Package ‘HDSOP’

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Title High-Dimensional Shrinkage Optimal Portfolios

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Description Applications of the shrinkage-type methods for estimation and inference of high-dimensional mean-variance portfolios. The techniques developed in Bodnar et al. (2018) <doi:10.1016/j.ejor.2017.09.028>, Bodnar et al. (2019) <doi:10.1109/TSP.2019.2929964>, Bodnar et al. (2020) <doi:10.1109/TSP.2020.3037369> 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 with shrinkage means and covariance matrices 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>.

License GPL-3

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**HDShOP-package**

**R topics documented:**

- HDShOP-package
- Class_MeanVar_portfolio
- CovarEstim
- CovShrinkBGP14
- InvCovShrinkBGP16
- MeanEstim
- MeanVar_portfolio
- mean_bop19
- mean_bs
- mean_js
- MVShrinkPortfolio
- new_GMV_portfolio_weights_BDPS19
- new_MeanVar_portfolio
- new_MV_portfolio_traditional
- new_MV_portfolio_weights_BDOPS21
- nonlin_shrinkLW
- plot_frontier
- RandCovMtrx
- Sigma_sample_estimator
- SP_daily_asset_returns
- test_MVSP
- validate_MeanVar_portfolio

---

**Index**

<table>
<thead>
<tr>
<th>HDShOP-package</th>
<th>A set of tools for shrinkage estimation of mean-variance optimal portfolios</th>
</tr>
</thead>
</table>

**Description**

Package HDShOP has the following three important functions: `MVShrinkPortfolio`, `CovarEstim` and `MeanEstim`. `MVShrinkPortfolio` creates mean-variance portfolios using shrinkage estimation methods for portfolio weights. `CovarEstim` computes estimates of covariance matrices while `MeanEstim` ones for mean vectors. Each of these three functions is supplied a name of the method to use to perform estimation. All portfolios are stored in objects of class `MeanVar_portfolio` and some have a subclass, specific to their kind, that inherits from `MeanVar_portfolio`. For the later class constructor, validator and helper functions are available, so that custom mean-variance portfolios may be coded by users.

**Methods**

- MeanEstim: (Bodnar et al. 2019), James-Stein and Bayes-Stein estimators (Jorion 1986).
- CovarEstim: (Bodnar et al. 2014), (Ledoit and Wolf 2020).
- MVShrinkPortfolio: (Bodnar et al. 2021), (Bodnar et al. 2019).
Class_MeanVar_portfolio

References


Class_MeanVar_portfolio

S3 class MeanVar_portfolio

Description

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

Slots

<table>
<thead>
<tr>
<th>Element</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>call</td>
<td>the function call with which it was created</td>
</tr>
<tr>
<td>cov_mtrx</td>
<td>the sample covariance matrix of the asset returns</td>
</tr>
<tr>
<td>inv_cov_mtrx</td>
<td>the inverse of the sample covariance matrix</td>
</tr>
<tr>
<td>means</td>
<td>sample mean vector estimate of the asset returns</td>
</tr>
<tr>
<td>weights</td>
<td>portfolio weights</td>
</tr>
<tr>
<td>Port_Var</td>
<td>portfolio variance</td>
</tr>
<tr>
<td>Port_mean_return</td>
<td>expected portfolio return</td>
</tr>
<tr>
<td>Sharpe</td>
<td>portfolio Sharpe ratio</td>
</tr>
</tbody>
</table>
CovarEstim

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

Covariance matrix estimator

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:

<table>
<thead>
<tr>
<th>Function</th>
<th>Paper</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sigma_sample_estimator</td>
<td></td>
<td>traditional</td>
</tr>
<tr>
<td>CovShrinkBGP14</td>
<td>Bodnar et al 2014</td>
<td>BGP14</td>
</tr>
<tr>
<td>nonlin_shrinkLW</td>
<td>Ledoit &amp; Wolf 2020</td>
<td>LW20</td>
</tr>
</tbody>
</table>

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)
CovShrinkBGP14

5

diag(TM) <- 1
Mtrx_bgp <- CovarEstim(x, type="BGP14", TM=TM)
Mtrx_lw <- CovarEstim(x, type="LW20")

CovShrinkBGP14

Linear shrinkage estimator of the covariance matrix (Bodnar et al. 2014)

Description

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

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

where \(\hat{\alpha}\) and \(\hat{\beta}\) are optimal shrinkage intensities given in Eq. (4.3) and (4.4) of Bodnar et al. (2014). \(\hat{\Sigma}\) is the sample covariance matrix (SCM, see Sigma_sample_estimator) and \(\Sigma_0\) is a positive definite symmetric matrix used as the target (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


Examples

# Parameter setting
n<-3e2
c<-0.7
p<-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**  
*Linear shrinkage estimator of the inverse covariance matrix (Bodnar et al. 2016)*

**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 sample inverse covariance matrix (iSCM) and $\Pi_0$ 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**

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:

<table>
<thead>
<tr>
<th>Function</th>
<th>Paper</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>.rowMeans</td>
<td>trad</td>
<td></td>
</tr>
<tr>
<td>mean_bs</td>
<td>Jorion 1986</td>
<td>bs</td>
</tr>
<tr>
<td>mean_js</td>
<td>Jorion 1986</td>
<td>js</td>
</tr>
<tr>
<td>mean_bop19</td>
<td>Bodnar et al 2019</td>
<td>BOP19</td>
</tr>
</tbody>
</table>
Value

A numeric vector containing the specified estimation of the mean vector.

References


Examples

```r
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)
```

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

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

where \( S^{-1} \) is the inverse of the covariance matrix, \( \bar{x} \) is the mean vector of asset returns, \( \gamma \) is the coefficient of risk aversion, and \( \hat{Q} \) is given by

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

The computation is made by \texttt{new_MeanVar_portfolio} and then the result is validated by \texttt{validate_MeanVar_portfolio}.

Usage

```r
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. 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

```r
n<-23 # number of realizations
p<-2*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 Eq.(7) of Bodnar et al. (2019) that minimize weighted quadratic loss for a given target vector \( \mu_0 \) (shrinkage target). \( \bar{x} \) stands for the sample mean vector.

Usage

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

Arguments

- **x**: a p by n matrix or a data frame. Rows represent different variables, columns-observations.
- **mu_0**: a numeric vector. The target vector used in the construction of the shrinkage estimator.
mean_bs

Value

a numeric vector containing the shrinkage estimation of the mean vector

References


Examples

```r
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)
```

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 ordinary sample mean, $\beta$ and $Y_0$ are derived using Bayesian approach (see Eq.14 and Eq.17 in Jorion (1986)).

Usage

mean_bs(x)

Arguments

x a numeric data matrix. Rows represent different variables, columns- observations.

Value

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

References

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)

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

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

where $\bar{x}$ is the sample mean vector, $\beta$ 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 numeric data matrix. Rows represent different variables, 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


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

Shrinkage mean variance portfolio

Description

The main function for mean variance (also known as expected utility) portfolio construction. It is a dispatcher using methods according to argument type.

Usage

MVShrinkPortfolio(x, gamma, type = "shrinkage", ...)

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, \(\gamma\) is the coefficient of risk aversion and \(\hat{Q}\) is given by

\[
\hat{Q} = S^{-1} - \frac{S^{-1}1'S^{-1}1}{1'S^{-1}1}.
\]

The shrinkage estimator for 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 \(\gamma \neq \infty\), estimation of \(\alpha\) is computed following Eq. (2.28) of Bodnar et al. (2016).

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

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

with \( \hat{\alpha} \) given in Eq. (2.31) Bodnar et al. (2018).

These three estimation methods are available as separate functions dispatched accordingly to the following parameter configurations:

<table>
<thead>
<tr>
<th>Function</th>
<th>Paper</th>
<th>Type</th>
<th>gamma</th>
</tr>
</thead>
<tbody>
<tr>
<td>new_MV_portfolio_weights_BDOPS21</td>
<td>Bodnar et al 2021</td>
<td>shrinkage</td>
<td>&lt; Inf</td>
</tr>
<tr>
<td>new_GMV_portfolio_weights_BDPS19</td>
<td>Bodnar et al 2019</td>
<td>shrinkage</td>
<td>Inf</td>
</tr>
<tr>
<td>new_MV_portfolio_traditional</td>
<td>Bodnar et al 2019</td>
<td>traditional</td>
<td>&gt; 0</td>
</tr>
</tbody>
</table>

**Value**

A portfolio in the form of an object of class `MeanVar_portfolio` potentially with a subclass. See `new_MeanVar_portfolio` for the details of the class.

**References**


**Examples**

```r
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 <- 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)
```
new_GMV_portfolio_weights_BDPS19

Constructor of GMV portfolio object.

Description
Constructor of global minimum variance portfolios. For more details of the method, see MVShrinkPortfolio.

Usage
new_GMV_portfolio_weights_BDPS19(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. The target for weight shrinkage.
- beta: a numeric variable. The confidence level for weight intervals.

Value
an object of class MeanVar_portfolio with subclass GMV_portfolio_weights_BDPS19.

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

weight_intervals contains a shrinkage estimate of portfolio weights, asymptotic confidence intervals for the true portfolio weights, value of test statistic and a 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. 2021).

References
**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**

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

**Arguments**

- `mean_vec`: mean vector of asset returns
- `cov_mtrx`: the covariance matrix of asset returns

**Value**

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

Usage

new_MV_portfolio_traditional(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

<table>
<thead>
<tr>
<th>Element</th>
<th>Description</th>
</tr>
</thead>
</table>

Examples

```r
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 <- rowMeans(x)

cust_port_BS_LW <- new_MeanVar_portfolio(mean_vec=means, cov_mtrx=cov_mtrx, gamma=2)
str(cust_port_BS_LW)
```
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 estimate of the asset returns

W_mv_hat sample estimate of portfolio weights

Port_Var portfolio variance

Port_mean_return expected portfolio return

Sharpe portfolio Sharpe ratio

Examples

n<-3e2 # number of realizations
p<-0.5*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. For more details of the method, see MVShrinkPortfolio.

Usage

new_MV_portfolio_weights_BDOPS21(x, gamma, b, beta)

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.

b a numeric variable. The target for weight shrinkage.

beta 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
new_MV_portfolio_weights_BDOPS21

<table>
<thead>
<tr>
<th>cov_mtrx</th>
<th>the sample covariance matrix of the asset returns</th>
</tr>
</thead>
<tbody>
<tr>
<td>inv_cov_mtrx</td>
<td>the inverse of the sample covariance matrix</td>
</tr>
<tr>
<td>means</td>
<td>sample mean vector estimate of the asset returns</td>
</tr>
<tr>
<td>W_mv_hat</td>
<td>sample estimate of the portfolio weights</td>
</tr>
<tr>
<td>weights</td>
<td>shrinkage estimate of the portfolio weights</td>
</tr>
<tr>
<td>alpha</td>
<td>shrinkage intensity for the weights</td>
</tr>
<tr>
<td>Port_Var</td>
<td>portfolio variance</td>
</tr>
<tr>
<td>Port_mean_return</td>
<td>expected portfolio return</td>
</tr>
<tr>
<td>Sharpe</td>
<td>portfolio Sharpe ratio</td>
</tr>
<tr>
<td>weight_intervals</td>
<td>A data frame</td>
</tr>
</tbody>
</table>

weight_intervals contains a shrinkage estimate of portfolio weights, asymptotic confidence intervals for the true portfolio weights, value of test statistic and a p-value of the test on the equality of the weight of each individual asset to zero (see Section 4.3 of Bodnar, Dette, Parolya and Thorsen 2021).

References


Examples

# Assets with a diagonal covariance matrix

```r
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

```r
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)
```
nonlin_shrinkLW  nonlinear shrinkage estimator of the covariance matrix of Ledoit and Wolf (2020)

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


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)
plot_frontier

Plot the Bayesian efficient frontier (Bauder et al. 2021) and the provided portfolios.

Description

The plotted Bayesian efficient frontier is provided by Eq. (8) in Bauder et al. (2021). It is the set of optimal portfolios obtained by employing the posterior predictive distribution on the asset returns. This efficient frontier can be used to assess the mean-variance efficiency of various estimators of the portfolio weights. The standard deviation of the portfolio return is plotted in the \(x\)-axis and the mean portfolio return in the \(y\)-axis. The portfolios with the weights \(w\) are added to the plot by computing \(\sqrt{w'\Sigma w}\) and \(w'\bar{x}\).

Usage

plot_frontier(x, weights.eff = rep(1/nrow(x), length = nrow(x)))

Arguments

- **x**: a \(p\) by \(n\) matrix or a data frame of asset returns. Rows represent different assets, columns – observations.
- **weights.eff**: matrix of portfolio weights. Each column contains \(p\) values of the weights for a given portfolio. Default: equally weighted portfolio.

Value

a ggplot object

References


Examples

```r
p = 150
n = 300
gamma <- 10
mu = seq(0.2,-0.2, length.out=p)
Sigma = RandCovMtrx(p=p)
x <- t(MASS::mvrnorm(n=n , mu=mu, Sigma=Sigma))
EW_port <- rep(1/p, length=p)
MV_shr_port <- new_MV_portfolio_weights_BDOPS21(x=x, gamma=gamma, b=EW_port, beta=0.05)$weights
GMV_shr_port <- new_MV_portfolio_weights_BDOPS21(x=x, gamma=Inf, b=EW_port, beta=0.05)$weights
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**

*Covariance matrix generator*

**Description**

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(0, 1, length = 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. By default, they are generated with exponential decay.

**Value**

covariance matrix

**Examples**

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

*Sample covariance estimator*

**Description**

It computes the sample covariance of matrix x as follows:

$$S_n = \frac{1}{n-1} \sum_{j=1}^{n} (x_j - \bar{x}_n)(x_j - \bar{x}_n)'$$

$$\bar{x}_n = \frac{1}{n} \sum_{j=1}^{n} x_j,$$

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**

```r
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 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 Test for mean-variance portfolio weights

Description

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

\[
H_0 : w_{MV} = w_0 \quad \text{vs} \quad H_1 : w_{MV} \neq w_0.
\]

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 confidence level for the test.

Details

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

Value

<table>
<thead>
<tr>
<th>Element</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>alpha_hat</td>
<td>the estimated shrinkage intensity</td>
</tr>
<tr>
<td>alpha_sd</td>
<td>the standard deviation of the shrinkage intensity</td>
</tr>
<tr>
<td>alpha_lower</td>
<td>the lower bound for the shrinkage intensity</td>
</tr>
<tr>
<td>alpha_upper</td>
<td>the upper bound for the shrinkage intensity</td>
</tr>
<tr>
<td>T_alpha</td>
<td>the value of the test statistic</td>
</tr>
<tr>
<td>p_value</td>
<td>the p-value for the test</td>
</tr>
</tbody>
</table>
References


Examples

```r
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(x)`

Arguments

- `x` : Object of class MeanVar_portfolio.

Value

If the object passes all the checks, then x 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))
Index

* datasets
  SP_daily_asset_returns, 22

Class_MeanVar_portfolio, 3
CovarEstim, 2, 4
CovShrinkBGP14, 4, 5

HDShOP-package, 2
InvCovShrinkBGP16, 6

mean_bop19, 7, 9
mean bs, 7, 10
mean js, 7, 11
MeanEstim, 2, 7
MeanVar_portfolio, 4, 8, 15
MVShrinkPortfolio, 2, 12, 14, 16, 17

new_GMV_portfolio_weights_BDPS19, 13, 14
new_MeanVar_portfolio, 4, 8, 13, 15
new_MV_portfolio_traditional, 13, 16
new_MV_portfolio_weights_BDOPS21, 13, 17
nonlin_shrinkLW, 4, 19

plot_frontier, 20

RandCovMtrx, 21

Sigma_sample_estimator, 4, 5, 22
SP_daily_asset_returns, 22

test_MVSP, 23

validate_MeanVar_portfolio, 4, 8, 24