

Package ‘HDSHOP’

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Title High-Dimensional Shrinkage Optimal Portfolios

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Description

Constructs shrinkage estimators of high-dimensional mean-variance portfolios and performs high-dimensional tests on optimality of a given portfolio. The techniques developed in Bodnar et al. (2018 <[doi:10.1016/j.ejor.2017.09.028](https://doi.org/10.1016/j.ejor.2017.09.028)>, 2019 <[doi:10.1109/TSP.2019.2929964](https://doi.org/10.1109/TSP.2019.2929964)>, 2020 <[doi:10.1109/TSP.2020.3037369](https://doi.org/10.1109/TSP.2020.3037369)>, 2021 <[doi:10.1080/07350015.2021.2004897](https://doi.org/10.1080/07350015.2021.2004897)>) are central to the package. They provide simple and feasible estimators and tests for optimal portfolio weights, which are applicable for 'large p and large n' situations where p is the portfolio dimension (number of stocks) and n is the sample size. The package also includes tools for constructing portfolios based on shrinkage estimators of the mean vector and covariance matrix as well as a new Bayesian estimator for the Markowitz efficient frontier recently developed by Bauder et al. (2021) <[doi:10.1080/14697688.2020.1748214](https://doi.org/10.1080/14697688.2020.1748214)>.

License GPL-3

URL <https://github.com/Otryakhin-Dmitry/global-minimum-variance-portfolio>

BugReports

<https://github.com/Otryakhin-Dmitry/global-minimum-variance-portfolio/issues>

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Class_MeanVar_portfolio
<i>S3 class MeanVar_portfolio</i>

Description

Class MeanVar_portfolio is designed to construct mean-variance portfolios with provided estimators of the mean vector, covariance matrix, and inverse covariance matrix. It includes the following elements:

Slots

Element	Description
call	the function call with which it was created
cov_mtrx	the sample covariance matrix of the asset returns
inv_cov_mtrx	the inverse of the sample covariance matrix
means	sample mean vector of the asset returns
weights	portfolio weights
Port_Var	portfolio variance
Port_mean_return	expected portfolio return
Sharpe	portfolio Sharpe ratio

See Also

summary.MeanVar_portfolio summary method for the class, [new_MeanVar_portfolio](#) class constructor, [validate_MeanVar_portfolio](#) class validator, [MeanVar_portfolio](#) class helper.

CovarEstim	<i>Covariance matrix estimator</i>
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Description

It is a function dispatcher for covariance matrix estimation. One can choose between traditional and shrinkage-based estimators.

Usage

```
CovarEstim(x, type = c("trad", "BGP14", "LW20"), ...)
```

Arguments

x	a p by n matrix or a data frame of asset returns. Rows represent different assets, columns – observations.
type	a character. The estimation method to be used.
...	arguments to pass to estimators

Details

The available estimation methods are:

Function	Paper	Type
Sigma_sample_estimator		traditional
CovShrinkBGP14	Bodnar et al 2014	BGP14

nonlin_shrinkLW

Ledoit & Wolf 2020 LW20

Value

an object of class matrix

Examples

```
n<-3e2 # number of realizations
p<-.5*n # number of assets

x <- matrix(data = rnorm(n*p), nrow = p, ncol = n)

Mtrx_trad <- CovarEstim(x, type="trad")

TM <- matrix(0, p, p)
diag(TM) <- 1
Mtrx_bgp <- CovarEstim(x, type="BGP14", TM=TM)

Mtrx_lw <- CovarEstim(x, type="LW20")
```

CovShrinkBGP14	<i>Linear shrinkage estimator of the covariance matrix (Bodnar et al. 2014)</i>
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Description

The optimal linear shrinkage estimator of the covariance matrix that minimizes the Frobenius norm:

$$\hat{\Sigma}_{OLSE} = \hat{\alpha}S + \hat{\beta}\Sigma_0,$$

where $\hat{\alpha}$ and $\hat{\beta}$ are optimal shrinkage intensities given in Eq. (4.3) and (4.4) of Bodnar et al. (2014). S is the sample covariance matrix (SCM, see [Sigma_sample_estimator](#)) and Σ_0 is a positive definite symmetric matrix used as the target matrix (TM), for example, $\frac{1}{p}I$.

Usage

```
CovShrinkBGP14(n, TM, SCM)
```

Arguments

n	sample size.
TM	the target matrix for the shrinkage estimator.
SCM	sample covariance matrix.

Value

a list containing an object of class matrix (S) and the estimated shrinkage intensities $\hat{\alpha}$ and $\hat{\beta}$.

References

Bodnar T, Gupta AK, Parolya N (2014). “On the strong convergence of the optimal linear shrinkage estimator for large dimensional covariance matrix.” *Journal of Multivariate Analysis*, **132**, 215–228.

Examples

```
# Parameter setting
n<-3e2
c<-0.7
p<-c*n
mu <- rep(0, p)
Sigma <- RandCovMtrx(p=p)

# Generating observations
X <- t(MASS::mvrnorm(n=n, mu=mu, Sigma=Sigma))

# Estimation
TM <- matrix(0, nrow=p, ncol=p)
diag(TM) <- 1/p
SCM <- Sigma_sample_estimator(X)
Sigma_shr <- CovShrinkBGP14(n=n, TM=TM, SCM=SCM)
Sigma_shr$S[1:6, 1:6]
```

InvCovShrinkBGP16	<i>Linear shrinkage estimator of the inverse covariance matrix (Bodnar et al. 2016)</i>
-------------------	---

Description

The optimal linear shrinkage estimator of the inverse covariance (precision) matrix that minimizes the Frobenius norm is given by:

$$\hat{\Pi}_{OLSE} = \hat{\alpha}\hat{\Pi} + \hat{\beta}\Pi_0,$$

where $\hat{\alpha}$ and $\hat{\beta}$ are optimal shrinkage intensities given in Eq. (4.4) and (4.5) of Bodnar et al. (2016). $\hat{\Pi}$ is the inverse of the sample covariance matrix (iSCM) and Π_0 is a positive definite symmetric matrix used as the target matrix (TM), for example, I.

Usage

```
InvCovShrinkBGP16(n, p, TM, iSCM)
```

Arguments

n	the number of observations
p	the number of variables (rows of the covariance matrix)
TM	the target matrix for the shrinkage estimator
iSCM	the inverse of the sample covariance matrix

Value

a list containing an object of class matrix (S) and the estimated shrinkage intensities $\hat{\alpha}$ and $\hat{\beta}$.

References

Bodnar T, Gupta AK, Parolya N (2016). “Direct shrinkage estimation of large dimensional precision matrix.” *Journal of Multivariate Analysis*, **146**, 223–236.

Examples

```
# Parameter setting
n <- 3e2
c <- 0.7
p <- c*n
mu <- rep(0, p)
Sigma <- RandCovMtrx(p=p)

# Generating observations
X <- t(MASS::mvrnorm(n=n, mu=mu, Sigma=Sigma))

# Estimation
TM <- matrix(0, nrow=p, ncol=p)
diag(TM) <- 1
iSCM <- solve(Sigma_sample_estimator(X))
Sigma_shr <- InvCovShrinkBGP16(n=n, p=p, TM=TM, iSCM=iSCM)
Sigma_shr$S[1:6, 1:6]
```

MeanEstim

Mean vector estimator

Description

A user-friendly function for estimation of the mean vector. Essentially, it is a function dispatcher for estimation of the mean vector that chooses a method accordingly to the type argument.

Usage

```
MeanEstim(x, type, ...)
```

Arguments

x	a p by n matrix or a data frame of asset returns. Rows represent different assets, columns – observations.
type	a character. The estimation method to be used.
...	arguments to pass to estimators

Details

The available estimation methods for the mean are:

Function	Paper	Type
.rowMeans		trad
mean_bs	Jorion 1986	bs
mean_js	Jorion 1986	js
mean_bop19	Bodnar et al 2019	BOP19

Value

a numeric vector— a value of the specified estimator of the mean vector.

References

Jorion P (1986). “Bayes-Stein estimation for portfolio analysis.” *Journal of Financial and Quantitative Analysis*, 279–292.

Bodnar T, Okhrin O, Parolya N (2019). “Optimal shrinkage estimator for high-dimensional mean vector.” *Journal of Multivariate Analysis*, **170**, 63–79.

Examples

```
n<-3e2 # number of realizations
p<-.5*n # number of assets

x <- matrix(data = rnorm(n*p), nrow = p, ncol = n)

Mean_trad <- MeanEstim(x, type="trad")

mu_0 <- rep(1/p, p)
Mean_BOP <- MeanEstim(x, type="BOP19", mu_0=mu_0)
```

MeanVar_portfolio *A helper function for MeanVar_portfolio*

Description

A user-friendly function making mean-variance portfolios for assets with customly computed covariance matrix and mean returns. The weights are computed in accordance with the formula

$$\hat{w}_{MV} = \frac{\hat{\Sigma}^{-1} \mathbf{1}}{\mathbf{1}' \hat{\Sigma}^{-1} \mathbf{1}} + \gamma^{-1} \hat{Q} \hat{\mu},$$

where $\hat{\Sigma}$ is an estimator for the covariance matrix, $\hat{\mu}$ is an estimator for the mean vector, γ is the coefficient of risk aversion, and $\hat{Q}$ is given by

$$\hat{Q} = \hat{\Sigma}^{-1} - \frac{\hat{\Sigma}^{-1} \mathbf{1} \mathbf{1}' \hat{\Sigma}^{-1}}{\mathbf{1}' \hat{\Sigma}^{-1} \mathbf{1}}.$$

The computation is made by [new_MeanVar_portfolio](#) and the result is validated by [validate_MeanVar_portfolio](#).

Usage

```
MeanVar_portfolio(mean_vec, cov_mtrx, gamma)
```

Arguments

mean_vec mean vector of asset returns provided in the form of a vector or a list.
 cov_mtrx the covariance matrix of asset returns. It could be a matrix or a data frame.
 gamma a numeric variable. Coefficient of risk aversion.

Value

Mean-variance portfolio in the form of object of S3 class MeanVar_portfolio.

Examples

```
n<-3e2 # number of realizations
p<-.5*n # number of assets
gamma<-1

x <- matrix(data = rnorm(n*p), nrow = p, ncol = n)

# Simple MV portfolio
cov_mtrx <- Sigma_sample_estimator(x)
means <- rowMeans(x)

cust_port_simp <- MeanVar_portfolio(mean_vec=means,
                                     cov_mtrx=cov_mtrx, gamma=2)

str(cust_port_simp)
```

mean_bop19

BOP shrinkage estimator

Description

Shrinkage estimator of the high-dimensional mean vector as suggested in Bodnar et al. (2019). It uses the formula

$$\hat{\mu}_{BOP} = \hat{\alpha}\bar{x} + \hat{\beta}\mu_0,$$

where $\hat{\alpha}$ and $\hat{\beta}$ are shrinkage coefficients given by Eq.(6) and Eg.(7) of Bodnar et al. (2019) that minimize weighted quadratic loss for a given target vector μ_0 (shrinkage target). $\bar{x}$ stands for the sample mean vector.

Usage

```
mean_bop19(x, mu_0 = rep(1, p))
```

Arguments

x	a p by n matrix or a data frame of asset returns. Rows represent different assets, columns – observations.
mu_0	a numeric vector. The target vector used in the construction of the shrinkage estimator.

Value

a numeric vector containing the shrinkage estimator of the mean vector

References

Bodnar T, Okhrin O, Parolya N (2019). “Optimal shrinkage estimator for high-dimensional mean vector.” *Journal of Multivariate Analysis*, **170**, 63–79.

Examples

```
n<-7e2 # number of realizations
p<-.5*n # number of assets
x <- matrix(data = rnorm(n*p), nrow = p, ncol = n)
mm <- mean_bop19(x=x, mu_0=rep(1,p))
```

mean_bs

*Bayes-Stein shrinkage estimator of the mean vector***Description**

Bayes-Stein shrinkage estimator of the mean vector as suggested in Jorion (1986). The estimator is given by

$$\hat{\mu}_{BS} = (1 - \beta)\bar{x} + \beta Y_0 1,$$

where $\bar{x}$ is the sample mean vector, β and Y_0 are derived using Bayesian approach (see Eq.(14) and Eq.(17) in Jorion (1986)).

Usage

```
mean_bs(x)
```

Arguments

x	a p by n matrix or a data frame of asset returns. Rows represent different assets, columns – observations.
---	--

Value

a numeric vector containing the Bayes-Stein shrinkage estimator of the mean vector

References

Jorion P (1986). “Bayes-Stein estimation for portfolio analysis.” *Journal of Financial and Quantitative Analysis*, 279–292.

Examples

```
n <- 7e2 # number of realizations
p <- .5*n # number of assets
x <- matrix(data = rnorm(n*p), nrow = p, ncol = n)
mm <- mean_bs(x=x)
```

mean_js

James-Stein shrinkage estimator of the mean vector

Description

James-Stein shrinkage estimator of the mean vector as suggested in Jorion (1986). The estimator is given by

$$\hat{\mu}_{JS} = (1 - \beta)\bar{x} + \beta Y_0 \mathbf{1},$$

where $\bar{x}$ is the sample mean vector, β is the shrinkage coefficient which minimizes a quadratic loss given by Eq.(11) in Jorion (1986). Y_0 is a prespecified value.

Usage

```
mean_js(x, Y_0 = 1)
```

Arguments

x a p by n matrix or a data frame of asset returns. Rows represent different assets, columns – observations.

Y_0 a numeric variable. Shrinkage target coefficient.

Value

a numeric vector containing the James-Stein shrinkage estimator of the mean vector.

References

Jorion P (1986). “Bayes-Stein estimation for portfolio analysis.” *Journal of Financial and Quantitative Analysis*, 279–292.

Examples

```
n<-7e2 # number of realizations
p<-.5*n # number of assets
x <- matrix(data = rnorm(n*p), nrow = p, ncol = n)
mm <- mean_js(x=x, Y_0 = 1)
```

MVShrinkPortfolio	<i>Shrinkage mean-variance portfolio</i>
-------------------	--

Description

The main function for mean-variance (also known as expected utility) portfolio construction. It is a dispatcher using methods according to argument type, values of gamma and dimensionality of matrix x.

Usage

```
MVShrinkPortfolio(x, gamma, type = c("shrinkage", "traditional"), ...)
```

Arguments

x	a p by n matrix or a data frame of asset returns. Rows represent different assets, columns – observations.
gamma	a numeric variable. Coefficient of risk aversion.
type	a character. The type of methods to use to construct the portfolio.
...	arguments to pass to portfolio constructors

Details

The sample estimator of the mean-variance portfolio weights, which results in a traditional mean-variance portfolio, is calculated by

$$\hat{w}_{MV} = \frac{S^{-1}1}{1'S^{-1}1} + \gamma^{-1}\hat{Q}\bar{x},$$

where S^{-1} and $\bar{x}$ are the inverse of the sample covariance matrix and the sample mean vector of asset returns respectively, γ is the coefficient of risk aversion and $\hat{Q}$ is given by

$$\hat{Q} = S^{-1} - \frac{S^{-1}11'S^{-1}}{1'S^{-1}1}.$$

In the case when $p > n$, S^{-1} becomes S^{+} - Moore-Penrose inverse. The shrinkage estimator for the mean-variance portfolio weights in a high-dimensional setting is given by

$$\hat{w}_{ShMV} = \hat{\alpha}\hat{w}_{MV} + (1 - \hat{\alpha})b,$$

where $\hat{\alpha}$ is the estimated shrinkage intensity and b is a target vector with the sum of the elements equal to one.

In the case $\gamma \neq \infty$, $\hat{\alpha}$ is computed following Eq. (2.22) of Bodnar et al. (2023) for $c < 1$ and following Eq. (2.29) of Bodnar et al. (2023) for $c > 1$.

The case of a fully risk averse investor ($\gamma = \infty$) leads to the traditional global minimum variance (GMV) portfolio with the weights given by

$$\hat{w}_{GMV} = \frac{S^{-1}1}{1'S^{-1}1}.$$

The shrinkage estimator for the GMV portfolio is then calculated by

$$\hat{w}_{ShGMV} = \hat{\alpha}\hat{w}_{GMV} + (1 - \hat{\alpha})b,$$

with $\hat{\alpha}$ given in Eq. (2.31) of Bodnar et al. (2018) for $c < 1$ and in Eq. (2.33) of Bodnar et al. (2018) for $c > 1$.

These estimation methods are available as separate functions employed by MVShrinkPortfolio accordingly to the following parameter configurations:

Function	Paper	Type	gamma	p/n
new_MV_portfolio_weights_BDOPS21	Bodnar et al. (2023)	shrinkage	< Inf	<1
new_MV_portfolio_weights_BDOPS21_pgn	Bodnar et al. (2023)	shrinkage	< Inf	>1
new_GMV_portfolio_weights_BDPS19	Bodnar et al. (2018)	shrinkage	Inf	<1
new_GMV_portfolio_weights_BDPS19_pgn	Bodnar et al. (2018)	shrinkage	Inf	>1
new_MV_portfolio_traditional		traditional	> 0	<1
new_MV_portfolio_traditional_pgn		traditional	> 0	>1

Value

A portfolio in the form of an object of class `MeanVar_portfolio` potentially with a subclass. See [Class_MeanVar_portfolio](#) for the details of the class.

References

- Bodnar T, Okhrin Y, Parolya N (2023). “Optimal shrinkage-based portfolio selection in high dimensions.” *Journal of Business & Economic Statistics*, **41**, 140-156.
- Bodnar T, Parolya N, Schmid W (2018). “Estimation of the global minimum variance portfolio in high dimensions.” *European Journal of Operational Research*, **266**(1), 371–390.

Examples

```
n<-3e2 # number of realizations
gamma<-1

# The case p<n

p<-.5*n # number of assets
b<-rep(1/p,p)

x <- matrix(data = rnorm(n*p), nrow = p, ncol = n)

test <- MVShrinkPortfolio(x=x, gamma=gamma,
                          type='shrinkage', b=b, beta = 0.05)
str(test)

test <- MVShrinkPortfolio(x=x, gamma=Inf,
                          type='shrinkage', b=b, beta = 0.05)
str(test)
```

```

test <- MVShrinkPortfolio(x=x, gamma=gamma, type='traditional')
str(test)

# The case p>n

p<-1.2*n # Re-define the number of assets
b<-rep(1/p,p)

x <- matrix(data = rnorm(n*p), nrow = p, ncol = n)

test <- MVShrinkPortfolio(x=x, gamma=gamma, type='shrinkage',
                          b=b, beta = 0.05)
str(test)

test <- MVShrinkPortfolio(x=x, gamma=Inf, type='shrinkage',
                          b=b, beta = 0.05)
str(test)

```

new_GMV_portfolio_weights_BDPS19

Constructor of GMV portfolio object.

Description

Constructor of global minimum variance portfolio. new_GMV_portfolio_weights_BDPS19 is for the case $p < n$, while new_GMV_portfolio_weights_BDPS19_pgn is for $p > n$, where p is the number of assets and n is the number of observations. For more details of the method, see [MVShrinkPortfolio](#).

Usage

```

new_GMV_portfolio_weights_BDPS19(x, b, beta)

new_GMV_portfolio_weights_BDPS19_pgn(x, b, beta)

```

Arguments

x	a p by n matrix or a data frame of asset returns. Rows represent different assets, columns – observations.
b	a numeric vector. $1 - \beta$ is the confidence level of the symmetric confidence interval, constructed for each weight.
beta	a numeric variable. The confidence level for weight intervals.

Value

an object of class MeanVar_portfolio with subclass GMV_portfolio_weights_BDPS19.

Element	Description
call	the function call with which it was created
cov_mtrx	the sample covariance matrix of the asset returns
inv_cov_mtrx	the inverse of the sample covariance matrix
means	sample mean vector estimate of the asset returns
w_GMVP	sample estimator of portfolio weights
weights	shrinkage estimator of portfolio weights
alpha	shrinkage intensity for the weights
Port_Var	portfolio variance
Port_mean_return	expected portfolio return
Sharpe	portfolio Sharpe ratio
weight_intervals	A data frame, see details

weight_intervals contains a shrinkage estimator of portfolio weights, asymptotic confidence intervals for the true portfolio weights, the value of test statistic and the p-value of the test on the equality of the weight of each individual asset to zero (see Section 4.3 of Bodnar et al. 2023). weight_intervals is only computed when $p < n$.

References

- Bodnar T, Dmytriv S, Parolya N, Schmid W (2019). “Tests for the weights of the global minimum variance portfolio in a high-dimensional setting.” *IEEE Transactions on Signal Processing*, **67**(17), 4479–4493.
- Bodnar T, Parolya N, Schmid W (2018). “Estimation of the global minimum variance portfolio in high dimensions.” *European Journal of Operational Research*, **266**(1), 371–390.
- Bodnar T, Dette H, Parolya N, Thorsén E (2023). “Corrigendum to "Sampling Distributions of Optimal Portfolio Weights and Characteristics in Low and Large Dimensions.".” *Random Matrices: Theory and Applications*, **12**, 2392001. doi:10.1142/S2010326323920016.

Examples

```
# c<1

n <- 3e2 # number of realizations
p <- .5*n # number of assets
b <- rep(1/p,p)

# Assets with a diagonal covariance matrix
x <- matrix(data = rnorm(n*p), nrow = p, ncol = n)

test <- new_GMV_portfolio_weights_BDPS19(x=x, b=b, beta=0.05)
str(test)

# Assets with a non-diagonal covariance matrix
Mtrx <- RandCovMtrx(p=p)
x <- t(MASS::mvrnorm(n=n , mu=rep(0,p), Sigma=Mtrx))

test <- new_GMV_portfolio_weights_BDPS19(x=x, b=b, beta=0.05)
```

```
summary(test)

# c>1

p <- 1.3*n # number of assets
b <- rep(1/p,p)

# Assets with a diagonal covariance matrix
x <- matrix(data = rnorm(n*p), nrow = p, ncol = n)

test <- new_GMV_portfolio_weights_BDPS19_pgn(x=x, b=b, beta=0.05)
str(test)
```

new_MeanVar_portfolio *A constructor for class MeanVar_portfolio*

Description

A light-weight constructor of objects of S3 class MeanVar_portfolio. This function is for development purposes. A helper function equipped with error messages and allowing more flexible input is [MeanVar_portfolio](#).

Usage

```
new_MeanVar_portfolio(mean_vec, cov_mtrx, gamma)
```

Arguments

mean_vec	mean vector of asset returns
cov_mtrx	the covariance matrix of asset returns
gamma	a numeric variable. Coefficient of risk aversion.

Value

Mean-variance portfolio in the form of object of S3 class MeanVar_portfolio.

Examples

```
n<-3e2 # number of realizations
p<-.5*n # number of assets
gamma<-1

x <- matrix(data = rnorm(n*p), nrow = p, ncol = n)

# Simple MV portfolio
cov_mtrx <- Sigma_sample_estimator(x)
means <- rowMeans(x)
```

```

cust_port_simp <- new_MeanVar_portfolio(mean_vec=means,
                                       cov_mtrx=cov_mtrx, gamma=2)
str(cust_port_simp)

# Portfolio with Bayes-Stein shrunk means
# and a Ledoit and Wolf estimator for covariance matrix
TM <- matrix(0, p, p)
diag(TM) <- 1
cov_mtrx <- CovarEstim(x, type="LW20", TM=TM)
means <- mean_bs(x)

cust_port_BS_LW <- new_MeanVar_portfolio(mean_vec=means$means,
                                       cov_mtrx=cov_mtrx, gamma=2)
str(cust_port_BS_LW)

```

new_MV_portfolio_traditional

Traditional mean-variance portfolio

Description

Mean-variance portfolios with the traditional (sample) estimators for the mean vector and the covariance matrix of asset returns. For more details of the method, see [MVShrinkPortfolio](#). new_MV_portfolio_traditional is for the case $p < n$, while new_MV_portfolio_traditional_pgn is for $p > n$, where p is the number of assets and n is the number of observations.

Usage

```

new_MV_portfolio_traditional(x, gamma)

new_MV_portfolio_traditional_pgn(x, gamma)

```

Arguments

x	a p by n matrix or a data frame of asset returns. Rows represent different assets, columns – observations.
gamma	a numeric variable. Coefficient of risk aversion.

Value

an object of class MeanVar_portfolio

Element	Description
call	the function call with which it was created
cov_mtrx	the sample covariance matrix of asset returns
inv_cov_mtrx	the inverse of the sample covariance matrix
means	sample mean estimator of the asset returns
W_mv_hat	sample estimator of portfolio weights

Port_Var	portfolio variance
Port_mean_return	expected portfolio return
Sharpe	portfolio Sharpe ratio

Examples

```
n <- 3e2 # number of realizations
p <- .5*n # number of assets
gamma <- 1

x <- matrix(data = rnorm(n*p), nrow = p, ncol = n)

test <- new_MV_portfolio_traditional(x=x, gamma=gamma)
str(test)
```

new_MV_portfolio_weights_BDOPS21

Constructor of MV portfolio object

Description

Constructor of mean-variance shrinkage portfolios. `new_MV_portfolio_weights_BDOPS21` is for the case $p < n$, while `new_MV_portfolio_weights_BDOPS21_pgn` is for $p > n$, where p is the number of assets and n is the number of observations. For more details of the method, see [MVShrinkPortfolio](#).

Usage

```
new_MV_portfolio_weights_BDOPS21(x, gamma, b, beta)
```

```
new_MV_portfolio_weights_BDOPS21_pgn(x, gamma, b, beta)
```

Arguments

<code>x</code>	a p by n matrix or a data frame of asset returns. Rows represent different assets, columns – observations.
<code>gamma</code>	a numeric variable. Coefficient of risk aversion.
<code>b</code>	a numeric variable. $1 - \beta$ is the confidence level of the symmetric confidence interval, constructed for each weight.
<code>beta</code>	a numeric variable. The confidence level for weight intervals.

Value

an object of class `MeanVar_portfolio` with subclass `MV_portfolio_weights_BDOPS21`.

Element	Description
call	the function call with which it was created

cov_mtrx	the sample covariance matrix of the asset returns
inv_cov_mtrx	the inverse of the sample covariance matrix
means	sample mean vector of the asset returns
W_mv_hat	sample estimator of the portfolio weights
weights	shrinkage estimator of the portfolio weights
alpha	shrinkage intensity for the weights
Port_Var	portfolio variance
Port_mean_return	expected portfolio return
Sharpe	portfolio Sharpe ratio
weight_intervals	A data frame, see details

weight_intervals contains a shrinkage estimator of portfolio weights, asymptotic confidence intervals for the true portfolio weights, value of the test statistic and the p-value of the test on the equality of the weight of each individual asset to zero (see Section 4.3 of Bodnar et al. 2023) weight_intervals is only computed when $p < n$.

References

- Bodnar T, Dmytriv S, Okhrin Y, Parolya N, Schmid W (2021). “Statistical Inference for the Expected Utility Portfolio in High Dimensions.” *IEEE Transactions on Signal Processing*, **69**, 1-14.
- Bodnar T, Dette H, Parolya N, Thorsén E (2023). “Corrigendum to "Sampling Distributions of Optimal Portfolio Weights and Characteristics in Low and Large Dimensions.".” *Random Matrices: Theory and Applications*, **12**, 2392001. doi:10.1142/S2010326323920016.

Examples

```
# c<1

# Assets with a diagonal covariance matrix

n <- 3e2 # number of realizations
p <- .5*n # number of assets
b <- rep(1/p,p)
gamma <- 1

x <- matrix(data = rnorm(n*p), nrow = p, ncol = n)

test <- new_MV_portfolio_weights_BDOPS21(x=x, gamma=gamma, b=b, beta=0.05)
summary(test)

# Assets with a non-diagonal covariance matrix

Mtrx <- RandCovMtrx(p=p)
x <- t(MASS::mvrnorm(n=n , mu=rep(0,p), Sigma=Mtrx))

test <- new_MV_portfolio_weights_BDOPS21(x=x, gamma=gamma, b=b, beta=0.05)
str(test)
```

```
# c>1

n <-2e2 # number of realizations
p <-1.2*n # number of assets
b <-rep(1/p,p)
x <- matrix(data = rnorm(n*p), nrow = p, ncol = n)

test <- new_MV_portfolio_weights_BDOPS21_pgn(x=x, gamma=gamma,
                                              b=b, beta=0.05)

summary(test)

# Assets with a non-diagonal covariance matrix
```

nonlin_shrinkLW	<i>nonlinear shrinkage estimator of the covariance matrix of Ledoit and Wolf (2020)</i>
-----------------	---

Description

The nonlinear shrinkage estimator of the covariance matrix, that minimizes the minimum variance loss functions as defined in Eq (2.1) of Ledoit and Wolf (2020).

Usage

```
nonlin_shrinkLW(x)
```

Arguments

x a p by n matrix or a data frame of asset returns. Rows represent different assets, columns – observations.

Value

an object of class matrix

References

Ledoit O, Wolf M (2020). “Analytical nonlinear shrinkage of large-dimensional covariance matrices.” *Annals of Statistics*, **48**(5), 3043–3065.

Examples

```
n<-3e2
c<-0.7
p<-c*n
mu <- rep(0, p)
Sigma <- RandCovMtrx(p=p)

X <- t(MASS::mvrnorm(n=n, mu=mu, Sigma=Sigma))
Sigma_shr <- nonlin_shrinkLW(X)
```



```

MV_trad_port <- new_MV_portfolio_traditional(x=x, gamma=gamma)$weights
GMV_trad_port <- new_MV_portfolio_traditional(x=x, gamma=Inf)$weights

weights.eff <- cbind(EW_port, MV_shr_port, GMV_shr_port,
                    MV_trad_port, GMV_trad_port)
colnames(weights.eff) <- c("EW", "MV_shr", "GMV_shr", "MV_trad", "GMV_trad")

Fplot <- plot_frontier(x, weights.eff)
Fplot

```

RandCovMtrx	<i>Covariance matrix generator</i>
-------------	------------------------------------

Description

Generates a covariance matrix from Wishart distribution with given eigenvalues or with exponentially decreasing eigenvalues. Useful for examples and tests when an arbitrary covariance matrix is needed.

Usage

```
RandCovMtrx(p = 200, eigenvalues = 0.1 * exp(5 * seq_len(p)/p))
```

Arguments

p	dimension of the covariance matrix
eigenvalues	the vector of positive eigenvalues

Details

This function generates a symmetric positive definite covariance matrix with given eigenvalues. The eigenvalues can be specified explicitly. Or, by default, they are generated with exponential decay.

Value

covariance matrix

Examples

```

p<-1e1
# A non-diagonal covariance matrix
Mtrx <- RandCovMtrx(p=p)
Mtrx

```

Sigma_sample_estimator

Sample covariance matrix

Description

It computes the sample covariance of matrix S as follows:

$$S = \frac{1}{n-1} \sum_{j=1}^n (x_j - \bar{x})(x_j - \bar{x})', \quad \bar{x} = \frac{1}{n} \sum_{j=1}^n x_j,$$

where x_j is the j -th column of the data matrix x .

Usage

```
Sigma_sample_estimator(x)
```

Arguments

x a p by n matrix or a data frame of asset returns. Rows represent different assets, columns – observations.

Value

Sample covariance estimation

Examples

```
p<-5 # number of assets
n<-1e1 # number of realizations

x <-matrix(data = rnorm(n*p), nrow = p, ncol = n)
Sigma_sample_estimator(x)
```

SP_daily_asset_returns

Daily log-returns of selected constituents S&P500.

Description

Daily log-returns of selected constituents of S&P500 in percents. The data are sampled in business time, i.e., weekends and holidays are omitted.

Usage

```
SP_daily_asset_returns
```

Format

a matrix with the first column containing the data and company names as column labels.

Source

Yahoo finance

test_MVSP	<i>Test for mean-variance portfolio weights</i>
-----------	---

Description

A high-dimensional asymptotic test on the mean-variance efficiency of a given portfolio with the weights w_0 . The tested hypotheses are

$$H_0 : w_{MV} = w_0 \quad vs \quad H_1 : w_{MV} \neq w_0.$$

The test statistic is based on the shrinkage estimator of mean-variance portfolio weights (see Eq.(44) of Bodnar et al. 2021).

Usage

```
test_MVSP(gamma, x, w_0, beta = 0.05)
```

Arguments

gamma	a numeric variable. Coefficient of risk aversion.
x	a p by n matrix or a data frame of asset returns. Rows represent different assets, columns – observations.
w_0	a numeric vector of tested weights.
beta	a significance level for the test.

Details

Note: when $\gamma == \text{Inf}$, we get the test for the weights of the global minimum variance portfolio as in Theorem 2 of Bodnar et al. (2019).

Value

Element	Description
alpha_hat	the estimated shrinkage intensity
alpha_sd	the standard deviation of the shrinkage intensity
alpha_lower	the lower bound for the shrinkage intensity
alpha_upper	the upper bound for the shrinkage intensity
T_alpha	the value of the test statistic
p_value	the p-value for the test

References

Bodnar T, Dmytriv S, Okhrin Y, Parolya N, Schmid W (2021). “Statistical Inference for the Expected Utility Portfolio in High Dimensions.” *IEEE Transactions on Signal Processing*, **69**, 1-14.

Bodnar T, Dmytriv S, Parolya N, Schmid W (2019). “Tests for the weights of the global minimum variance portfolio in a high-dimensional setting.” *IEEE Transactions on Signal Processing*, **67**(17), 4479–4493.

Examples

```
n<-3e2 # number of realizations
p<-.5*n # number of assets
b<-rep(1/p,p)
gamma<-1

x <- matrix(data = rnorm(n*p), nrow = p, ncol = n)

T_alpha <- test_MVSP(gamma=gamma, x=x, w_0=b, beta=0.05)
T_alpha
```

validate_MeanVar_portfolio

A validator for objects of class MeanVar_portfolio

Description

A validator for objects of class MeanVar_portfolio

Usage

```
validate_MeanVar_portfolio(w)
```

Arguments

w Object of class MeanVar_portfolio.

Value

If the object passes all the checks, then w itself is returned, otherwise an error is thrown.

Examples

```
n<-3e2 # number of realizations
p<-.5*n # number of assets
gamma<-1

x <- matrix(data = rnorm(n*p), nrow = p, ncol = n)

# Simple MV portfolio
cov_mtrx <- Sigma_sample_estimator(x)
means <- rowMeans(x)

cust_port_simp <- new_MeanVar_portfolio(mean_vec=means,
                                       cov_mtrx=cov_mtrx, gamma=2)
str(validate_MeanVar_portfolio(cust_port_simp))
```

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