

Package ‘quantilogram’

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Title Cross-Quantilogram

Version 3.2.1

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Description Estimation and inference methods for the cross-quantilogram.

The cross-quantilogram is a measure of nonlinear dependence between two variables, based on either unconditional or conditional quantile functions. It can be considered an extension of the correlogram, which is a correlation function over multiple lag periods that mainly focuses on linear dependency. One can use the cross-quantilogram to detect the presence of directional predictability from one time series to another. This package provides a statistical inference method based on the stationary bootstrap. For detailed theoretical and empirical explanations, see Linton and Whang (2007) for univariate time series analysis and Han, Linton, Oka and Whang (2016) for multivariate time series analysis. The full references for these key publications are as follows: (1) Linton, O., and Whang, Y. J. (2007). The quantilogram: with an application to evaluating directional predictability. *Journal of Econometrics*, 141(1), 250-282 <doi:10.1016/j.jeconom.2007.01.004>; (2) Han, H., Linton, O., Oka, T., and Whang, Y. J. (2016). The cross-quantilogram: measuring quantile dependence and testing directional predictability between time series. *Journal of Econometrics*, 193(1), 251-270 <doi:10.1016/j.jeconom.2016.03.001>.

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Description

This package provides a comprehensive set of tools for quantilogram analysis in R. It includes functions for computing and visualizing cross-quantilograms, which are useful for analyzing dependence structures in financial time series data. The package implements methods described in Han et al. (2016) for measuring quantile dependence and testing directional predictability between time series.

Details

The package's functions can be categorized into several groups:

Core Quantilogram Functions:

- `crosssq`: Compute basic cross-quantilogram
- `crosssq.sb`: Cross-quantilogram with stationary bootstrap
- `crosssq.sb.opt`: Optimized cross-quantilogram with bootstrap

Visualization Functions:

- `crosssq.heatmap`: Create heatmap visualization of cross-quantilograms
- `crosssq.plot`: Plot method for `crosssq` objects

Advanced Analysis Functions:

- `crosssq.max`: Compute maximum cross-quantilogram
- `crosssq.partial`: Compute partial cross-quantilogram

For a complete list of functions, see the package index.

Author(s)

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- Oliver Linton [contributor]
- Yoon-Jae Whang [contributor]

References

Han, H., Linton, O., Oka, T., & Whang, Y. J. (2016). The cross-quantilogram: Measuring quantile dependence and testing directional predictability between time series. *Journal of Econometrics*, 193(1), 251-270.

corr.lag	<i>Correlation Function</i>
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Description

The correlation statistics for a given lag order

Usage

```
corr.lag(math, k)
```

Arguments

math	The matrix with the column size of 2
k	The lag order (integer)

Details

The function obtains the simple correlation statistics. The values in the first column of input matrix is interacted with the k-lagged values in the second column.

Value

Correlation

Author(s)

Heejoon Han, Oliver Linton, Tatsushi Oka and Yoon-Jae Whang

corr.lag.partial	<i>Partial Cross-correlation function</i>
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Description

A function used to obtain partial cross-correlation function for a give lag order

Usage

```
corr.lag.partial(math, k)
```

Arguments

math	A matrix with multiple columns (more than 3 columns)
k	The lag order (integer)

Details

This function obtains the partial corss-correlation and the simple correlation. To obtain the partial cross-correlation, this function uses the first column of the input matrix and k-lagged values of the rest of the matrix.

Value

Partial corss-correlation at k lags and the correlation statistics at k lags.

Author(s)

Heejoon Han, Oliver Linton, Tatsushi Oka and Yoon-Jae Whang

crossq	<i>Cross-Quantilogram</i>
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Description

Returns the cross-quantilogram

Usage

```
crossq(DATA, vecA, k)
```

Arguments

DATA	An input matrix of dimensions T x 2, where T is the number of observations. Column 1 contains the first variable and Column 2 contains the second variable. This function will apply a k-period lag to the second variable during computation.
vecA	A pair of two probability values at which sample quantiles are estimated
k	A lag order (integer)

Details

This function obtains the cross-quantilogram at the k lag order.

Value

Cross-Quantilogram

Author(s)

Heejoon Han, Oliver Linton, Tatsushi Oka and Yoon-Jae Whang

References

Han, H., Linton, O., Oka, T., and Whang, Y. J. (2016). "The cross-quantilogram: Measuring quantile dependence and testing directional predictability between time series." *Journal of Econometrics*, 193(1), 251-270.

Examples

```
## data source
data("sys.risk")

## data: 2 variables
D = sys.risk[,c("Market", "JPM")]

# probability levels for the 2 variables
vecA = c(0.1, 0.5)

## cross-quantilogram with the lag of 5
crosssq(D, vecA, 5)
```

crosssq.heatmap	<i>Heatmap of Cross-Quantilogram</i>
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Description

This function creates a customizable heatmap visualization of the cross-quantilogram matrix and returns a list containing the plot and a data frame of cross-quantilogram values with critical values. Each cell is colored and labelled by the cross-quantilogram value. Cells that are significant at the given level (stationary bootstrap) are labelled in bold. The critical values are obtained by stationary bootstrap.

Usage

```
crosssq.heatmap(
  DATA,
  k,
  vec.q,
  Bsize,
  sigLev = 0.05,
  var1_name = NULL,
  var2_name = NULL,
  title = "Cross-Quantilogram Heatmap",
  subtitle = NULL,
  colors = c("blue", "lightblue", "white", "pink", "red"),
  color_values = c(-1, -0.15, 0, 0.15, 1),
  tile_border_color = "black",
  tile_border_width = 0.5,
  x_angle = 90,
```

```

    x_lab = NULL,
    y_lab = NULL,
    legend_title = "Cross-Q",
    gamma = NULL,
    text_size = 3
  )

```

Arguments

DATA	An input matrix of dimensions T x 2, where T is the number of observations. Column 1 contains the first variable and Column 2 contains the second variable. This function will apply a k-period lag to the second variable during computation.
k	An integer representing the lag.
vec.q	A numeric vector of quantiles.
Bsize	Bootstrap sample size for stationary bootstrap.
sigLev	Significance level for statistical test. Default is 0.05 (5% significance level).
var1_name	Name of the first variable (predicted variable). If NULL, defaults to "Variable 1".
var2_name	Name of the second variable (predicting variable). If NULL, defaults to "Variable 2".
title	Plot title. Default is "Cross-Quantilogram Heatmap".
subtitle	Plot subtitle. Default is NULL (no subtitle).
colors	A vector of colors for the heatmap. Default is c("blue", "lightblue", "white", "pink", "red").
color_values	A vector of values for color scaling. Default is c(-1, -0.15, 0, 0.15, 1).
tile_border_color	Color for tile borders. Default is "black".
tile_border_width	Width for tile borders. Default is 0.5.
x_angle	Angle for x-axis labels. Default is 90.
x_lab	X-axis label. If NULL (default), it's automatically generated.
y_lab	Y-axis label. If NULL (default), it's automatically generated.
legend_title	Title for the legend. Default is "Cross-Q".
gamma	Stationary-bootstrap parameter (the mean block length is 1/gamma). If NULL (default), it is chosen once by the Politis-White rule via <code>np::b.star</code> on the two series. Supplying a value avoids the dependency on the np package.
text_size	Font size of the per-cell cross-quantilogram value. Default is 3.

Value

A list containing two elements:

plot A ggplot object representing the cross-quantilogram heatmap.

`df.res` A data frame containing cross-quantilogram values and critical values. It includes the following columns:

- `Quantile1`: The quantile values for the first variable.
- `Quantile2`: The quantile values for the second variable.
- `vCRQ`: The cross-quantilogram values.
- `Lower_CV`: The lower critical values.
- `Upper_CV`: The upper critical values.
- `Significant`: A logical vector indicating whether the cross-quantilogram is significant at the given significance level.

Author(s)

Heejoon Han, Oliver Linton, Tatsushi Oka and Yoon-Jae Whang

References

Han, H., Linton, O., Oka, T., and Whang, Y. J. (2016). "The cross-quantilogram: Measuring quantile dependence and testing directional predictability between time series." *Journal of Econometrics*, 193(1), 251-270.

Examples

```
## Not run:
## data source
data("sys.risk")

## two variables data: T x 2
DATA = sys.risk[,c("JPM", "Market")]

## setup and estimation
k = 1                                ## lag order
vec.q = seq(0.05, 0.95, 0.05)       ## a list of quantiles
B.size = 200                         ## Repetition of bootstrap
res = crossq.heatmap(DATA, k, vec.q, B.size)

## result
print(res$plot)

## End(Not run)
```

crossq.max

Corss-Quantilogram up to a Given Lag Order

Description

The cross-quantilograms from 1 to a given lag order.

Usage

```
crossq.max(DATA, vecA, Kmax)
```

Arguments

DATA	An input matrix
vecA	A pair of two probability values at which sample quantiles are estimated
Kmax	The maximum lag order (integer)

Details

This function calculates the partial cross-quantilograms up to the lag order users specify.

Value

A vector of cross-quantilogram

Author(s)

Heejoon Han, Oliver Linton, Tatsushi Oka and Yoon-Jae Whang

References

Han, H., Linton, O., Oka, T., and Whang, Y. J. (2016). "The cross-quantilogram: Measuring quantile dependence and testing directional predictability between time series." *Journal of Econometrics*, 193(1), 251-270.

Examples

```
## data source
data("sys.risk")

## data: 2 variables
D = sys.risk[,c("Market", "JPM")]

# probability levels for the 2 variables
vecA = c(0.1, 0.5)

## cross-quantilogram with lags between 1 and 5
crossq.max(D, vecA, 5)
```

crosssq.max.partial	<i>Partial Corss-Quantilogram upto a given lag order</i>
---------------------	--

Description

The partial cross-quantilograms from 1 to a given lag order.

Usage

```
crosssq.max.partial(DATA, vecA, Kmax)
```

Arguments

DATA	An input matrix
vecA	A vector of probability values at which sample quantiles are estimated
Kmax	The maximum lag order (integer)

Details

This function calculates the partial cross-quantilograms up to the lag order users specify.

Value

A vector of cross-quantilogram and a vector of partial cross-quantilograms

Author(s)

Heejoon Han, Oliver Linton, Tatsushi Oka and Yoon-Jae Whang

References

Han, H., Linton, O., Oka, T., and Whang, Y. J. (2016). "The cross-quantilogram: Measuring quantile dependence and testing directional predictability between time series." *Journal of Econometrics*, 193(1), 251-270.

Examples

```
## data source
data("sys.risk")

## data with 3 variables
D = sys.risk[,c("Market", "JPM", "VIX")]

## probablity levels for the 3 variables
vecA = c(0.1, 0.1, 0.1)

## partial cross-quantilogram with lags from 1 to 5
crosssq.max.partial(D, vecA, 5)
```

crossq.partial	<i>Partial Cross-Quantilogram</i>
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Description

Returns the partial cross-quantilogram

Usage

```
crossq.partial(DATA, vecA, k)
```

Arguments

DATA	A matrix
vecA	A vector of probability values at which sample quantiles are estimated
k	The lag order

Details

This function obtains the partial cross-quantilogram and the cross-quantilogram. To obtain the partial cross-correlation given an input matrix, this function interacts the values of the first column and the k-lagged values of the rest of the matrix.

Value

The partial cross-quantilogram and the cross-quantilogram

Author(s)

Heejoon Han, Oliver Linton, Tatsushi Oka and Yoon-Jae Whang

References

Han, H., Linton, O., Oka, T., and Whang, Y. J. (2016). "The cross-quantilogram: Measuring quantile dependence and testing directional predictability between time series." *Journal of Econometrics*, 193(1), 251-270.

Examples

```
## data source
data("sys.risk")

## data with 3 variables
D = sys.risk[,c("Market", "JPM", "VIX")]

## probability levels for the 3 variables
vecA = c(0.1, 0.1, 0.1)
```

```
## partial cross-quantilogram with the lag of 5
crossq.max.partial(D, vecA, 5)
```

crossq.partial.sb	<i>Stationary Bootstrap for the Partial Cross-Quantilogram</i>
-------------------	--

Description

Returns critical values for the partial cross-quantilogram, based on the stationary bootstrap.

Usage

```
crossq.partial.sb(DATA, vecA, k, gamma, Bsize, sigLev)
```

Arguments

DATA	The original data matrix
vecA	A pair of two probability values at which sample quantiles are estimated
k	A lag order
gamma	A parameter for the stationary bootstrap
Bsize	The number of repetition of bootstrap
sigLev	The statistical significance level

Details

This function generates critical values for the partial cross-quantilogram, using the stationary bootstrap in Politis and Romano (1994).

Value

The bootstrap critical values

Author(s)

Heejoon Han, Oliver Linton, Tatsushi Oka and Yoon-Jae Whang

References

Politis, Dimitris N., and Joseph P. Romano. "The stationary bootstrap." *Journal of the American Statistical Association* 89.428 (1994): 1303-1313.

crossq.partial.sb.opt *Stationary Bootstrap for the Partial Cross-Quantilogram dwith the choice of the stationary-bootstrap parameter*

Description

Returns critical values for the partial cross-quantilogram, based on the stationary bootstrap with the choice of the stationary-bootstrap parameter.

Usage

```
crossq.partial.sb.opt(DATA, vecA, k, Bsize, sigLev)
```

Arguments

DATA	The original data matrix
vecA	A pair of two probability values at which sample quantiles are estimated
k	A lag order
Bsize	The number of repetition of bootstrap
sigLev	The statistical significance level

Details

This function generates critical values for for the partial cross-quantilogram, using the stationary bootstrap in Politis and Romano (1994).

Value

The boostrap critical values

Author(s)

Heejoon Han, Oliver Linton, Tatsushi Oka and Yoon-Jae Whang

References

Han, H., Linton, O., Oka, T., and Whang, Y. J. (2016). "The cross-quantilogram: Measuring quantile dependence and testing directional predictability between time series." *Journal of Econometrics*, 193(1), 251-270.

Patton, A., Politis, D. N., and White, H. (2009). Correction to "Automatic block-length selection for the dependent bootstrap" by D. Politis and H. White. *Econometric Reviews*, 28(4), 372-375.

Politis, D. N., and White, H. (2004). "Automatic block-length selection for the dependent bootstrap." *Econometric Reviews*, 23(1), 53-70.

Politis, Dimitris N., and Joseph P. Romano. (1994). "The stationary bootstrap." *Journal of the American Statistical Association* 89.428: 1303-1313.

crossq.plot

*Plot of Cross-Quantilogram***Description**

This function creates a plot of the cross-quantilogram with confidence intervals. It computes the cross-quantilogram and its confidence intervals using stationary bootstrap, then creates a ggplot visualization of the results.

Usage

```
crossq.plot(
  DATA,
  vecA,
  Kmax,
  Bsize,
  sigLev = 0.05,
  y.min = -1,
  y.max = 1,
  ribbon_color = "gray",
  ribbon_alpha = 0.8,
  bar_color = "black",
  bar_width = 0.2,
  title = "",
  subtitle = NULL,
  gamma = NULL
)
```

Arguments

DATA	A matrix of dimensions T x 2, where T is the number of observations. Column 1 contains the first variable and Column 2 contains the second variable.
vecA	A numeric vector of quantiles for the first variable.
Kmax	An integer representing the maximum lag to compute.
Bsize	Bootstrap sample size for stationary bootstrap.
sigLev	Significance level for confidence intervals. Default is 0.05 (95% confidence level).
y.min	The minimum y-axis value. Default is -1.
y.max	The maximum y-axis value. Default is 1.
ribbon_color	Color for the confidence interval ribbon. Default is "gray".
ribbon_alpha	Alpha (transparency) for the confidence interval ribbon. Default is 0.8.
bar_color	Color for the quantilogram bars. Default is "black".
bar_width	Width of the quantilogram bars. Default is 0.2.
title	Plot title. Default is an empty string.

subtitle	Plot subtitle. Default is NULL (no subtitle).
gamma	Stationary-bootstrap parameter (the mean block length is $1/\text{gamma}$). If NULL (default), it is chosen once by the Politis-White rule via <code>np::b.star</code> on the two series. Supplying a value avoids the dependency on the <code>np</code> package.

Value

A list containing two elements:

plot	A ggplot object representing the cross-quantilogram plot over lags.
df.res	A data frame containing cross-quantilogram values and critical values. It includes the following columns: • lag: lag orders. • crossQ: The cross-quantilogram values. • CI_lower: The lower critical values for the confidence interval. • CI_upper: The upper critical values for the confidence interval.

Author(s)

Heejoon Han, Oliver Linton, Tatsushi Oka and Yoon-Jae Whang

References

Han, H., Linton, O., Oka, T., and Whang, Y. J. (2016). "The cross-quantilogram: Measuring quantile dependence and testing directional predictability between time series." *Journal of Econometrics*, 193(1), 251-270.

Examples

```
## Not run:
data("sys.risk")
DATA = sys.risk[,c("JPM", "Market")]
vecA = 0.05
Kmax = 20
Bsize = 200
result = crossq.plot(DATA, vecA, Kmax, Bsize)
print(result$plot)

## End(Not run)
```

crossq.sb

*Stationary Bootstrap for the Cross-Quantilogram***Description**

Returns critical values for the cross-quantilogram, based on the stationary bootstrap.

Usage

```
crossq.sb(DATA, vecA, k, gamma, Bsize, sigLev)
```

Arguments

DATA	An input matrix of dimensions $T \times 2$, where T is the number of observations. Column 1 contains the first variable and Column 2 contains the second variable. This function will apply a k -period lag to the second variable during computation.
vecA	A pair of two probability values at which sample quantiles are estimated
k	A lag order
gamma	A parameter for the stationary bootstrap
Bsize	The number of repetition of bootstrap
sigLev	The statistical significance level

Details

This function generates critical values for the cross-quantilogram, using the stationary bootstrap in Politis and Romano (1994).

Value

The bootstrap critical values

Author(s)

Heejoon Han, Oliver Linton, Tatsushi Oka and Yoon-Jae Whang

References

- Han, H., Linton, O., Oka, T., and Whang, Y. J. (2016). "The cross-quantilogram: Measuring quantile dependence and testing directional predictability between time series." *Journal of Econometrics*, 193(1), 251-270.
- Politis, Dimitris N., and Joseph P. Romano. "The stationary bootstrap." *Journal of the American Statistical Association* 89.428 (1994): 1303-1313.

Examples

```
data("sys.risk") ## data source
D = sys.risk[,c("Market", "JPM")] ## data: 2 variables

# probability levels for the 2 variables
vecA = c(0.1, 0.5)

## setup for stationary bootstrap
gamma = 1/10 ## bootstrap parameter depending on data
Bsize = 5    ## small size, 5, for test
sigLev = 0.05 ## significance level

## cross-quantilogram with the lag of 5
crossq.sb(D, vecA, 5, gamma, Bsize, sigLev)
```

crossq.sb.opt	<i>Stationary Bootstrap for the Cross-Quantilogram with the choice of the stationary-bootstrap parameter</i>
---------------	--

Description

Returns critical values for the cross-quantilogram, based on the stationary bootstrap with the choice of the stationary-bootstrap parameter.

Usage

```
crossq.sb.opt(DATA, vecA, k, Bsize, sigLev = 0.05)
```

Arguments

DATA	An input matrix of dimensions $T \times 2$, where T is the number of observations. Column 1 contains the first variable and Column 2 contains the second variable. This function will apply a k -period lag to the second variable during computation.
vecA	A pair of two probability values at which sample quantiles are estimated
k	A lag order
Bsize	The number of repetition of bootstrap
sigLev	The statistical significance level. Default is 0.05 (5% significance level).

Details

This function generates critical values for the cross-quantilogram, using the stationary bootstrap in Politis and Romano (1994). To choose parameter for the stationary bootstrap, this function first obtains the optimal value for each time series using the result provided by Politis and White (2004) and Patton, Politis and White (2004) (The R-package, "np", written by Hayfield and Racine is used). Next, the average of the obtained values is used as the parameter value.

Value

The bootstrap critical values

Author(s)

Heejoon Han, Oliver Linton, Tatsushi Oka and Yoon-Jae Whang

References

- Han, H., Linton, O., Oka, T., and Whang, Y. J. (2016). "The cross-quantilogram: Measuring quantile dependence and testing directional predictability between time series." *Journal of Econometrics*, 193(1), 251-270.
- Patton, A., Politis, D. N., and White, H. (2009). Correction to "Automatic block-length selection for the dependent bootstrap" by D. Politis and H. White. *Econometric Reviews*, 28(4), 372-375.
- Politis, D. N., and White, H. (2004). "Automatic block-length selection for the dependent bootstrap." *Econometric Reviews*, 23(1), 53-70.
- Politis, Dimitris N., and Joseph P. Romano. (1994). "The stationary bootstrap." *Journal of the American Statistical Association* 89.428: 1303-1313.

Examples

```
## data source
data("sys.risk")

## data: 2 variables
D = sys.risk[,c("Market", "JPM")]

# probability levels for the 2 variables
vecA = c(0.1, 0.5)

## setup for stationary bootstrap
Bsize = 5    ## small size 5 for test
sigLev = 0.05 ## significance level

## cross-quantilogram with the lag of 5
crossq.sb.opt(D, vecA, 5, Bsize, sigLev)
```

crossqreg

Cross-Quantilogram

Description

Returns the cross-quantilogram

Usage

```
crossqreg(DATA1, DATA2, vecA, k)
```

Arguments

DATA1	An input matrix ($T \times p1$)
DATA2	An input matrix ($T \times p2$)
vecA	A pair of two probability values at which sample quantiles are estimated
k	A lag order (integer)

Details

This function obtains the cross-quantilogram at the k lag order.

Value

Cross-Quantilogram

Author(s)

Heejoon Han, Oliver Linton, Tatsushi Oka and Yoon-Jae Whang

References

- Han, H., Linton, O., Oka, T., and Whang, Y. J. (2016). "The cross-quantilogram: Measuring quantile dependence and testing directional predictability between time series." *Journal of Econometrics*, 193(1), 251-270.
- Koenker, R., and Bassett Jr, G. (1978). "Regression quantiles." *Econometrica*, 46(1), 33-50.

Examples

```
## data source
data(sys.risk)

## sample size
T = nrow(sys.risk)

## matrix for quantile regressions
## - 1st column: dependent variables
## - the rest: regressors or predictors
D1 = cbind(sys.risk[2:T,"Market"], sys.risk[1:(T-1),"Market"])
D2 = cbind(sys.risk[2:T,"JPM"], sys.risk[1:(T-1),"JPM"])

## probability levels
vecA = c(0.1, 0.2)

## cross-quantilogram with the lag of 5, after quantile regression
crossqreg(D1, D2, vecA, 5)
```

crossqreg.max

*Corss-Quantilogram up to a Given Lag Order***Description**

The cross-quantilograms from 1 to a given lag order.

Usage

```
crossqreg.max(DATA1, DATA2, vecA, Kmax)
```

Arguments

DATA1	An input matrix (T x p1)
DATA2	An input matrix (T x p2)
vecA	A pair of two probability values at which sample quantiles are estimated
Kmax	The maximum lag order (integer)

Details

This function calculates the partial cross-quantilograms up to the lag order users specify.

Value

A vector of cross-quantilogram

Author(s)

Heejoon Han, Oliver Linton, Tatsushi Oka and Yoon-Jae Whang

References

Han, H., Linton, O., Oka, T., and Whang, Y. J. (2016). "The cross-quantilogram: Measuring quantile dependence and testing directional predictability between time series." *Journal of Econometrics*, 193(1), 251-270.

crossqreg.max.partial *Partial Corss-Quantilogram upto a given lag order*

Description

The partial cross-quantilograms from 1 to a given lag order.

Usage

```
crossqreg.max.partial(DATA1, DATA2, vecA, Kmax)
```

Arguments

DATA1	An input matrix (T x p1)
DATA2	An input matrix (T x p2)
vecA	A vector of probability values at which sample quantiles are estimated
Kmax	The maximum lag order (integer)

Details

This function calculates the partial cross-quantilograms up to the lag order users specify.

Value

A vector of cross-quantilogram and a vector of partial cross-quantilograms

Author(s)

Heejoon Han, Oliver Linton, Tatsushi Oka and Yoon-Jae Whang

References

Han, H., Linton, O., Oka, T., and Whang, Y. J. (2016). "The cross-quantilogram: Measuring quantile dependence and testing directional predictability between time series." *Journal of Econometrics*, 193(1), 251-270.

crossqreg.partial	<i>Parital Cross-Quantilogram</i>
-------------------	-----------------------------------

Description

Returns the partial cross-quantilogram

Usage

```
crossqreg.partial(DATA1, DATA2, vecA, k)
```

Arguments

DATA1	An input matrix ($T \times p1$)
DATA2	An input matrix ($T \times p2$)
vecA	A vector of probability values at which sample quantiles are estiamted
k	The lag order

Details

This function obtains the partial corss-quantilogram and the cross-quantilogram. To obtain the partial cross-correlation given an input matrix, this function interacts the values of the first column and the k-lagged values of the rest of the matrix.

Value

The partial corss-quantilogram and the cross-quantilogram

Author(s)

Heejoon Han, Oliver Linton, Tatsushi Oka and Yoon-Jae Whang

References

Han, H., Linton, O., Oka, T., and Whang, Y. J. (2016). "The cross-quantilogram: Measuring quantile dependence and testing directional predictability between time series." *Journal of Econometrics*, 193(1), 251-270.

crossqreg.sb

Stationary Bootstrap for the Cross-Quantilogram

Description

Returns critical values for the cross-quantilogram, based on the stationary bootstrap.

Usage

```
crossqreg.sb(DATA1, DATA2, vecA, k, gamma, Bsize, sigLev)
```

Arguments

DATA1	The original data matrix (T x p1)
DATA2	The original data matrix (T x p2)
vecA	A pair of two probability values at which sample quantiles are estimated
k	A lag order
gamma	A parameter for the stationary bootstrap
Bsize	The number of repetition of bootstrap
sigLev	The statistical significance level

Details

This function generates critical values for for the cross-quantilogram, using the stationary bootstrap in Politis and Romano (1994).

Value

The bootstrap critical values

Author(s)

Heejoon Han, Oliver Linton, Tatsushi Oka and Yoon-Jae Whang

References

Han, H., Linton, O., Oka, T., and Whang, Y. J. (2016). "The cross-quantilogram: Measuring quantile dependence and testing directional predictability between time series." *Journal of Econometrics*, 193(1), 251-270.

Politis, Dimitris N., and Joseph P. Romano. "The stationary bootstrap." *Journal of the American Statistical Association* 89.428 (1994): 1303-1313.

Examples

```

data(sys.risk)

## sample size
T = nrow(sys.risk)

## matrix for quantile regressions
## - 1st column: dependent variables
## - the rest: regressors or predictors
D1 = cbind(sys.risk[2:T,"Market"], sys.risk[1:(T-1),"Market"])
D2 = cbind(sys.risk[2:T,"JPM"], sys.risk[1:(T-1),"JPM"])

## probability levels
vecA = c(0.1, 0.2)

## setup for stationary bootstrap
gamma = 1/10 ## bootstrap parameter depending on data
Bsize = 5    ## small size, 5, for test
sigLev = 0.05 ## significance level

## cross-quantilogram with the lag of 5, after quantile regression
crossqreg.sb(D1, D2, vecA, 5, gamma, Bsize, sigLev)

```

q.hit

*Quantile Hit***Description**

Returns the matrix of quantil-hits

Usage

```
q.hit(DATA, vecA)
```

Arguments

DATA	A matrix that has time-series observations in its columns
vecA	A vector of probabilty values at which sample quantiles are estimated

Details

This function generates the quantile hits given a vector of probabilty values. The quantile hits are obtained for each column of an input matrix.

Value

A matrix of quantile-hits

Author(s)

Heejoon Han, Oliver Linton, Tatsushi Oka and Yoon-Jae Whang

qreg.hit

Quantile Hit

Description

Returns the matrix of quantil-hits

Usage

```
qreg.hit(DATA1, DATA2, vecA)
```

Arguments

DATA1	An input matrix ($T \times p1+1$) with the first column of the dependent variable and the the rest of columns with regressors
DATA2	An input matrix ($T \times p2+1$) with the first column of the dependent variable and the the rest of columns with regressors
vecA	A vector of probabilty values at which sample quantiles are estimated

Details

This function generates the quantile hits based on quantile regression, given a vector of probability values. The quantile regressions are esimated for each matrix of data and a pair of quantile hits are produced.

Value

A matrix of quantile-hits

Author(s)

Heejoon Han, Oliver Linton, Tatsushi Oka and Yoon-Jae Whang

References

Koenker, R., and Bassett Jr, G. (1978). "Regression quantiles." *Econometrica*, 46(1), 33-50.

Qstat	<i>Q-statistics</i>
-------	---------------------

Description

The Box-Pierce and Ljung-Box type Q-statistics

Usage

```
Qstat(vecTest, Tsize)
```

Arguments

vecTest	A vector of test statistics ordered with respect the number of lags
Tsize	A original sample size

Details

This function returns Box-Pierce and Ljung-Box type Q-statistics

Value

the Box-Pierce and Ljung-Box statistics

Author(s)

Heejoon Han, Oliver Linton, Tatsushi Oka and Yoon-Jae Whang

References

Box, G. EP, and D. A. Pierce. (1970). "Distribution of residual autocorrelations in autoregressive-integrated moving average time series models." *Journal of the American Statistical Association* 65.332, pp.1509-1526.

Ljung, G. M., and G. EP Box. (1978). "On a measure of lack of fit in time series models." *Biometrika* 65.2, pp.297-303.

Qstat.reg.sb

*Stationary Bootstrap for Q statistics***Description**

Stationary Bootstrap procedure to generate critical values for both Box-Pierce and Ljung-Box type Q-statistics

Usage

```
Qstat.reg.sb(DATA1, DATA2, vecA, Psize, gamma, Bsize, sigLev)
```

Arguments

DATA1	The original data set (1)
DATA2	The original data set (2)
vecA	A pair of two probability values at which sample quantiles are estimated
Psize	The maximum number of lags
gamma	A parameter for the stationary bootstrap
Bsize	The number of repetition of bootstrap
sigLev	The statistical significance level

Details

This function returns critical values for for both Box-Pierce and Ljung-Box type Q-statistics through the stationanry bootstrap proposed by Politis and Romano (1994).

Value

The bootstrap critical values

Author(s)

Heejoon Han, Oliver Linton, Tatsushi Oka and Yoon-Jae Whang

References

Han, H., Linton, O., Oka, T., and Whang, Y. J. (2016). "The cross-quantilogram: Measuring quantile dependence and testing directional predictability between time series." *Journal of Econometrics*, 193(1), 251-270.

Politis, Dimitris N., and Joseph P. Romano. (1994). "The stationary bootstrap." *Journal of the American Statistical Association* 89.428, pp.1303-1313.

Examples

```
data(sys.risk)

## sample size
T = nrow(sys.risk)

## matrix for quantile regressions
## - 1st column: dependent variables
## - the rest: regressors or predictors
D1 = cbind(sys.risk[2:T,"Market"], sys.risk[1:(T-1),"Market"])
D2 = cbind(sys.risk[2:T,"JPM"], sys.risk[1:(T-1),"JPM"])

## probability levels
vecA = c(0.1, 0.2)

## setup for stationary bootstrap
gamma = 1/10 ## bootstrap parameter depending on data
Bsize = 5    ## small size, 5, for test
sigLev = 0.05 ## significance level

## Q statistics with lags from 1 to 5, after quantile regression
Qstat.reg.sb(D1, D2, vecA, 5, gamma, Bsize, sigLev)
```

Qstat.sb

Stationary Bootstrap for Q statistics

Description

Stationary Bootstrap procedure to generate critical values for both Box-Pierce and Ljung-Box type Q-statistics

Usage

```
Qstat.sb(DATA, vecA, Psize, gamma, Bsize, sigLev)
```

Arguments

DATA	The original data
vecA	A pair of two probability values at which sample quantiles are estimated
Psize	The maximum number of lags
gamma	A parameter for the stationary bootstrap
Bsize	The number of repetition of bootstrap
sigLev	The statistical significance level

Details

This function returns critical values for for both Box-Pierce and Ljung-Box type Q-statistics through the stationanry bootstrap proposed by Politis and Romano (1994).

Value

The bootstrap critical values

Author(s)

Heejoon Han, Oliver Linton, Tatsushi Oka and Yoon-Jae Whang

References

Han, H., Linton, O., Oka, T., and Whang, Y. J. (2016). "The cross-quantilogram: Measuring quantile dependence and testing directional predictability between time series." *Journal of Econometrics*, 193(1), 251-270.

Politis, Dimitris N., and Joseph P. Romano. (1994). "The stationary bootstrap." *Journal of the American Statistical Association* 89.428, pp.1303-1313.

Examples

```
data("sys.risk") ## data source
D = sys.risk[,c("Market", "JPM")] ## data: 2 variables

# probability levels for the 2 variables
vecA = c(0.1, 0.5)

## setup for stationary bootstrap
gamma = 1/10 ## bootstrap parameter depending on data
Bsize = 5    ## small size, 5, for test
sigLev = 0.05 ## significance level

## Q statistics with lags from 1 to5
Qstat.sb(D, vecA, 5, gamma, Bsize, sigLev)
```

Qstat.sb.opt

Stationary Bootstrap for Q statistics

Description

Stationary Bootstrap procedure to generate critical values for both Box-Pierce and Ljung-Box type Q-statistics with the choice of the stationary-bootstrap parameter.

Usage

```
Qstat.sb.opt(DATA, vecA, Psize, Bsize, sigLev)
```

Arguments

DATA	The original data
vecA	A pair of two probability values at which sample quantiles are estimated
Psize	The maximum number of lags
Bsize	The number of repetition of bootstrap
sigLev	The statistical significance level

Details

This function returns critical values for for both Box-Pierce and Ljung-Box type Q-statistics through the stationary bootstrap proposed by Politis and Romano (1994). To choose parameter for the stationary bootstrap, this function first obtains the optimal value for each time series using the result provided by Politis and White (2004) and Patton, Politis and White (2004) (The R-package, "np", written by Hayfield and Racine is used). Next, the average of the obtained values is used as the parameter value.

Value

The bootstrap critical values

Author(s)

Heejoon Han, Oliver Linton, Tatsushi Oka and Yoon-Jae Whang

References

- Han, H., Linton, O., Oka, T., and Whang, Y. J. (2016). "The cross-quantilogram: Measuring quantile dependence and testing directional predictability between time series." *Journal of Econometrics*, 193(1), 251-270.
- Patton, A., Politis, D. N., and White, H. (2009). Correction to "Automatic block-length selection for the dependent bootstrap" by D. Politis and H. White. *Econometric Reviews*, 28(4), 372-375.
- Politis, D. N., and White, H. (2004). "Automatic block-length selection for the dependent bootstrap." *Econometric Reviews*, 23(1), 53-70.
- Politis, Dimitris N., and Joseph P. Romano. (1994). "The stationary bootstrap." *Journal of the American Statistical Association* 89.428: 1303-1313.

Examples

```
data("sys.risk") ## data source
D = sys.risk[,c("Market", "JPM")] ## data: 2 variables

# probability levels for the 2 variables
vecA = c(0.1, 0.5)

## setup for stationary bootstrap
Bsize = 5    ## small size, 5, for test
sigLev = 0.05 ## significance level
```

```
## Q statistics with lags from 1 to5  
Qstat.sb.opt(D, vecA, 5, Bsize, sigLev)
```

sb.index	<i>Stationary Bootstrap Index</i>
----------	-----------------------------------

Description

A subfunction for the stationanry bootstrap

Usage

```
sb.index(Nsize, gamma)
```

Arguments

Nsize	The size of the stationary bootstrap resample
gamma	A parameter for the stationary bootstrap.

Details

This function resamples blocks of indicies with random block lengths. This code follows the MATLAB file of the Oxford MFE Toolbox written by Kevin Sheppard.

Value

A vector of indicies for the stationary bootstrap

Author(s)

Heejoon Han, Oliver Linton, Tatsushi Oka and Yoon-Jae Whang

References

The Oxford MFE toolbox (http://www.kevinsheppard.com/wiki/MFE_Toolbox) by Kevin Sheppard

stock

The Data Set of Monthly Stock Return and Stock Variance

Description

The dataset contains monthly excess stock returns and stock variance, which are included in the data set analyzed in Goyal and Welch (2008). Stock returns are measured by the S&P 500 index and include dividends. A treasury-bill rate is subtracted from stock returns to give excess stock returns. The stock variance is a volatility estimate based on daily squared returns and is treated as an estimate of equity risk in the literature. The sample period is from February 1885 to December 2005 with sample size 1,451.

- Date: Year-Month-Day
- Return: excess stock returns
- Variance: stock variance

Usage

```
data(stock)
```

Format

A data object with two variables

References

Han, H., Linton, O., Oka, T., and Whang, Y. J. (2016). "The cross-quantilogram: Measuring quantile dependence and testing directional predictability between time series." *Journal of Econometrics*, 193(1), 251-270.

Welch, Ivo, and Amit Goyal. "A comprehensive look at the empirical performance of equity premium prediction." *Review of Financial Studies* 21.4 (2008): 1455-1508.

sys.risk

The Data Set for Systemic Risk Analysis

Description

The data set contains the daily CRSP market value weighted index returns, which are used as the market index returns in Brownlees and Engle (2012), and also includes daily stock returns on JP Morgan Chase (JPM), Goldman Sachs (GS) and American International Group (AIG). The sample period is from 2 Jan. 2001 to 30 Dec. 2011 with sample size 2,767.

Usage

```
data(sys.risk)
```

Format

A data object with five variables

Details

- date: The time index (day)
- Market: The daily CRSP market value weighted index returns
- JPM: stock returns on JP Morgan Chase (JPM)
- GS: stock returns on Goldman Sachs (GS)
- AIG: stock returns on American International Group (AIG)

References

Brownlees, Christian T., and Robert F. Engle. "Volatility, correlation and tails for systemic risk measurement." *Available at SSRN* 1611229 (2012).

Han, H., Linton, O., Oka, T., and Whang, Y. J. (2016). "The cross-quantilogram: Measuring quantile dependence and testing directional predictability between time series." *Journal of Econometrics*, 193(1), 251-270.

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