaR calculation; default is `0.975`
`method`	method to be used for calculation; default is `'plain'`
`lambda`	decay factor for the calculation of weights; default is `0.98`

Value

Returns a list with the following elements:

VaR Calculated Value at Risk

ES Calculated Expected Shortfall (Conditional Value at Risk)

p Confidence level for VaR calculation

Examples

```
prices <- DAX$price_close
returns <- diff(log(prices))
hs(x = returns, p = 0.975, method = 'plain')
hs(x = returns, p = 0.975, method = 'age', lambda = 0.98)
```

`HSI` *Hang Seng Index (HSI) Financial Time Series Data*

Description

A dataset that contains the daily financial data of the HSI from 2000 to December 2023.

Usage

```
HSI
```

Format

A data frame with 5914 rows and 11 variables:

ticker id of the stock

ref_date date in format YY-MM-DD

price_open opening price (daily)

price_high highest price (daily)

price_low lowest price (daily)

price_close closing price (daily)

volume trading volume

price_adjusted adjusted closing price (daily)

ret_adjusted_prices returns obtained from the adj. closing prices

ret_closing_prices returns obtained from the closing prices

cumret_adjusted_prices accumulated arithmetic/log return for the period

Source

The data was obtained from Yahoo Finance.

`lossfun` *Loss Functions*

Description

This functions allows for the calculation of loss functions in order to assess the performance of models in regard to forecasting ES.

Usage

```
lossfun(obj = list(loss = NULL, ES = NULL), beta = 1e-04)
```

Arguments

obj
: a list that contains the following elements:

  `loss` a numeric vector that contains the values of a loss series ordered from past to present; is set to `NULL` by default

  `ES` a numeric vector that contains the estimated values of the ES for the same time points of the loss series `loss`; is set to `NULL` by default

  Please note that a list returned by the `rollcast` function can be directly passed to `lossfun`.

beta
: a single numeric value; a measure for the opportunity cost of capital; default is `1e-04`.

Details

Given a negative return series `obj$loss`, the corresponding Expected Shortfall (ES) estimates `obj$ES` and a parameter `beta` that defines the opportunity cost of capital, four different definitions of loss functions are considered.

Value

an S3 class object, which is a list of

loss.fun1 regulatory loss function

loss.fun2 firm's loss function following Sarma et al. (2003)

loss.fun3 loss function following Abad et al. (2015)

loss.fun4 Feng's loss function; a compromise of regulatory and firm's loss function

References

Abad, P., Muela, S. B., & Martín, C. L. (2015). The role of the loss function in value-at-risk comparisons. The Journal of Risk Model Validation, 9(1), 1-19.

Sarma, M., Thomas, S., & Shah, A. (2003). Selection of Value-at-Risk models. Journal of Forecasting, 22(4), 337-358.

Examples

```
prices <- DAX$price_close
returns <- diff(log(prices))
n <- length(returns)
nout <- 250 # number of obs. for out-of-sample forecasting
nwin <- 500 # window size for rolling forecasts
results <- rollcast(x = returns, p = 0.975, method = 'age', nout = nout,
                    nwin = nwin)
loss <- -results$xout
ES <- results$ES
loss.data <- list(loss = loss, ES = ES)
lossfun(loss.data)

# directly passing the output object of 'rollcast()' to 'lossfun()'
```

```
lossfun(results)
```

`NIK225` *Nikkei Heikin Kabuka Index (NIK) Financial Time Series Data*

Description

A dataset that contains the daily financial data of the NIK from 2000 to December 2023.

Usage

```
NIK225
```

Format

A data frame with 5881 rows and 11 variables:

ticker id of the stock

ref_date date in format YY-MM-DD

price_open opening price (daily)

price_high highest price (daily)

price_low lowest price (daily)

price_close closing price (daily)

volume trading volume

price_adjusted adjusted closing price (daily)

ret_adjusted_prices returns obtained from the adj. closing prices

ret_closing_prices returns obtained from the closing prices

cumret_adjusted_prices accumulated arithmetic/log return for the period

Source

The data was obtained from Yahoo Finance.

plop — *Profit & Loss operator function*

Description

Calculates portfolio returns or losses by assigning weights

Usage

```
plop(x, wts = NULL, approxim = c(0, 1))
```

Arguments

`x`	a numeric matrix of asset returns or losses
`wts`	a numeric vector or matrix containing the portfolio weights; portfolio value is standardized to 1 on any observation unit; sum of weights should not exceed 1 (row-wise for matrices); by default the portfolio is equally weighted over time and across all assets; if a vector is passed to `wts` the portfolio is equally weighted over time
`approxim`	controls if a first-order approximation for the calculation of returns or losses is used; default is `1` (first-order approximation is employed)

Value

Returns a list with the following elements:

pl Weighted portfolio returns or losses

wts Portfolio weights

Examples

```
# creating portfolio
portfol <- cbind(SP500$price_close, DJI$price_close)
returns <- apply(portfol, 2, function(x) diff(log(x)))
# defining weights and applying the P&L operator function
wts <- c(0.4, 0.6)
portret <- plop(returns, wts = wts, approxim = 1)
portloss <- plop(-returns, wts = wts, approxim = 1)
plot.ts(cbind(portret$pl, portloss$pl))
```

plot.quarks — *Plot Method for the Package 'quarks'*

Description

This function regulates how objects created by the package quarks are plotted.

Usage

```
## S3 method for class 'quarks'
plot(x, ...)
```

Arguments

x	an input object of class quarks.
...	additional arguments of the standard plot method.

Value

None

print.quarks — *Print Method for the Package 'quarks'*

Description

This function regulates how objects created by the package quarks are printed.

Usage

```
## S3 method for class 'quarks'
print(x, ...)
```

Arguments

x	an input object of class quarks.
...	included for compatibility; additional arguments will however not affect the output.

Value

None

`rollcast` *Rolling one-step ahead forecasts of Value at Risk and Expected Shortfall*

Description

Computes rolling one-step ahead forecasts of Value at Risk and Expected Shortfall (Conditional Value at Risk) by means of plain historical simulation age- and volatility-weighted historical simulation as well as filtered historical simulation.

Usage

```
rollcast(
  x,
  p = 0.975,
  model = c("EWMA", "GARCH"),
  method = c("plain", "age", "vwhs", "fhs"),
  lambda = c(0.94, 0.98),
  nout = NULL,
  nwin = NULL,
  nboot = NULL,
  smoothscale = c("none", "lpr", "auto"),
  smoothopts = list(),
  ...
)
```

Arguments

`x`	a numeric vector of asset returns
`p`	confidence level for VaR calculation; default is `0.975`
`model`	model for estimating conditional volatility; options are `'EWMA'` and `'GARCH'`; if `model = 'GARCH'`, additional arguments can be adjusted via `...`; default is `'EWMA'`
`method`	method to be used for calculation; default is `'plain'`
`lambda`	decay factor for the calculation of weights; default is `0.98` for `method = 'age'` and `0.94` for `method = 'vwhs'` or `method = 'fhs'`
`nout`	number of out-of-sample observations; most recent observations are used; default is `NULL`
`nwin`	window size for rolling one-step forecasting; most recent observations before out-of-sample are used; default is `NULL`
`nboot`	size of bootstrap sample; must be a single non-NA integer value with `nboot > 0`; default is `NULL`

smoothscale
: a character object; defines the smoothing approach for the unconditional variance from the logarithm of the squared centralized returns; for `smoothscale = 'lpr'`, the unconditional variance is smoothed via the `smoots::gsmooth()` function from the `smoots` package; the bandwidth has to be chosen manually; otherwise the default is used; if `smoothscale = 'auto'`, the function `smoots::msmooth()` is employed and the bandwidth is chosen automatically (data-driven); see the documentation of the `smoots` package for more information; is set to `smoothscale = 'none'` by default

smoothopts
: additional arguments of `smoots::gsmooth()` and `smoots::msmooth()`; see the documentation of the `smoots` package for more information; is set to customized default settings

...
: additional arguments of the `ugarchspec` function from the `rugarch`-package; only applied if `model = 'GARCH'`; default settings for the arguments `variance.model` and `mean.model` are:

  `variance.model = list(model = 'sGARCH', garchOrder = c(1, 1))`

  `mean.model = list(armaOrder = c(0, 0))`

Value

Returns a list with the following elements:

VaR Numerical vector containing out-of-sample forecasts of Value at Risk

ES Numerical vector containing out-of-sample forecasts of Expected Shortfall (Conditional Value at Risk)

xout Numerical vector containing out-of-sample returns

p Confidence level for VaR calculation

model Model for estimating conditional volatility

method Method to be used for calculation

nout Number of out-of-sample observations

nwin Window size for rolling one-step forecasting

nboot Size of bootstrap sample

Examples

```
prices <- DAX$price_close
returns <- diff(log(prices))
n <- length(returns)
nout <- 250 # number of obs. for out-of-sample forecasting
nwin <- 1000 # window size for rolling forecasts


### Example 1 - plain historical simulation
results1 <- rollcast(x = returns, p = 0.975, method = 'plain', nout = nout,
                     nwin = nwin)
matplot(1:nout, cbind(-results1$xout, results1$VaR, results1$ES),
  type = 'hll',
  xlab = 'number of out-of-sample obs.', ylab = 'losses, VaR and ES',
```

```
  main = 'Plain HS - 97.5% VaR and ES for the DAX30 return series')

### Example 2 - age weighted historical simulation
results2 <- rollcast(x = returns, p = 0.975, method = 'age', nout = nout,
                     nwin = nwin)
matplot(1:nout, cbind(-results2$xout, results2$VaR, results2$ES),
  type = 'hll',
  xlab = 'number of out-of-sample obs.', ylab = 'losses, VaR and ES',
  main = 'Age weighted HS - 97.5% VaR and ES for the DAX30 return series')

### Example 3 - volatility weighted historical simulation - EWMA
results3 <- rollcast(x = returns, p = 0.975, model = 'EWMA',
                     method = 'vwhs', nout = nout, nwin = nwin)
matplot(1:nout, cbind(-results3$xout, results3$VaR, results3$ES),
  type = 'hll',
  xlab = 'number of out-of-sample obs.', ylab = 'losses, VaR and ES',
  main = 'Vol. weighted HS (EWMA) - 97.5% VaR and ES for the DAX30 return
  series')

### Example 4 - volatility weighted historical simulation - GARCH
results4 <- rollcast(x = returns, p = 0.975, model = 'GARCH',
                     method = 'vwhs', nout = nout, nwin = nwin)
matplot(1:nout, cbind(-results4$xout, results4$VaR, results4$ES),
  type = 'hll',
  xlab = 'number of out-of-sample obs.', ylab = 'losses, VaR and ES',
  main = 'Vol. weighted HS (GARCH) - 97.5% VaR and ES for the DAX30 return
  series')

### Example 5 - filtered historical simulation - EWMA
results5 <- rollcast(x = returns, p = 0.975, model = 'EWMA',
                     method = 'fhs', nout = nout, nwin = nwin, nboot = 10000)
matplot(1:nout, cbind(-results5$xout, results5$VaR, results5$ES),
  type = 'hll',
  xlab = 'number of out-of-sample obs.', ylab = 'losses, VaR and ES',
  main = 'Filtered HS (EWMA) - 97.5% VaR and ES for the DAX30 return
  series')

### Example 6 - filtered historical simulation - GARCH
results6 <- rollcast(x = returns, p = 0.975, model = 'GARCH',
                     method = 'fhs', nout = nout, nwin = nwin, nboot = 10000)
matplot(1:nout, cbind(-results6$xout, results6$VaR, results6$ES),
  type = 'hll',
  xlab = 'number of out-of-sample obs.', ylab = 'losses, VaR and ES',
  main = 'Filtered HS (GARCH) - 97.5% VaR and ES for the DAX30 return
  series')
```

---

runFTSdata *Application for downloading data from Yahoo Finance*

Description

Application for downloading data from Yahoo Finance

Usage

```
runFTSdata()
```

Value

None

SP500 *Standard and Poor's (SP500) Financial Time Series Data*

Description

A dataset that contains the daily financial data of the SP500 from 2000 to December 2023 (currency in USD).

Usage

```
SP500
```

Format

A data frame with 6037 rows and 11 variables:

ticker id of the stock

ref_date date in format YY-MM-DD

price_open opening price (daily)

price_high highest price (daily)

price_low lowest price (daily)

price_close closing price (daily)

volume trading volume

price_adjusted adjusted closing price (daily)

ret_adjusted_prices returns obtained from the adj. closing prices

ret_closing_prices returns obtained from the closing prices

cumret_adjusted_prices accumulated arithmetic/log return for the period

Source

The data was obtained from Yahoo Finance.

`trftest` *Backtesting of Value-at-Risk via Traffic Light Test*

Description

The Traffic Light Test, is applied to previously calculated Value-at-Risk series.

Usage

```
trftest(obj)
```

Arguments

`obj`	A list returned by the `rollcast` function, that contains a Value-at-Risk series; any other list that follows the name conventions of the `rollcast` function can be used as well.

Details

This function uses an object returned by the `rollcast` function of the `quarks` package as an input for the function argument `obj`. A list with different elements, such as the cumulative probabilities for the VaR series within `obj`, is returned. Instead of the list, only the traffic light backtesting results are printed to the R console.

Value

A list of class `quarks` is returned with the following elements.

model selected model for estimation

method selected method for estimation

p_VaR cumulative probability of observing the number of breaches or fewer for (1 - `p`)100%-VaR

pot_VaR number of exceedances for (1 - `p`)100%-VaR

p coverage level for (1-`p`)100% VaR

Examples

```
prices <- DAX$price_close
returns <- diff(log(prices))
n <- length(returns)
nout <- 250 # number of obs. for out-of-sample forecasting
nwin <- 500 # window size for rolling forecasts
results <- rollcast(x = returns, p = 0.975, method = 'age', nout = nout,
                    nwin = nwin)
trftest(results)
```

vwhs *Volatility weighted historical simulation*

Description

Calculates univariate Value at Risk and Expected Shortfall (Conditional Value at Risk) by means of volatility weighted historical simulation. Volatility can be estimated with an exponentially weighted moving average or a GARCH-type model.

Usage

```
vwhs(x, p = 0.975, model = c("EWMA", "GARCH"), lambda = 0.94, ...)
```

Arguments

x	a numeric vector of asset returns
p	confidence level for VaR calculation; default is `0.975`
model	model for estimating conditional volatility; default is `'EWMA'`
lambda	decay factor for the calculation of weights; default is `0.94`
...	additional arguments of the `ugarchspec` function from the `rugarch`-package; the default settings for the arguments `variance.model` and `mean.model` are `list(model = 'sGARCH',garchOrder = c(1, 1))` and `list(armaOrder = c(0, 0))`, respectively

Value

Returns a list with the following elements:

VaR Calculated Value at Risk

ES Calculated Expected Shortfall (Conditional Value at Risk)

p Confidence level for VaR calculation

garchmod The model fit. Is the respective GARCH fit for `model = 'GARCH'` (see `rugarch` documentation) and `'EWMA'` for `model = 'EWMA'`

Examples

```
prices <- DAX$price_close
returns <- diff(log(prices))
# volatility weighting via EWMA
ewma <- vwhs(x = returns, p = 0.975, model = "EWMA", lambda = 0.94)
ewma
# volatility weighting via GARCH
garch <- vwhs(x = returns, p = 0.975, model = "GARCH", variance.model =
list(model = "sGARCH"))
garch
```

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