Package 'quasar'

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Type Package

Title Valid Inference on Multiple Quantile Regressions

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Description The approach is based on the closed testing procedure to control familywise error rate in a strong sense.
The local tests implemented are Wald-type and rank-score.
The method is described in De Santis, et al., (2026), <doi:10.48550/arXiv.2511.07999>.

Depends quantreg, Matrix, MASS, pracma, methods, sn

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Contents

.pImhof *The Imhof method for x=0 and central variables only.*

Description

The Imhof method for x=0 and central variables only.

Usage

```
.pImhof(lams, eps = c(1e-04, 1e-04), x)
```

Arguments

lams	eigenvalues
eps	tolerance vector (one for integrate, one for quadgk)
x	observed stat test

closedTesting *Closed testing for quantile regression*

Description

Applies the closed testing procedure to strongly control the familywise error rate (FWER) when testing the effect of a covariate of interest across multiple quantile regression models.

Usage

```
closedTesting(mod, X, tau = NULL, test = "rank-score", ...)
```

Arguments

mod	An object of class rqs returned by rq, representing the fitted quantile regression models.
X	A string indicating the covariate of interest.
tau	A numeric vector of quantiles of interest used in mod. If NULL (default), all quantiles from the mod object are considered.
test	Character. Type of test to be used. Options are "rank-score" and "wald".
...	Additional arguments, see rankTest, waldTest.

Details

This procedure requires that the covariate of interest X is either numeric or, if categorical, has at most two levels. Multilevel categorical covariates are not supported and will trigger an error.

The weighting matrix used in the multivariate rank test is the identity matrix, i.e., it is currently the only one implemented explicitly as a shortcut within the closed testing procedure.

Value

An object of class `quasar` containing:

- `Quantile`: quantile level
- `Coefficient`: estimated coefficient
- `Statistic`: test statistic
- `p.value`: raw p-value
- `p.value.adjusted`: adjusted p-value from the closed testing procedure

Author(s)

Angela Andreella

References

Marcus, R., Eric, P., & Gabriel, K. R. (1976). On closed testing procedures with special reference to ordered analysis of variance. *Biometrika*, 63(3), 655–660.

Goeman, J. J., Hemerik, J., & Solari, A. (2021). Only closed testing procedures are admissible for controlling false discovery proportions. *The Annals of Statistics*, 49(2), 1218–1238.

See Also

`rq`, `rankTest`, `waldTest`

Examples

```
# Simulate data
set.seed(1234)
D <- simulateData(n = 100, gamma = 0.5, sigma.y = "1 + 2 * pmax(X, 0)")

# Quantile regressions at different levels
tau <- c(0.1, 0.25, 0.5, 0.75, 0.9)
mod <- quantreg::rq(y ~ X + Z1, tau = tau, data=D)

# Closed testing
res <- closedTesting(mod, X = "X")
res

# Summary and plot
summary(res, alpha = 0.1)
plot(res, alpha = 0.1, legend.position = "bottomright")
```

`plot.quasar` *Plot method for quasar objects*

Description

Produces a plot of a `quasar` object, typically returned by the `closedTesting` function. It shows the estimated coefficients by quantile level, highlighting statistically significant coefficients based on adjusted p-values.

Usage

```
## S3 method for class 'quasar'
plot(
  x,
  alpha = 0.05,
  legend.position = "topright",
  main = NULL,
  xlab = "Quantile level",
  ylab = "Coefficient",
  col.line = "darkgrey",
  col.sig = "darkred",
  col.nonsig = "darkgrey",
  pch.sig = 19,
  pch.nonsig = 17,
  show.legend = TRUE,
  ...
)
```

Arguments

`x`	An object of class `quasar`.
`alpha`	Significance level.
`legend.position`	Position of the legend.
`main`	Main plot title.
`xlab`	Label for the x-axis.
`ylab`	Label for the y-axis.
`col.line`	Color of the connecting line.
`col.sig`	Color for significant points.
`col.nonsig`	Color for non-significant points.
`pch.sig`	Point character for significant points.
`pch.nonsig`	Point character for non-significant points.
`show.legend`	Logical; whether to display a legend.
`...`	Additional graphical parameters passed to `plot()`.

Value

A base R plot.

Author(s)

Anna Vesely

See Also

`closedTesting`

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quasar-methods *Print and summary methods for quasar objects*

Description

These methods provide basic information about objects of class `quasar`, typically returned by the `closedTesting` function.

Usage

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

## S3 method for class 'quasar'
summary(object, ..., alpha = 0.05)
```

Arguments

`x, object`	An object of class `quasar`.
`...`	Additional arguments passed to other methods.
`alpha`	Significance level.

Value

The input object invisibly.

Author(s)

Anna Vesely

rankTest *Rank-score test for quantile regression*

Description

Performs the rank-score test for the covariate of interest X, at the quantiles defined in tau, using a fitted quantile regression model. The test evaluates the null hypothesis that the coefficient of X is equal to zero against a two-sided alternative, at each specified quantile level. Testing equality to a non-zero value is not yet implemented.

Usage

```
rankTest(mod, X, tau = NULL, full = FALSE, h = NULL, alpha = 0.05,
eps = c(1e-04,1e-04), B = "identity", error.distr = NULL, error.par = NULL)
```

Arguments

mod	An object of class rqs returned by rq, representing the fitted quantile regression models.
X	A string indicating the coefficient of interest, i.e. the name of a column in the model matrix
tau	A numeric vector of quantiles of interest used in mod. If NULL (default), all quantiles from the mod object are considered.
full	Logical. If TRUE, the function returns the test statistics and corresponding p-values for all intersection hypotheses containing tau. If FALSE (default), only the results for the single hypotheses are returned.
h	Character string specifying the bandwidth selection method for sparsity estimation. One of "Hall-Sheather" or "Bofinger". The default, NULL, uses the Hall-Sheather (1988) rule.
alpha	A numeric value used for bandwidth estimation. Following Koenker (2005), it is typically set equal to the desired significance level.
eps	Numeric vector of length 2 specifying the relative accuracies requested for approximating the distribution of the test statistic using Imhof's (1961) method, "Computing the Distribution of Quadratic Forms in Normal Variables". The first component controls the accuracy of the initial (more accurate) numerical integration (using integrate), while the second component controls the accuracy of a subsequent, less accurate integration step (using quadgk).
B	Weight specification used in the computation of the test statistic. One of "identity" (default), "distribution", "inverse diagonal", or "inverse variance" (not recommended). Alternatively, the user can supply a numeric matrix of dimension length(mod$tau) x length(mod$tau). This argument is ignored when full = TRUE.
error.distr	A character string specifying the assumed distribution of the regression errors, used only when B = "distribution". Allowed values are "normal", "skew-normal", "t".

`error.par` A named list of parameters associated with `error.distr`. Required elements depend on the chosen distribution:

- For `"normal"`: `mean`, `sd`.
- For `"skew-normal"`: `xi`, `omega`, `alpha`.
- For `"t"`: `df`.

Details

This procedure requires that the covariate of interest `X` is either numeric or, if categorical, has at most two levels. Multilevel categorical covariates are not supported and will trigger an error.

If `full = TRUE`, `B` is ignored and the identity weight is used. If `B` is user-defined (a matrix), it must be square, symmetric, positive definite, and numerically invertible.

Value

A `data.frame` containing:

- `Quantiles.Set`: quantile levels
- `Statistic`: rank-score test statistic
- `p.value`: corresponding test-specific (unadjusted) p-value

Author(s)

Angela Andreella

References

Koenker, R. (2005). *Quantile Regression*. Cambridge University Press.

Imhof, J. P. (1961). Computing the distribution of quadratic forms in normal variables. *Biometrika*, 48(3–4), 419–426.

De Santis, R., Veselý, A., and Andreella, A. (2026). Inference on multiple quantiles in regression models by a rank-score approach. *arXiv preprint* <doi:10.48550/arXiv.2511.07999>.

See Also

`rq`, `waldTest`

Examples

```
set.seed(1234)
D <- simulateData(n = 100, gamma = 0.5, sigma.y = "1 + 2 * pmax(X, 0)")

#Quantile regressions at different levels
tau <- c(0.1, 0.25, 0.5, 0.75, 0.9)
mod <- quantreg::rq(y ~ X + Z1, tau = tau, data=D)

# Rank test
rankTest(mod, X = "X")
```

`simulateData` *Simulate data*

Description

Simulates a main covariate `X`, a vector of additional covariates `Z`, and a response `y` drawn from the chosen distribution.

Usage

```
simulateData(n, beta = 0, gamma = 0, mu = 0, Sigma = NULL,
             sigma.y = 1, distribution = "normal", df = 5,
             xi = -1.453, omega = 2, alpha = 2.2, seed = NULL)
```

Arguments

`n`	Integer. Number of observations.
`beta`	Numeric scalar. Effect of `X`.
`gamma`	Numeric vector. Effects of `Z` (length `p - 1`, where `p = ncol(Sigma)`).
`mu`	Numeric scalar. Intercept.
`Sigma`	Numeric `p x p` symmetric positive-definite covariance matrix for `(X, Z)`. The first column corresponds to `X`, the remaining columns to `Z1, Z2, ...`.
`sigma.y`	Either a numeric scalar or a one-sided expression/string (e.g., `"0.3 * abs(X) + 0.1"`) defining the scale of `y`.
`distribution`	Character. One of `"normal"`, `"t"`, or `"skew-normal"`. This is the distribution of `y`.
`df`	Numeric scalar > 0. Degrees of freedom for t-distribution.
`xi`	Numeric scalar. Location parameter for the skew-normal distribution. In particular, this will be `mu + X * beta + Z %*% gamma + xi`. Default -1.453.
`omega`	Numeric scalar > 0. Scale parameter for the skew-normal distribution. In particular, this will be `sigma.y + omega`. Default 2.
`alpha`	Numeric scalar. Slant parameter for the skew-normal distribution. Default 2.2.
`seed`	Numeric scalar > 0. Seed for random number generator.

Details

The response is generated as `y = mu + X * beta + Z %*% gamma + error`. The error term can be drawn from a normal distribution, scaled Student-t with `df` degrees of freedom, or a skew-normal. Its standard deviation is defined by `sigma.y`: if numeric, a fixed scale is used; if a character expression, the scale can vary with `X` and/or `Z1`.

Value

A `data.frame` with columns `y`, `X`, and `Z1, ..., Zk`.

Author(s)

Angela Andreella

Examples

```
set.seed(1)
p <- 3
Sigma <- diag(p)

# Normal
dat_n <- simulateData(n = 200, beta = 0.5, gamma = c(0.2,-0.1),
                      sigma.y = 0.5, distribution = "normal")

# Student-t
dat_t0 <- simulateData(n = 200, beta = 0.5, gamma = c(0.2,-0.1),
                       sigma.y = 0.5, distribution = "t", df = 7)
# Skew-normal
dat_sn <- simulateData(n = 200, beta = 0.5, gamma = c(0.2,-0.1),
                      sigma.y = "abs(Z1) + 1", distribution = "skew-normal")
```

---

waldTest *Wald-type test for quantile regression*

Description

Performs the Wald-type test for the covariate of interest `X`, at the quantiles defined in `tau`, using a fitted quantile regression model. The test evaluates the null hypothesis that the coefficient of `X` is equal to a given value `beta` against a two-sided alternative, at each specified quantile level.

Usage

```
waldTest(mod, X, tau = NULL, full = FALSE, h = NULL, beta = 0, alpha = 0.05)
```

Arguments

`mod`	An object of class `rqs` returned by `rq`, representing the fitted quantile regression models.
`X`	A string indicating the covariate of interest.
`tau`	A numeric vector of quantiles of interest used in `mod`. If `NULL` (default), all quantiles from the `mod` object are considered.
`full`	Logical. If `TRUE`, the function returns the test statistics and corresponding p-values for all intersection hypotheses containing `tau`. If `FALSE` (default), only the results for the single hypotheses are returned.
`h`	A numeric value for the bandwidth.
`beta`	Numeric value of the parameter of interest under the null hypothesis.
`alpha`	A numeric value used for bandwidth estimation. Following Koenker (2005), it is typically set equal to the desired significance level.

Details

This procedure requires that the covariate of interest `X` is either numeric or, if categorical, has at most two levels. Multilevel categorical covariates are not supported and will trigger an error.

Value

A `data.frame` containing:

- `Quantiles.Set`: quantile levels
- `Statistic`: Wald-type test statistic
- `p.value`: corresponding test-specific (unadjusted) p-value

Author(s)

Angela Andreella

References

Koenker, R. (2005). *Quantile Regression*. Cambridge University Press.

See Also

`rq`, `rankTest`

Examples

```
set.seed(1234)
D <- simulateData(n = 100, gamma = 0.5, sigma.y = "1 + 2 * pmax(X, 0)")

#Quantile regressions at different levels
tau <- c(0.1, 0.25, 0.5, 0.75, 0.9)
mod <- quantreg::rq(y ~ X + Z1, tau = tau, data=D)

# Wald test
waldTest(mod, X = "X")
```

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