

# Package ‘rqPen’

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**Type** Package

**Title** Penalized Quantile Regression

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**Description** Performs penalized quantile regression for LASSO, SCAD and MCP functions including group penalties. Provides a function that automatically generates lambdas and evaluates different models with cross validation or BIC, including a large p version of BIC.

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## R topics documented:

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|---------------|-----------------------------------------------------------------------------------------------------------|
| rqPen-package | <i>Penalized quantile regression for LASSO, SCAD, and MCP penalty functions including group penalties</i> |
|---------------|-----------------------------------------------------------------------------------------------------------|

---

## Description

This package provides functions to find solutions to penalized quantile regression problems. Throughout this package, the estimated coefficients are the minimizers of the penalized quantile regression objective function:

$$\beta = \frac{1}{n} \sum_{i=1}^n \rho_{\tau}(y_i - x_i^T \beta) + \sum_{j=1}^p p_{\lambda}(|\beta_j|)$$

, where

$$\rho_{\tau}(u) = u(\tau - I(u < 0))$$

. This package can handle three different penalty functions with  $\lambda > 0$ :

LASSO:

$$p_\lambda(|\beta_j|) = \lambda|\beta_j|$$

SCAD:

$$p_\lambda(|\beta_j|) = \lambda|\beta_j|I(0 \leq |\beta_j| < \lambda) + \frac{a\lambda|\beta_j| - (\beta_j^2 + \lambda^2)/2}{a-1}I(\lambda \leq |\beta_j| \leq a\lambda) + \frac{(a+1)\lambda^2}{2}I(|\beta_j| > a\lambda),$$

for  $a > 2$

MCP:

$$p_\lambda(|\beta_j|) = \lambda\left(|\beta_j| - \frac{\beta_j^2}{2a\lambda}\right)I(0 \leq |\beta_j| \leq a\lambda) + \frac{a\lambda^2}{2}I(|\beta_j| > a\lambda),$$

for  $a > 1$ .

beta\_plots

*Plots of Betas*

## Description

Plots how the beta estimates changes with the different values of lambda.

## Usage

```
beta_plots(model, voi=NULL, logLambda=TRUE, loi=NULL, ...)
```

## Arguments

|           |                                                                                     |
|-----------|-------------------------------------------------------------------------------------|
| model     | "cv.rq.pen" object.                                                                 |
| voi       | Index of betas to include. Default is all of the lambdas from "cv.rq.pen" object.   |
| logLambda | Plot of lambdas is on the log scale.                                                |
| loi       | Index of lambdas to include. Default is all of the lambdas from "cv.rq.pen" object. |
| ...       | Additional arguments to be sent to plot.                                            |

## Value

Plot of how beta estimates change with lambda.

## Author(s)

Ben Sherwood

## Examples

```
set.seed(1)
x <- matrix(rnorm(800), nrow=100)
y <- 1 + x[,1] - 3*x[,5] + rnorm(100)
lassoModels <- cv.rq.pen(x,y)
b_plot <- beta_plots(lassoModels)
```

---

|       |                                |
|-------|--------------------------------|
| check | <i>Quantile check function</i> |
|-------|--------------------------------|

---

**Description**

Evaluates the check function for quantile tau at value x. Check function is the objective function defined in Koenker and Bassett (1978).

**Usage**

```
check(x, tau)
```

**Arguments**

|     |                                                  |
|-----|--------------------------------------------------|
| x   | Number to be evaluated.                          |
| tau | Number between 0 and 1 for quantile of interest. |

**Value**

```
x*(tau-I(x < 0))
```

**Author(s)**

Ben Sherwood

**References**

[1] Koenker, R. and Bassett, G. (1978). Regression Quantiles, *Econometrica*, **46**, 33–50.

**Examples**

```
check(2, .5)  
check(-2, .5)  
check(2, .2)  
check(2, .8)
```

---

`coef.cv.rq.group.pen` *Group Penalized Quantile Regression Coefficients*

---

**Description**

Returns coefficients for a `cv.rq.pen` object with default values being coefficients associated with minimum cross-validation value.

**Usage**

```
## S3 method for class 'cv.rq.group.pen'  
coef(object, lambda='min',...)
```

**Arguments**

|                     |                                                                                                                                                                                                                                                                                          |
|---------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>object</code> | <code>cv.rq.group.pen</code> object                                                                                                                                                                                                                                                      |
| <code>lambda</code> | Tuning parameter <code>lambda</code> . Default is to select minimum <code>lambda</code> from cross-validation method. User can also select a specific value of <code>lambda</code> , but it needs to be a <code>lambda</code> that was part of the fit of <code>cv.rq.pen</code> object. |
| <code>...</code>    | Additional arguments, but currently not used.                                                                                                                                                                                                                                            |

**Value**

Coefficients for selected value of `lambda`.

**Author(s)**

Ben Sherwood

**Examples**

```
## Not run:  
x <- matrix(rnorm(400),nrow=100)  
y <- 1 + x[,1] - 3*x[,3] + rnorm(100)  
cv_model <- cv.rq.group.pen(x,y,groups=c(rep(1,2),rep(2,2)))  
coefficients(cv_model)  
  
## End(Not run)
```

---

|                |                                                   |
|----------------|---------------------------------------------------|
| coef.cv.rq.pen | <i>Penalized Quantile Regression Coefficients</i> |
|----------------|---------------------------------------------------|

---

**Description**

Returns coefficients for a cv.rq.pen object with default values being coefficients associated with minimum cross-validation value.

**Usage**

```
## S3 method for class 'cv.rq.pen'
coef(object, lambda='min',...)
```

**Arguments**

|        |                                                                                                                                                                                                                       |
|--------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| object | cv.rq.pen object                                                                                                                                                                                                      |
| lambda | Tuning parameter lambda. Default is to select minimum lambda from cross-validation method. User can also select a specific value of lambda, but it needs to be a lambda that was part of the fit of cv.rq.pen object. |
| ...    | Additional arguments, currently not used.                                                                                                                                                                             |

**Value**

Coefficients for selected value of lambda.

**Author(s)**

Ben Sherwood

**Examples**

```
x <- matrix(rnorm(100),nrow=20)
y <- 1 + x[,1] - 3*x[,5] + rnorm(20)
cv_model <- cv.rq.pen(x,y)
coefficients(cv_model)
```

---

|                 |                                                               |
|-----------------|---------------------------------------------------------------|
| cv.rq.group.pen | <i>Cross Validated quantile regression with group penalty</i> |
|-----------------|---------------------------------------------------------------|

---

**Description**

Similar to cv.rq.pen function, but uses group penalty. Group penalties use the L1 norm instead of L2 for computational convenience. As a result of this the group lasso penalty is the same as the typical lasso penalty and thus you should only use a SCAD or MCP penalty. Only the SCAD and MCP penalties incorporate the group structure into the penalty. The group lasso penalty is implemented because it is needed for the SCAD and MCP algorithm. QICD is a group penalty extension of the algorithm presented by Peng and Wang (2015). LP does a linear programming version of the group penalty.

**Usage**

```
cv.rq.group.pen(x, y, groups, tau = 0.5, lambda = NULL, penalty = "SCAD",
  intercept = TRUE, criteria = "CV", cvFunc = "check", nfolds = 10,
  foldid = NULL, nlambda = 100, eps = 1e-04, init.lambda = 1, alg="QICD",
  penGroups=NULL, ...)
```

**Arguments**

|             |                                                                                                                                 |
|-------------|---------------------------------------------------------------------------------------------------------------------------------|
| x           | Matrix of predictors.                                                                                                           |
| y           | Vector of response values.                                                                                                      |
| groups      | Vector assigning columns of x to groups.                                                                                        |
| tau         | Conditional quantile being modelled.                                                                                            |
| lambda      | Vector of lambdas. Default is for lambdas to be automatically generated.                                                        |
| penalty     | Type of penalty: "LASSO", "SCAD" or "MCP".                                                                                      |
| intercept   | Whether model should include an intercept. Constant does not need to be included in "x".                                        |
| criteria    | How models will be evaluated. Either cross-validation "CV", BIC "BIC" or large P BIC "PBIC".                                    |
| cvFunc      | If cross-validation is used how errors are evaluated. Check function "check", "SqErr" (Squared Error) or "AE" (Absolute Value). |
| nfolds      | K for K-folds cross-validation.                                                                                                 |
| foldid      | Group id for cross-validation. Function will randomly generate groups if not specified.                                         |
| nlambda     | Number of lambdas for which models are fit.                                                                                     |
| eps         | Smallest lambda used.                                                                                                           |
| init.lambda | Initial lambda used to find the maximum lambda. Not needed if lambda values are set.                                            |
| alg         | Algorithm used for fit. "QICD" or "LP".                                                                                         |
| penGroups   | Specify which groups will be penalized. Default is to penalize all groups.                                                      |
| ...         | Additional arguments to be sent to rq.group.fit or groupQICDMultLambda.                                                         |

**Value**

Returns the following:

|            |                                                                                               |
|------------|-----------------------------------------------------------------------------------------------|
| beta       | Matrix of coefficients for different values of lambda                                         |
| residuals  | Matrix of residuals for different values of lambda.                                           |
| rho        | Vector of rho, unpenalized portion of the objective function, for different values of lambda. |
| cv         | Data frame with "lambda" and second column is the evaluation based on the criteria selected.  |
| lambda.min | Lambda which provides the smallest statistic for the selected criteria.                       |
| penalty    | Penalty selected.                                                                             |
| intercept  | Whether intercept was included in model.                                                      |
| groups     | Group structure for penalty function.                                                         |

**Author(s)**

Ben Sherwood

**References**

- [1] Yuan, M. and Lin, Y. (2006). Model selection and estimation in regression with grouped variables. *J. R. Statist. Soc. B*, **68**, 49-67.
- [2] Peng, B. and Wang, L. (2015). An Iterative Coordinate Descent Algorithm for High-Dimensional Nonconvex Penalized Quantile Regression. *Journal of Computational and Graphical Statistics*, **24**, 676-694.

**Examples**

```
## Not run:
x <- matrix(rnorm(800),nrow=100)
y <- 1 + x[,1] - 3*x[,5] + rnorm(100)
cv_model <- cv.rq.group.pen(x,y,groups=c(rep(1,4),rep(2,4)))

## End(Not run)
```

cv.rq.pen

*Cross Validated quantile regression***Description**

Produces penalized quantile regression models for a range of lambdas and penalty of choice. If lambda is unselected than an iterative algorithm is used to find a maximum lambda such that the penalty is large enough to produce an intercept only model. Then range of lambdas goes from the maximum lambda found to "eps" on the log scale. For non-convex penalties local linear approximation approach used by Wang, Wu and Li to extend LLA as proposed by Zou and Li (2008) to the quantile regression setting.

**Usage**

```
cv.rq.pen(x,y,tau=.5,lambda=NULL,weights=NULL,penalty="LASSO",
          intercept=TRUE,criteria="CV",cvFunc="check",nfolds=10,
          foldid=NULL,nlambda=100,eps=.0001,init.lambda=1, penVars=NULL,
          alg = ifelse(ncol(x) < 50, "LP", "QICD"),...)
```

**Arguments**

|        |                                                                          |
|--------|--------------------------------------------------------------------------|
| x      | Matrix of predictors.                                                    |
| y      | Vector of response values.                                               |
| tau    | Conditional quantile being modelled.                                     |
| lambda | Vector of lambdas. Default is for lambdas to be automatically generated. |



|             |                                                                                                                                 |
|-------------|---------------------------------------------------------------------------------------------------------------------------------|
| weights     | Weights for the objective function.                                                                                             |
| penalty     | Type of penalty: "LASSO", "SCAD" or "MCP".                                                                                      |
| intercept   | Whether model should include an intercept. Constant does not need to be included in "x".                                        |
| criteria    | How models will be evaluated. Either cross-validation "CV", BIC "BIC" or large P BIC "PBIC".                                    |
| cvFunc      | If cross-validation is used how errors are evaluated. Check function "check", "SqErr" (Squared Error) or "AE" (Absolute Value). |
| nfolds      | K for K-folds cross-validation.                                                                                                 |
| foldid      | Group id for cross-validation. Function will randomly generate groups if not specified.                                         |
| nlambda     | Number of lambdas for which models are fit.                                                                                     |
| eps         | Smallest lambda used.                                                                                                           |
| init.lambda | Initial lambda used to find the maximum lambda. Not needed if lambda values are set.                                            |
| penVars     | Variables that should be penalized. With default value of NULL all variables are penalized.                                     |
| alg         | Algorithm that will be used, either linear programming (LP) or coordinate descent (QICD) algorithm from Peng and Wang (2015).   |
| ...         | Additional arguments to be sent to rq.lasso.fit or rq.nc.fit.                                                                   |

### Value

Returns the following:

|            |                                                                                                           |
|------------|-----------------------------------------------------------------------------------------------------------|
| models     | List of penalized models fit. Number of models will match number of lambdas and correspond to cv\$lambda. |
| cv         | Data frame with "lambda" and second column is the evaluation based on the criteria selected.              |
| lambda.min | Lambda which provides the smallest statistic for the selected criteria.                                   |
| penalty    | Penalty selected.                                                                                         |

### Author(s)

Ben Sherwood

### References

- [1] Peng, B. and Wang, L. An iterative coordinate descent algorithm for high-dimensional nonconvex penalized quantile regression. *Journal of Computational and Graphical Statistics*, **24**, 676-694.
- [2] Wang, L., Wu, Y. and Li, R. Quantile regression of analyzing heterogeneity in ultra-high dimension. *J. Am. Statist. Ass.*, **107**, 214-222.
- [3] Wu, Y. and Liu, Y. (2009). Variable selection in quantile regression. *Statistica Sinica*, **19**, 801-817.
- [4] Zou, H. and Li, R. (2008). One-step sparse estimates in nonconcave penalized likelihood models. *Ann. Statist.*, **36**, 1509-1533.

## Examples

```
## Not run:
x <- matrix(rnorm(800),nrow=100)
y <- 1 + x[,1] - 3*x[,5] + rnorm(100)
cv_model <- cv.rq.pen(x,y)

## End(Not run)
```

---

cv\_plots

*Plots of Cross-validation results*

---

## Description

Slightly misnamed as user could choose BIC as a criteria for "cv.rq.pen" object. Function is able to discern between the two types of evaluation criteria and provides appropriate labels for the plot.

## Usage

```
cv_plots(model, logLambda=TRUE, loi=NULL, ...)
```

## Arguments

|           |                                                                                        |
|-----------|----------------------------------------------------------------------------------------|
| model     | "cv.rq.pen" object.                                                                    |
| logLambda | Plot of lambdas is on the log scale.                                                   |
| loi       | Index of lambdas to be plotted. Default is all of the lambdas from "cv.rq.pen" object. |
| ...       | Additional items to be sent to plot function.                                          |

## Value

Plot of how cross validation statistic changes with lambda.

## Author(s)

Ben Sherwood

## Examples

```
x <- matrix(rnorm(100),nrow=20)
y <- 1 + x[,1] - 3*x[,5] + rnorm(20)
lassoModels <- cv.rq.pen(x,y)
cv_plot <- cv_plots(lassoModels)
```

---

|        |                                 |
|--------|---------------------------------|
| getRho | <i>Objective Function Value</i> |
|--------|---------------------------------|

---

**Description**

Returns unpenalized portion of the objective function for a penalized quantile regression object.

**Usage**

```
getRho(model)
```

**Arguments**

model                    Object with rho as an attribute

**Value**

Rho is the value of the unpenalized portion of the objective function.

**Author(s)**

Ben Sherwood

**Examples**

```
x <- matrix(rnorm(800),nrow=100)
y <- 1 + x[,1] - 3*x[,5] + rnorm(100)
lassoModel <- rq.lasso.fit(x,y,lambda=.5)
getRho(lassoModel)
```

---

|              |                                                                         |
|--------------|-------------------------------------------------------------------------|
| get_coef_pen | <i>Returns the coefficient part of the penalized objective function</i> |
|--------------|-------------------------------------------------------------------------|

---

**Description**

Returns the value for the penalized portion of the penalized objective function.

**Usage**

```
get_coef_pen(coefs, lambda, intercept, penVars, penalty="LASSO")
```

**Arguments**

coefs                    Coefficients to be transformed.  
lambda                    The penalty tuning parameter.  
intercept                If the intercept is part of the coefficients.  
penVars                  Variables that were penalized.  
penalty                  The penalty function used.

**Author(s)**

Ben Sherwood

groupMultLambda

*Quantile Regression with Group Penalty for multiple lambdas***Description**

Fit multiple models with L1 group penalty. QICD algorithm is using an adaptation of the algorithm presented by Peng and Wang (2015).

**Usage**

```
groupMultLambda(x, y, groups, tau = 0.5, lambda, intercept = TRUE,
  penalty="LASSO", alg="QICD_warm", penGroups=NULL, ...)
```

**Arguments**

|           |                                                                                          |
|-----------|------------------------------------------------------------------------------------------|
| x         | Matrix of predictors.                                                                    |
| y         | Vector of response values.                                                               |
| groups    | Vector assigning columns of x to groups.                                                 |
| tau       | Conditional quantile being modelled.                                                     |
| lambda    | Vector of lambdas. Default is for lambdas to be automatically generated.                 |
| intercept | Whether model should include an intercept. Constant does not need to be included in "x". |
| penalty   | Type of penalty: "LASSO", "SCAD" or "MCP".                                               |
| alg       | "QICD" for QICD implementation. Otherwise linear programming approach is implemented.    |
| penGroups | Specify which groups will be penalized. Default is to penalize all groups.               |
| ...       | Additional parameters to be sent to rq.group.fit.                                        |

**Value**

Returns a list of rq.group.pen objects. Each element of the list is a fit for a different value of lambda.

**Author(s)**

Ben Sherwood

**References**

- [1] Yuan, M. and Lin, Y. (2006). Model selection and estimation in regression with grouped variables. *J. R. Statist. Soc. B*, **68**, 49-67.
- [2] Peng, B. and Wang, L. (2015). An Iterative Coordinate Descent Algorithm for High-Dimensional Nonconvex Penalized Quantile Regression. *Journal of Computational and Graphical Statistics*, **24**, 676-694.

**Examples**

```
## Not run:
x <- matrix(rnorm(400),nrow=100)
y <- 1 + x[,1] - 3*x[,3] + rnorm(100)
cv_model <- groupMultLambda(x,y,groups=c(rep(1,2),rep(2,2)),lambda=seq(.1,.5,.1))

## End(Not run)
```

---

|              |                                      |
|--------------|--------------------------------------|
| group_derivs | <i>Derivative of a group penalty</i> |
|--------------|--------------------------------------|

---

**Description**

Used to estimate non-convex group penalties.

**Usage**

```
group_derivs(deriv_func,groups,coefs,lambda,a=3.7)
```

**Arguments**

|            |                                          |
|------------|------------------------------------------|
| deriv_func | Target derivative function.              |
| groups     | Vector assigning columns of x to groups. |
| coefs      | Coefficients.                            |
| lambda     | Lambda value for deriv_func.             |
| a          | Additional parameter for deriv_func.     |

**Value**

Returns the derivative of the L1 group penalty function.

**Author(s)**

Ben Sherwood

---

|       |              |
|-------|--------------|
| lasso | <i>Lasso</i> |
|-------|--------------|

---

**Description**

LASSO penalty function.

**Usage**

```
lasso(x, lambda)
```

**Arguments**

|        |                         |
|--------|-------------------------|
| x      | Number to be evaluated  |
| lambda | Tuning parameter lambda |

**Value**

lambda\*abs(x)

**Author(s)**

Ben Sherwood

**References**

[1] Tibshirani, R. (1996). Regression shrinkage and selection via the lasso. *Journal of the Royal Statistical Society. Series B*, **58**, 267–288.

**Examples**

```
lasso(3,1)
lasso(-3,1)
lasso(-3,2)
```

---

|           |                                            |
|-----------|--------------------------------------------|
| LASSO.fit | <i>LASSO Penalized Quantile Regression</i> |
|-----------|--------------------------------------------|

---

**Description**

LASSO.fit obtains coefficient estimates for Lasso penalized quantile regression. It is called by the QICD and QICD.group functions to obtain initial estimates when they are not provided.

**Usage**

```
LASSO.fit(y, x, tau, lambda, intercept, coef.cutoff, weights=NULL)
```

**Arguments**

|             |                                                                                                                                                                                 |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| y           | Vector of responses.                                                                                                                                                            |
| x           | n x p matrix of covariates.                                                                                                                                                     |
| tau         | Conditional quantile being modelled.                                                                                                                                            |
| lambda      | Tuning parameter. Must be positive.                                                                                                                                             |
| intercept   | If TRUE, an intercept is included in the model. If FALSE, no intercept is included.                                                                                             |
| coef.cutoff | Coefficients with magnitude less than this value are set to 0.                                                                                                                  |
| weights     | If not NULL, weights must be a vector of length n with a positive weight for each observation. This is used for the linear programming solution for the SCAD and MCP penalties. |

**Details**

This is a barebones function that only provides coefficient estimates. It will not provide any warnings or errors, so you need to check that inputs are accurate and appropriate. The `rq.lasso.fit` function should be used to obtain more information from the Lasso fit.

**Value**

Returns a vector containing the intercept (if `intercept=TRUE`) and the estimated coefficients for each column in `x`.

**Author(s)**

Adam Maidman

**References**

[1] Tibshirani, R. (1996). Regression shrinkage and selection via the lasso. *Journal of the Royal Statistical Society. Series B*, **58**, 267–288.

**Examples**

```
n = 50
p = 100
x <- matrix(rnorm(n*p), nrow=n)
y <- 0 + x[,1] - 3*x[,5] + rnorm(n)
fit1 <- LASSO.fit(y,x, tau=.5, lambda=1, intercept=TRUE, coef.cutoff=1e-08)
fit2 <- LASSO.fit(y,x, tau=.5, lambda=.1, intercept=TRUE, coef.cutoff=1e-08)
```

---

|                  |                                                                                |
|------------------|--------------------------------------------------------------------------------|
| LASSO.fit.nonpen | <i>LASSO Penalized Quantile Regression with some nonpenalized coefficients</i> |
|------------------|--------------------------------------------------------------------------------|

---

### Description

LASSO.fit.nonpen obtains coefficient estimates for Lasso penalized quantile regression with some nonpenalized coefficients. It is called by the QICD.nonpen function to obtain initial estimates when they are not provided.

### Usage

```
LASSO.fit.nonpen(y, x, z, tau, lambda, intercept, coef.cutoff, weights=NULL)
```

### Arguments

|             |                                                                                                                                                                                                                                       |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| y           | Vector of responses.                                                                                                                                                                                                                  |
| x           | n x p matrix of covariates.                                                                                                                                                                                                           |
| z           | n x q matrix of observations with each row corresponding to one observation. Penalties (and variable selection) WILL NOT be applied to these coefficients. Do not include column of 1's; set intercept=TRUE, if intercept is desired. |
| tau         | Conditional quantile being modelled.                                                                                                                                                                                                  |
| lambda      | Tuning parameter. Must be positive.                                                                                                                                                                                                   |
| intercept   | If TRUE, an intercept is included in the model. If FALSE, no intercept is included.                                                                                                                                                   |
| coef.cutoff | Coefficients with magnitude less than this value are set to 0.                                                                                                                                                                        |
| weights     | If not NULL, weights must be a vector of length n with a positive weight for each observation. This is used for the linear programming solution for the SCAD and MCP penalties.                                                       |

### Details

This is a barebones function that only provides coefficient estimates. It will not provide any warnings or errors, so you need to check that inputs are accurate and appropriate. The rq.lasso.fit function should be used to obtain more information from the Lasso fit.

### Value

Returns a vector containing the intercept (if intercept=TRUE) and the estimated coefficients for each column in x and z.

### Author(s)

Adam Maidman



## References

[1] Tibshirani, R. (1996). Regression shrinkage and selection via the lasso. *Journal of the Royal Statistical Society. Series B*, **58**, 267–288.

## Examples

```
library(splines)
n = 50
p = 100
x <- matrix(rnorm(n*p), nrow=n)
z1 <- runif(n)
z <- bs(z1)
y <- 0 + x[,1] - 3*x[,5] + z1^3 + rnorm(n)
fit1 <- LASSO.fit.nonpen(y,x,z, tau=.5, lambda=1, intercept=TRUE, coef.cutoff=1e-08)
fit2 <- LASSO.fit.nonpen(y,x,z, tau=.5, lambda=.1, intercept=TRUE, coef.cutoff=1e-08)
```

---

mcp

MCP

---

## Description

MCP function as described in Fan and Li (2001).

## Usage

```
mcp(x, lambda, a)
```

## Arguments

|        |                         |
|--------|-------------------------|
| x      | Number to be evaluated  |
| lambda | Tuning parameter lambda |
| a      | Tuning parameter a      |

## Value

MCP function with tuning parameters lambda and "a" evaluated at "x".

## Author(s)

Ben Sherwood

## References

[1] Zhang, C. Nearly unbiased variable selection under minimax concave penalty. (2010). *Ann. Statist.*, **38**, 894–942.

**Examples**

```
mcp(3,1)
mcp(-3,1)
mcp(.001,2)
```

---

`mcp_deriv`*MCP Derivative*

---

**Description**

Derivative of MCP function as described in Fan and Li (2001).

**Usage**

```
mcp_deriv(x,lambda,a)
```

**Arguments**

|                     |                         |
|---------------------|-------------------------|
| <code>x</code>      | Number to be evaluated  |
| <code>lambda</code> | Tuning parameter lambda |
| <code>a</code>      | Tuning parameter a      |

**Value**

Derivative of MCP function with tuning parameters lambda and "a" evaluated at "x".

**Author(s)**

Ben Sherwood

**References**

[1] Zhang, C. Nearly unbiased variable selection under minimax concave penalty. (2010). *Ann. Statist.*, **38**, 894–942.

**Examples**

```
mcp(3,1)
mcp(-3,1)
mcp(.001,2)
```

---

model\_eval

*Model Evaluation*


---

### Description

Used for cross-validation. For a model of class "rqPen" it provides the average prediction error given the evaluation function of choice.

### Usage

```
model_eval(model, test_x, test_y, test_w=NULL, func="check",...)
```

### Arguments

|        |                                                                                                                                       |
|--------|---------------------------------------------------------------------------------------------------------------------------------------|
| model  | Model of class "rqPen".                                                                                                               |
| test_x | Covariates used for prediction.                                                                                                       |
| test_y | Response to compare predictions against.                                                                                              |
| test_w | Weights for a weighted mean, typically used if weights were used to fit the model.                                                    |
| func   | Function used for evaluation. Options: "check" (Quantile Check), "SqErr" (Squared Error), "AE" (Absolute Value)                       |
| ...    | Additional arguments to be sent to evaluation function. For instance check requires tau which is not part of the model_eval function. |

### Value

Mean of prediction errors using the chosen function.

### Author(s)

Ben Sherwood

### Examples

```
x <- matrix(rnorm(800),ncol=8)
y <- 1 + x[,1] - 3*x[,5] + rnorm(100)
l_model <- rq.lasso.fit(x,y,lambda=1)
nc_model <- rq.nc.fit(x,y,lambda=1)
newx <- matrix(rnorm(16),ncol=8)
newy <- 1 + newx[,1] - 3*newx[,5] + rnorm(2)
model_eval(l_model, newx, newy)
model_eval(l_model, newx, newy, func="SqErr")
model_eval(nc_model, newx, newy)
```

nonzero

*Nonzero*

---

**Description**

Calls nonzero function based on object.

**Usage**

```
nonzero(obj)
```

**Arguments**

obj                    Model.

**Value**

Returns if coefficients or groups are nonzero or not. TRUE if they are not zero and FALSE if they are.

**Author(s)**

Ben Sherwood

**Examples**

```
## Not run:
x <- matrix(rnorm(400),nrow=100)
y <- 1 + x[,1] - 3*x[,3] + rnorm(100)
cv_model <- cv.rq.group.pen(x,y,groups=c(rep(1,2),rep(2,2)))
nonzero(cv_model)

## End(Not run)
```

---

nonzero.cv.rq.group.pen*Nonzero*

---

**Description**

Calls nonzero function.

**Usage**

```
## S3 method for class 'cv.rq.group.pen'
nonzero(obj)
```

**Arguments**

obj                    cv.rq.group.pen object.

**Value**

Returns true if all elements in a group are non-zero and FALSE if they are not. Chooses the model associated with lambda.min.

**Author(s)**

Ben Sherwood

**Examples**

```
## Not run:
x <- matrix(rnorm(400),nrow=100)
y <- 1 + x[,1] - 3*x[,3] + rnorm(100)
cv_model <- cv.rq.group.pen(x,y,groups=c(rep(1,2),rep(2,2)))
nonzero(cv_model)

## End(Not run)
```

---

plot.cv.rq.group.pen    *Plot cv.rq.group.pen*

---

**Description**

Plots the validation criteria against the lambda values.

**Usage**

```
## S3 method for class 'cv.rq.group.pen'
plot(x,y=NULL,...)
```

**Arguments**

x                    cv.rq.group.pen object.  
y                    holder value to match up with default plot program  
...                  Additional values to function, but not currently used

**Value**

Plots the validation criteria against the lambda values.

**Author(s)**

Ben Sherwood

**Examples**

```
## Not run:  
x <- matrix(rnorm(400),nrow=100)  
y <- 1 + x[,1] - 3*x[,3] + rnorm(100)  
cv_model <- cv.rq.group.pen(x,y,groups=c(rep(1,2),rep(2,2)))  
plot(cv_model)  
  
## End(Not run)
```

---

pos\_part

*Positive part*

---

**Description**

Returns  $\min(0,x)$

**Usage**

```
pos_part(x)
```

**Arguments**

x                    Number to be evaluated

**Value**

$\min(0,x)$

**Author(s)**

Ben Sherwood

**Examples**

```
pos_part(5)  
pos_part(-5)
```

---

|                   |                                                                 |
|-------------------|-----------------------------------------------------------------|
| predict.cv.rq.pen | <i>Prediction from a cv quantile regression penalized model</i> |
|-------------------|-----------------------------------------------------------------|

---

## Description

Returns predicted values from "rqPen" model associated with lambda for "newx" covariates.

## Usage

```
## S3 method for class 'cv.rq.pen'  
predict(object, newx, lambda,...)
```

## Arguments

|        |                                                                                                                                                                                                   |
|--------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| object | "cv.rq.pen" object.                                                                                                                                                                               |
| newx   | Matrix of covariates used for prediction.                                                                                                                                                         |
| lambda | Lambda associated with the model from which predictions should be made. Default is to use the lambda that provides the minimum criteria (cross-validation or BIC) that was selected by cv.rq.pen. |
| ...    | Needed for consistency with generic predict.                                                                                                                                                      |

## Value

Returns predicted values from the model for the selected lambda.

## Author(s)

Ben Sherwood

## Examples

```
x <- matrix(rnorm(800),nrow=100)  
y <- 1 + x[,1] - 3*x[,5] + rnorm(100)  
cv_model <- cv.rq.pen(x,y)  
n2 <- matrix(rnorm(80),nrow=10)  
preds <- predict(cv_model,n2)
```

---

|                |                                                              |
|----------------|--------------------------------------------------------------|
| predict.rq.pen | <i>Prediction from a quantile regression penalized model</i> |
|----------------|--------------------------------------------------------------|

---

**Description**

Returns predicted values from "rq.pen" object for "newx" covariates.

**Usage**

```
## S3 method for class 'rq.pen'
predict(object, newx,...)
```

**Arguments**

|        |                                              |
|--------|----------------------------------------------|
| object | rq.pen object.                               |
| newx   | Matrix of covariates used for prediction.    |
| ...    | Needed for consistency with generic predict. |

**Value**

Returns predicted values from the model.

**Author(s)**

Ben Sherwood

**Examples**

```
x <- matrix(rnorm(800),nrow=100)
y <- 1 + x[,1] - 3*x[,5] + rnorm(100)
lassoModel <- rq.lasso.fit(x,y,lambda=1)
n2 <- matrix(rnorm(80),nrow=10)
preds <- predict(lassoModel,n2)
```

---

|                 |                               |
|-----------------|-------------------------------|
| print.cv.rq.pen | <i>Print cv.rq.pen object</i> |
|-----------------|-------------------------------|

---

**Description**

Prints the cross validation (or bic) results and reports coefficients for a cv.rq.pen object. Default coefficients are for value that minimizes cross validation or BIC.

**Usage**

```
## S3 method for class 'cv.rq.pen'
print(x,...)
```



**Arguments**

x                    Object to be printed.  
...                   Additional arguments for coefficient function

**Author(s)**

Ben Sherwood

---

print.rq.pen                    *Print rq.pen object*

---

**Description**

Reports coefficients for a rq.pen object.

**Usage**

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

**Arguments**

x                    Object to be printed.  
...                   Additional arguments for coefficient function

**Author(s)**

Ben Sherwood

---

qaSIS                            *Quantile Adaptive Sure Independence Screening*

---

**Description**

Implements quantile adaptive screening as outlined by He, Wang and Hong

**Usage**

```
qaSIS(x,y,tau,linear=FALSE,...)
```

**Arguments**

|        |                                                                                             |
|--------|---------------------------------------------------------------------------------------------|
| x      | Matrix of predictors.                                                                       |
| y      | Vector of response values.                                                                  |
| tau    | Conditional quantile being modelled.                                                        |
| linear | If true linear screening will be done, otherwise splines will be fit to each column vector. |
| ...    | Additional items to be sent to bs function from splines package.                            |

**Value**

Returns the ranking of important predictors, from highest to lowest.

**Author(s)**

Ben Sherwood

**References**

[1] He, X., Wang, L. and Hong, H. (2013). Quantile-Adaptive Model-free Variable Screening for High-dimensional Heterogeneous Data. *The Annals of Statistics*, **41**, 342–369.

**Examples**

```
x <- pnorm(matrix(rnorm(800),nrow=100))
y <- 1 + 2*cos(2*pi*x[,1])+exp(2*x[,2]) + rnorm(100,sd=.1)
var_ranks <- qaSIS(x,y)
```

---

qbic

*Quantile Regresion BIC*


---

**Description**

Quantile regression BIC with large p alternative as described in Lee, Noh and Park (2013).

**Usage**

```
qbic(model, largeP=FALSE)
```

**Arguments**

|        |                                                                                                                      |
|--------|----------------------------------------------------------------------------------------------------------------------|
| model  | Model of class "rqPen".                                                                                              |
| largeP | Large P version using an additional penalty factor of log(s) where "s" is the total number of covariates considered. |

**Value**

Numeric value representing BIC of selected model.

**Author(s)**

Ben Sherwood

**References**

[1] Lee, E., Noh, H. and Park, B. (2014). Model selection via Bayesian Information Criterion for quantile regression models., *J. Am. Statist. Ass.*, **109**, 216–229.

**Examples**

```
x <- matrix(rnorm(800),nrow=100)
y <- 1 + x[,1] - 3*x[,5] + rnorm(100)
l_model <- rq.lasso.fit(x,y, lambda=1)
nc_model <- rq.nc.fit(x,y, lambda=1)
qbic(l_model)
qbic(nc_model)
qbic(l_model, largeP=TRUE)
qbic(nc_model, largeP=TRUE)
```

---

 QICD

*Penalized Quantile Regression with QICD Algorithm*


---

**Description**

QICD produces penalized quantile regression estimates using the QICD algorithm. If no initial values are given, LASSO estimates will be used. This function can handle the LASSO, SCAD, and MCP penalties.

**Usage**

```
QICD(y, x, tau=.5, lambda, intercept=TRUE, penalty="SCAD",
      initial_beta=NULL, maxin=100, maxout=20, eps = 1e-05, coef.cutoff=1e-08,
      a=3.7, scalex=TRUE, ...)
```

**Arguments**

|           |                                                                                                                                                         |
|-----------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
| y         | Vector of response values.                                                                                                                              |
| x         | n x p matrix of observations with each row corresponding to one observation. Do not include column of 1's; set intercept=TRUE, if intercept is desired. |
| tau       | Conditional quantile being modelled.                                                                                                                    |
| lambda    | Tuning parameter for LASSO, SCAD, and MCP penalties. Must be positive.                                                                                  |
| intercept | If TRUE, an intercept is included in the model. If FALSE, no intercept is included.                                                                     |
| penalty   | Penalty function for the coefficients. Either "SCAD", "MCP", or "LASSO". See details for description of penalties.                                      |

|                           |                                                                                                                                                                                                                                                                  |
|---------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>initial_beta</code> | Vector of initial values for QICD algorithm. The vector should contain the intercept first (if <code>intercept=TRUE</code> ) and then the <code>p</code> coefficients. If <code>NULL</code> , exact LASSO estimates will be computed and used as initial values. |
| <code>maxin</code>        | Maximum number of iterations on the minimization step of the QICD algorithm.                                                                                                                                                                                     |
| <code>maxout</code>       | Maximum number of iterations on the majorization step of the QICD algorithm.                                                                                                                                                                                     |
| <code>eps</code>          | Threshold for convergence of algorithm.                                                                                                                                                                                                                          |
| <code>coef.cutoff</code>  | Coefficients with magnitude less than this value are set to 0.                                                                                                                                                                                                   |
| <code>a</code>            | Second tuning parameter for SCAD and MCP penalties. Must be greater than 2 for SCAD and greater than 1 for MCP.                                                                                                                                                  |
| <code>scalex</code>       | If <code>TRUE</code> the <code>x</code> predictors are transformed to have mean zero and standard deviation one before fitting the model. Output is returned on the original scale of the data.                                                                  |
| <code>...</code>          | The extra arguments will not be used.                                                                                                                                                                                                                            |

### Details

The QICD algorithm should only be used for the LASSO penalty if `initial_beta` can be set to LASSO estimates with a similar `lambda` (similar to a "warm start"). Otherwise, exact LASSO estimates will be used as initial values for the QICD algorithm: this will cause unnecessary computations and could lead to less accurate estimates.

### Value

Returns a vector containing the intercept (if `intercept=TRUE`) and the estimated coefficients for each column in `x`.

### Author(s)

Adam Maidman

### References

- [1] Wang, L., Wu, Y. and Li, R. (2012). Quantile regression of analyzing heterogeneity in ultra-high dimension. *J. Am. Statist. Ass.*, **107**, 214–222.
- [2] Wu, Y. and Liu, Y. (2009). Variable selection in quantile regression. *Statistica Sinica*, **19**, 801–817.
- [3] Zou, H. and Li, R. (2008). One-step sparse estimates in nonconcave penalized likelihood models. *Ann. Statist.*, **36**, 1509–1533.
- [4] Peng, B. and Wang, L. (2015). An iterative coordinate-descent algorithm for high-dimensional nonconvex penalized quantile regression. *J. Comp. Graph.*, **24**, 676–694.

### Examples

```
n = 50
p = 5
x <- matrix(rnorm(n*p), nrow=n)
y <- 0 + x[,1] - 3*x[,5] + rnorm(n)
```

```
fit1 <- QICD(y,x, tau=.5, lambda=1, intercept=TRUE, penalty="SCAD")
fit2 <- QICD(y,x, tau=.7, lambda=1, intercept=TRUE, penalty="SCAD")
```

---

QICD.group

*Group Penalized Quantile Regression with QICD Algorithm*


---

### Description

QICD.group produces group penalized quantile regression estimates using the QICD algorithm. If no initial values are given, LASSO estimates will be used. This function can handle the LASSO, SCAD, and MCP penalties.

### Usage

```
QICD.group(y, x, groups, tau=.5, lambda, intercept=TRUE, penalty="SCAD",
           initial_beta=NULL, maxin=100, maxout=20, eps = 1e-05,
           coef.cutoff=1e-08, a=3.7, scalex, ...)
```

### Arguments

|              |                                                                                                                                                                                                                         |
|--------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| y            | Vector of response values.                                                                                                                                                                                              |
| x            | n x p matrix of observations with each row corresponding to one observation. Do not include column of 1's; set intercept=TRUE, if intercept is desired.                                                                 |
| groups       | Vector of length p with the group number of the corresponding coefficient. Coefficients in the same group will either all be 0, or none will be 0.                                                                      |
| tau          | Conditional quantile being modelled.                                                                                                                                                                                    |
| lambda       | Tuning parameter for LASSO, SCAD, and MCP penalties. Must be positive.                                                                                                                                                  |
| intercept    | If TRUE, an intercept is included in the model. If FALSE, no intercept is included.                                                                                                                                     |
| penalty      | Penalty function for the coefficients. Either "SCAD", "MCP", or "LASSO". See details for description of penalties.                                                                                                      |
| initial_beta | Vector of initial values for QICD algorithm. The vector should contain the intercept first (if intercept=TRUE) and then the p coefficients. If NULL, exact LASSO estimates will be computed and used as initial values. |
| maxin        | Maximum number of iterations on the minimization step of the QICD algorithm.                                                                                                                                            |
| maxout       | Maximum number of iterations on the majorization step of the QICD algorithm.                                                                                                                                            |
| eps          | Threshold for convergence of algorithm.                                                                                                                                                                                 |
| coef.cutoff  | Coefficients with magnitude less than this value are set to 0.                                                                                                                                                          |
| a            | Second tuning parameter for SCAD and MCP penalties. Must be greater than 2 for SCAD and greater than 1 for MCP.                                                                                                         |
| scalex       | If set to true the predictors will be scaled to have mean zero and standard deviation of one before fitting the model. The output returned will be on the original scale of the data.                                   |
| ...          | The extra arguments will not be used.                                                                                                                                                                                   |

## Details

The QICD algorithm should only be used for the LASSO penalty if `initial_beta` can be set to LASSO estimates with a similar `lambda` (similar to a "warm start"). Otherwise, exact LASSO estimates will be used as initial values for the QICD algorithm: this will cause unnecessary computations and could lead to less accurate estimates.

## Value

Returns a vector containing the intercept (if `intercept=TRUE`) and the estimated coefficients for each column in `x`.

## Author(s)

Adam Maidman

## References

- [1] Wang, L., Wu, Y. and Li, R. (2012). Quantile regression of analyzing heterogeneity in ultra-high dimension. *J. Am. Statist. Ass.*, **107**, 214–222.
- [2] Wu, Y. and Liu, Y. (2009). Variable selection in quantile regression. *Statistica Sinica*, **19**, 801–817.
- [3] Zou, H. and Li, R. (2008). One-step sparse estimates in nonconcave penalized likelihood models. *Ann. Statist.*, **36**, 1509–1533.
- [4] Peng, B. and Wang, L. (2015). An iterative coordinate-descent algorithm for high-dimensional nonconvex penalized quantile regression. *J. Comp. Graph.*, **24**, 676–694.
- [5] Yuan, M. and Lin, Y. (2006). Model selection and estimation in regression with grouped variables. *J. R. Statist. Soc. B*, **68**, 49-67.

## Examples

```
library(splines)
n = 50
p = 100
x <- matrix(rnorm(n*p),nrow=n)
z1 <- runif(n)
z2 <- runif(n)
x <- cbind(x, bs(z1), bs(z2))
groups <- c( 1:p, rep(101,3), rep(102,3) )
y <- 0 + x[,1] - 3*x[,5] + z1^3 + rnorm(n)
fit1 <- QICD.group(y,x, groups, tau=.5, lambda=1, intercept=TRUE, penalty="SCAD")
fit2 <- QICD.group(y,x, groups, tau=.7, lambda=1, intercept=TRUE, penalty="SCAD")
```

---

|             |                                                                                                              |
|-------------|--------------------------------------------------------------------------------------------------------------|
| QICD.master | <i>Master QICD Function for Regular QICD, group QICD, and Partially Penalized QICD with Multiple Lambdas</i> |
|-------------|--------------------------------------------------------------------------------------------------------------|

---

### Description

QICD.master produces penalized quantile regression estimates for all three cases of the QICD algorithm (QICD, QICD.nonpen, QICD.group). This function will find estimates for multiple lambdas.

### Usage

```
QICD.master(y, x, z=NULL, groups=NULL, tau=.5, lambda, intercept=TRUE,
  penalty="SCAD", initial_beta, maxin=100, maxout=20,
  eps = 1e-05, coef.cutoff=1e-08, a=3.7, ...)
```

### Arguments

|              |                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|--------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| y            | Vector of response values.                                                                                                                                                                                                                                                                                                                                                                                                                      |
| x            | n x p matrix of observations with each row corresponding to one observation. Penalties (and variable selection) will be applied to these coefficients. Do not include column of 1's; set intercept=TRUE, if intercept is desired.                                                                                                                                                                                                               |
| z            | n x q matrix of observations with each row corresponding to one observation. Penalties (and variable selection) WILL NOT be applied to these coefficients. Do not include column of 1's; set intercept=TRUE, if intercept is desired. Set to NULL if all coefficients (except for intercept) should be penalized. Currently no support for z and groups.                                                                                        |
| groups       | Vector of length p with the group number of the corresponding coefficient. Coefficients in the same group will either all be 0, or none will be 0. Set to NULL if no groups. Currently no support for groups and z.                                                                                                                                                                                                                             |
| tau          | Conditional quantile being modelled.                                                                                                                                                                                                                                                                                                                                                                                                            |
| lambda       | Tuning parameters for LASSO, SCAD, and MCP penalties. Must be positive.                                                                                                                                                                                                                                                                                                                                                                         |
| intercept    | If TRUE, an intercept is included in the model. If FALSE, no intercept is included.                                                                                                                                                                                                                                                                                                                                                             |
| penalty      | Penalty function for the coefficients. Either "SCAD", "MCP", or "LASSO". See details for description of penalties.                                                                                                                                                                                                                                                                                                                              |
| initial_beta | Vector of initial values for QICD algorithm. The vector should contain the intercept first (if intercept=TRUE) and then the p coefficients corresponding to x. Initial values for the coefficients corresponding to z can be passed after the the x coefficients, but will be ignored. These initial values will be used for all values of lambda. It is recommended to use LASSO estimates (with appropriately chosen lambda) as initial_beta. |
| maxin        | Maximum number of iterations on the minimization step of the QICD algorithm.                                                                                                                                                                                                                                                                                                                                                                    |
| maxout       | Maximum number of iterations on the majorization step of the QICD algorithm.                                                                                                                                                                                                                                                                                                                                                                    |
| eps          | Threshold for convergence of algorithm.                                                                                                                                                                                                                                                                                                                                                                                                         |

|                          |                                                                                                                 |
|--------------------------|-----------------------------------------------------------------------------------------------------------------|
| <code>coef.cutoff</code> | Coefficients with magnitude less than this value are set to 0.                                                  |
| <code>a</code>           | Second tuning parameter for SCAD and MCP penalties. Must be greater than 2 for SCAD and greater than 1 for MCP. |
| <code>...</code>         | For partially penalized penalties, the method can be changed. See <code>QICD.nonpen</code> function.            |

### Value

Returns the following:

|                           |                                                                                                                                                       |
|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>coefficients</code> | Matrix of estimated coefficients corresponding to each value of lambda. The <i>i</i> th column corresponds to the <i>i</i> th lambda value in lambda. |
| <code>lambda</code>       | Unique values of lambda sorted into ascending order.                                                                                                  |

### Author(s)

Adam Maidman

### References

- [1] Wang, L., Wu, Y. and Li, R. (2012). Quantile regression of analyzing heterogeneity in ultra-high dimension. *J. Am. Statist. Ass.*, **107**, 214–222.
- [2] Wu, Y. and Liu, Y. (2009). Variable selection in quantile regression. *Statistica Sinica*, **19**, 801–817.
- [3] Zou, H. and Li, R. (2008). One-step sparse estimates in nonconcave penalized likelihood models. *Ann. Statist.*, **36**, 1509–1533.
- [4] Peng, B. and Wang, L. (2015). An iterative coordinate-descent algorithm for high-dimensional nonconvex penalized quantile regression. *J. Comp. Graph.*, **24**, 676–694.

### Examples

```
n = 50
p = 100
x <- matrix(rnorm(n*p), nrow=n)
y <- 0 + x[,1] - 3*x[,5] + rnorm(n)
lambda <- exp(-20:0)
# fit1 <- QICD.master(y,x, tau=.5, lambda=lambda, intercept=TRUE, penalty="SCAD")
# fit2 <- QICD.master(y,x, tau=.7, lambda=lambda, intercept=TRUE, penalty="SCAD")
# head(fit1)
# fit2
```



---

|             |                                                                                              |
|-------------|----------------------------------------------------------------------------------------------|
| QICD.nonpen | <i>Penalized Quantile Regression with some nonpenalized coefficients with QICD Algorithm</i> |
|-------------|----------------------------------------------------------------------------------------------|

---

### Description

QICD.nonpen produces penalized quantile regression estimates with some nonpenalized coefficients using the QICD algorithm. If no initial values are given, LASSO estimates will be used. This function can handle the LASSO, SCAD, and MCP penalties. This can be useful when you would like to perform variable selection only on some covariates and would like to guarantee that other covariates remain in the model.

### Usage

```
QICD.nonpen(y, x, z, tau=.5, lambda, intercept=TRUE, penalty="SCAD",
            initial_beta=NULL, maxin=100, maxout=20, eps = 1e-05,
            coef.cutoff=1e-08, a=3.7, method="br", scalex=TRUE, ...)
```

### Arguments

|              |                                                                                                                                                                                                                                                                                                                                                                    |
|--------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| y            | Vector of response values.                                                                                                                                                                                                                                                                                                                                         |
| x            | n x p matrix of observations with each row corresponding to one observation. Penalties (and variable selection) will be applied to these coefficients. Do not include column of 1's; set intercept=TRUE, if intercept is desired.                                                                                                                                  |
| z            | n x q matrix of observations with each row corresponding to one observation. Penalties (and variable selection) WILL NOT be applied to these coefficients. Do not include column of 1's; set intercept=TRUE, if intercept is desired.                                                                                                                              |
| tau          | Conditional quantile being modelled.                                                                                                                                                                                                                                                                                                                               |
| lambda       | Tuning parameter for LASSO, SCAD, and MCP penalties. Must be positive.                                                                                                                                                                                                                                                                                             |
| intercept    | If TRUE, an intercept is included in the model. If FALSE, no intercept is included.                                                                                                                                                                                                                                                                                |
| penalty      | Penalty function for the coefficients. Either "SCAD", "MCP", or "LASSO". See details for description of penalties.                                                                                                                                                                                                                                                 |
| initial_beta | Vector of initial values for QICD algorithm. The vector should contain the intercept first (if intercept=TRUE) and then the p coefficients corresponding to x. Initial values for the coefficients corresponding to z can be passed after the the x coefficients, but will be ignored. If NULL, exact LASSO estimates will be computed and used as initial values. |
| maxin        | Maximum number of iterations on the minimization step of the QICD algorithm.                                                                                                                                                                                                                                                                                       |
| maxout       | Maximum number of iterations on the majorization step of the QICD algorithm.                                                                                                                                                                                                                                                                                       |
| eps          | Threshold for convergence of algorithm.                                                                                                                                                                                                                                                                                                                            |
| coef.cutoff  | Coefficients with magnitude less than this value are set to 0.                                                                                                                                                                                                                                                                                                     |
| a            | Second tuning parameter for SCAD and MCP penalties. Must be greater than 2 for SCAD and greater than 1 for MCP.                                                                                                                                                                                                                                                    |

|        |                                                                                                                                                                                     |
|--------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| method | Method used in QICD algorithm. Default is "br" method. When sample size is several thousand, method "fn" should be used for increased speed. See quantreg package for more details. |
| scalex | If TRUE the x predictors are transformed to have mean zero and standard deviation one before fitting the model. Output is returned on the original scale of the data.               |
| ...    | The extra arguments will not be used.                                                                                                                                               |

### Details

The QICD algorithm should only be used for the LASSO penalty if `initial_beta` can be set to LASSO estimates with a similar `lambda` (similar to a "warm start"). Otherwise, exact LASSO estimates will be used as initial values for the QICD algorithm: this will cause unnecessary computations and could lead to less accurate estimates.

### Value

Returns a vector containing the intercept (if `intercept=TRUE`) and the estimated coefficients for each column in `x` and `z`.

### Author(s)

Adam Maidman

### References

- [1] Wang, L., Wu, Y. and Li, R. (2012). Quantile regression of analyzing heterogeneity in ultra-high dimension. *J. Am. Statist. Ass.*, **107**, 214–222.
- [2] Wu, Y. and Liu, Y. (2009). Variable selection in quantile regression. *Statistica Sinica*, **19**, 801–817.
- [3] Zou, H. and Li, R. (2008). One-step sparse estimates in nonconcave penalized likelihood models. *Ann. Statist.*, **36**, 1509–1533.
- [4] Peng, B. and Wang, L. (2015). An iterative coordinate-descent algorithm for high-dimensional nonconvex penalized quantile regression. *J. Comp. Graph.*, **24**, 676–694.

### Examples

```
library(splines)
n = 50
p = 100
x <- matrix(rnorm(n*p), nrow=n)
z1 <- runif(n)
z2 <- runif(n)
z <- cbind(bs(z1), bs(z2))
y <- 0 + x[,1] - 3*x[,5] + z1^3 + sin(2*pi*z2) + rnorm(n)
fit1 <- QICD.nonpen(y,x,z, tau=.5, lambda=1, intercept=TRUE, penalty="SCAD")
fit2 <- QICD.nonpen(y,x,z, tau=.7, lambda=1, intercept=TRUE, penalty="SCAD")
```

---

|                 |                        |
|-----------------|------------------------|
| randomly_assign | <i>Randomly Assign</i> |
|-----------------|------------------------|

---

**Description**

Randomly assign n samples into k groups

**Usage**

```
randomly_assign(n,k)
```

**Arguments**

|   |                    |
|---|--------------------|
| n | Number of samples. |
| k | Number of groups.  |

**Value**

A vector of length n having entries of 1,...k.

**Author(s)**

Ben Sherwood

**Examples**

```
randomly_assign(37,5)
randomly_assign(11,3)
```

---

|              |                                              |
|--------------|----------------------------------------------|
| rq.group.fit | <i>Quantile Regresion with Group Penalty</i> |
|--------------|----------------------------------------------|

---

**Description**

Similar to cv.rq.pen function, but uses group penalty. Group penalties use the L1 norm instead of L2 for computational convenience. As a result of this the group lasso penalty is the same as the typical lasso penalty and thus you should only use a SCAD or MCP penalty. Only the SCAD and MCP penalties incorporate the group structure into the penalty. The group lasso penalty is implemented because it is needed for the SCAD and MCP algorithm. We use a group penalty extension of the QICD algorithm presented by Peng and Wang (2015).

**Usage**

```
rq.group.fit(x, y, groups, tau = 0.5, lambda, intercept = TRUE,
             penalty = "SCAD", alg = "QICD", a=3.7, penGroups=NULL, ...)
```

**Arguments**

|           |                                                                                                                                                                              |
|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| x         | Matrix of predictors.                                                                                                                                                        |
| y         | Vector of response values.                                                                                                                                                   |
| groups    | Vector assigning columns of x to groups.                                                                                                                                     |
| tau       | Conditional quantile being modelled.                                                                                                                                         |
| lambda    | Vector of lambdas. Default is for lambdas to be automatically generated.                                                                                                     |
| intercept | Whether model should include an intercept. Constant does not need to be included in "x".                                                                                     |
| penalty   | Type of penalty: "SCAD" or "MCP".                                                                                                                                            |
| alg       | If set to QICD algorithm will use coordinate descent algorithm. Otherwise, will use a linear programming algorithm, which is an extension of algorithm used in rq.lasso.fit. |
| a         | The additional tuning parameter for SCAD and MCP.                                                                                                                            |
| penGroups | Specify which groups will be penalized. Default is to penalize all groups.                                                                                                   |
| ...       | Additional arguments to be sent to rq.lasso.fit or groupQICD.                                                                                                                |

**Value**

Returns the following:

|              |                                                |
|--------------|------------------------------------------------|
| coefficients | Coefficients of the model.                     |
| residuals    | Residuals from the fitted model.               |
| rho          | Unpenalized portion of the objective function. |
| tau          | Quantile being modeled.                        |
| n            | Sample size.                                   |
| intercept    | Whether intercept was included in model.       |

**Author(s)**

Ben Sherwood; Adam Maidman

**References**

- [1] Yuan, M. and Lin, Y. (2006). Model selection and estimation in regression with grouped variables. *J. R. Statist. Soc. B*, **68**, 49-67.
- [2] Peng, B. and Wang, L. (2015). An Iterative Coordinate Descent Algorithm for High-Dimensional Nonconvex Penalized Quantile Regression. *Journal of Computational and Graphical Statistics*, **24**, 676-694.

**Examples**

```
x <- matrix(rnorm(800),nrow=100)
y <- 1 + x[,1] - 3*x[,5] + rnorm(100)
cv_model <- rq.group.fit(x,y,groups=c(rep(1,4),rep(2,4)),lambda=1,penalty="SCAD")
```

---

|                   |                                                                                  |
|-------------------|----------------------------------------------------------------------------------|
| rq.group.lin.prog | <i>Quantile Regression with Group Penalty using linear programming algorithm</i> |
|-------------------|----------------------------------------------------------------------------------|

---

**Description**

Linear programming implementation of quantile regression with a group penalty.

**Usage**

```
rq.group.lin.prog(x,y,groups,tau,lambda,intercept=TRUE,eps=1e-05,
  penalty="SCAD", a=3.7, coef.cutoff=1e-08, initial_beta=NULL,
  iterations=10,converge_criteria=.0001,penGroups=NULL,...)
```

**Arguments**

|                   |                                                                                          |
|-------------------|------------------------------------------------------------------------------------------|
| x                 | Matrix of predictors.                                                                    |
| y                 | Vector of response values.                                                               |
| groups            | Vector assigning columns of x to groups.                                                 |
| tau               | Conditional quantile being modelled.                                                     |
| lambda            | Vector of lambdas. Default is for lambdas to be automatically generated.                 |
| intercept         | Whether model should include an intercept. Constant does not need to be included in "x". |
| eps               | Multiplier for smallest lambda.                                                          |
| penalty           | Type of penalty: "LASSO", "SCAD" or "MCP".                                               |
| a                 | Additional parameter for non-convex penalties.                                           |
| coef.cutoff       | Estimates below this value are set to zero.                                              |
| initial_beta      | Initial beta estimate.                                                                   |
| iterations        | Maximum number of iterations.                                                            |
| converge_criteria | Convergence criteria                                                                     |
| penGroups         | Specify which groups will be penalized. Default is to penalize all groups.               |
| ...               | Additional arguments to be sent to rq.lasso.fit.                                         |

**Value**

Returns the following:

|              |                                                |
|--------------|------------------------------------------------|
| coefficients | Coefficients of the model.                     |
| residuals    | Residuals from the fitted model.               |
| rho          | Unpenalized portion of the objective function. |
| tau          | Quantile being modelled.                       |

|           |                                          |
|-----------|------------------------------------------|
| n         | Sample size.                             |
| intercept | Whether intercept was included in model. |
| penalty   | Penalty used for fitting the model.      |
| class     | rqPen and rqNC                           |

**Author(s)**

Ben Sherwood

**Examples**

```
## Not run:
x <- matrix(rnorm(800),nrow=100)
y <- 1 + x[,1] - 3*x[,5] + rnorm(100)
cv_model <- rq.group.lin.prog(x,y,groups=c(rep(1,4),rep(2,4)), tau=.5, lambda=1)

## End(Not run)
```

---

 rq.lasso.fit

*Quantile Regression with LASSO penalty*


---

**Description**

Fits a quantile regression model with the LASSO penalty. Algorithm is similar to LASSO code presented in Koenker and Mizera (2014).

**Usage**

```
rq.lasso.fit(x,y,tau=.5,lambda=NULL,weights=NULL,
             intercept=TRUE,coef.cutoff=.00000001,
             method="br", penVars=NULL,scalex=TRUE, ...)
```

**Arguments**

|             |                                                                                                                                  |
|-------------|----------------------------------------------------------------------------------------------------------------------------------|
| x           | Matrix of predictors.                                                                                                            |
| y           | Vector of response values.                                                                                                       |
| tau         | Conditional quantile being modelled.                                                                                             |
| lambda      | Tuning parameter.                                                                                                                |
| weights     | Weights for the objective function.                                                                                              |
| intercept   | Whether model should include an intercept. Constant does not need to be included in "x".                                         |
| coef.cutoff | Coefficients below this value will be set to zero.                                                                               |
| method      | Use method "br" or "fn" as outlined in quantreg package. We have found "br" to be more stable for penalized regression problems. |

|         |                                                                                                                                                                                                                 |
|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| penVars | Variables that should be penalized. With default value of NULL all variables are penalized.                                                                                                                     |
| scalex  | If set to true the predictors will be scaled to have mean zero and standard deviation of one before fitting the model. The output returned will be on the original scale of the data.                           |
| ...     | Additional items to be sent to rq. Note this will have to be done carefully as rq is run on the augmented data to account for penalization and could provide strange results if this is not taken into account. |

### Value

Returns the following:

|              |                                                    |
|--------------|----------------------------------------------------|
| coefficients | Coefficients from the penalized model.             |
| PenRho       | Penalized objective function value.                |
| residuals    | Residuals from the model.                          |
| rho          | Objective function evaluation without the penalty. |
| tau          | Conditional quantile being modelled.               |
| n            | Sample size.                                       |

### Author(s)

Ben Sherwood

### References

- [1] Koenker, R. and Mizera, I. (2014). Convex optimization in R. *Journal of Statistical Software*, **60**, 1–23.
- [2] Tibshirani, R. (1996). Regression shrinkage and selection via the lasso. *Journal of the Royal Statistical Society. Series B*, **58**, 267–288.
- [3] Wu, Y. and Liu, Y. (2009). Variable selection in quantile regression. *Statistica Sinica*, **19**, 801–817.

### Examples

```
x <- matrix(rnorm(800),nrow=100)
y <- 1 + x[,1] - 3*x[,5] + rnorm(100)
lassoModel <- rq.lasso.fit(x,y,lambda=1)
```

---

|                   |                                                                               |
|-------------------|-------------------------------------------------------------------------------|
| rq.lasso.fit.mult | <i>Fit Quantile Regression model for varying quantiles with LASSO penalty</i> |
|-------------------|-------------------------------------------------------------------------------|

---

### Description

Fits quantile regression models for multiple quantiles with the LASSO penalty. Algorithm is similar to LASSO code presented in Koenker and Mizera (2014).

### Usage

```
rq.lasso.fit.mult(x,y,tau_seq=c(.1,.3,.5,.7,.9),lambda=NULL,
                 weights=NULL,intercept=TRUE,coef.cutoff=.0000001,...)
```

### Arguments

|             |                                                                                                                                                                                                                 |
|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| x           | Matrix of predictors.                                                                                                                                                                                           |
| y           | Vector of response values.                                                                                                                                                                                      |
| tau_seq     | Vector of quantiles of interest                                                                                                                                                                                 |
| lambda      | Tuning parameter.                                                                                                                                                                                               |
| weights     | Weights for the objective function.                                                                                                                                                                             |
| intercept   | Whether model should include an intercept. Constant does not need to be included in "x".                                                                                                                        |
| coef.cutoff | Coefficients below this value will be set to zero.                                                                                                                                                              |
| ...         | Additional items to be sent to rq. Note this will have to be done carefully as rq is run on the augmented data to account for penalization and could provide strange results if this is not taken into account. |

### Value

Returns a list of rq.pen, rqLASSO objects.

### Author(s)

Ben Sherwood

### References

- [1] Koenker, R. and Mizera, I. (2014). Convex optimization in R. *Journal of Statistical Software*, **60**, 1–23.
- [2] Tibshirani, R. (1996). Regression shrinkage and selection via the lasso. *Journal of the Royal Statistical Society. Series B*, **58**, 267–288.
- [3] Wu, Y. and Liu, Y. (2009). Variable selection in quantile regression. *Statistica Sinica*, **19**, 801–817.



**Examples**

```
x <- matrix(rnorm(800),nrow=100)
y <- 1 + x[,1] - 3*x[,5] + rnorm(100)
lassoModel <- rq.lasso.fit.mult(x,y,lambda=1)
```

rq.nc.fit

*Non-convex penalized quantile regression***Description**

Produces penalized quantile regression models for a range of lambdas and penalty of choice. If lambda is unselected than an iterative algorithm is used to find a maximum lambda such that the penalty is large enough to produce an intercept only model. Then range of lambdas goes from the maximum lambda found to "eps" on the log scale. Local linear approximation approach used by Wang, Wu and Li to extend LLA as proposed by Zou and Li (2008) to the quantile regression setting.

**Usage**

```
rq.nc.fit(x,y,tau=.5,lambda=NULL,weights=NULL,intercept=TRUE,
          penalty="SCAD",a=3.7,iterations=10,
          converge_criteria=1e-06,alg=ifelse(p<50,"LP","QICD"),
          penVars=NULL, ...)
```

**Arguments**

|                   |                                                                                                                                                                                                                                                       |
|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| x                 | Matrix of predictors.                                                                                                                                                                                                                                 |
| y                 | Vector of response values.                                                                                                                                                                                                                            |
| tau               | Conditional quantile being modeled.                                                                                                                                                                                                                   |
| lambda            | Tuning parameter.                                                                                                                                                                                                                                     |
| weights           | Weights for the objective function.                                                                                                                                                                                                                   |
| intercept         | Whether model should include an intercept. Constant does not need to be included in "x".                                                                                                                                                              |
| penalty           | MCP or SCAD.                                                                                                                                                                                                                                          |
| a                 | Second tuning parameter.                                                                                                                                                                                                                              |
| iterations        | Number of iterations to be done for iterative LLA algorithm.                                                                                                                                                                                          |
| converge_criteria | Difference in betas from iteration process that would satisfy convergence.                                                                                                                                                                            |
| alg               | Defaults for small p to linear programming (LP), see Wang, Wu and Li (2012) for details. Otherwise a coordinate descent algorithm is used (QICD), see Peng and Wang (2015) for details. Both methods rely on the One-step sparse estimates algorithm. |
| penVars           | Variables that should be penalized. With default value of NULL all variables are penalized.                                                                                                                                                           |
| ...               | Additional items to be sent to rq.lasso.fit.                                                                                                                                                                                                          |

**Value**

Returns the following:

|              |                                                    |
|--------------|----------------------------------------------------|
| coefficients | Coefficients from the penalized model.             |
| PenRho       | Penalized objective function value.                |
| residuals    | Residuals from the model.                          |
| rho          | Objective function evaluation without the penalty. |
| tau          | Conditional quantile being modeled.                |
| n            | Sample size.                                       |
| penalty      | Penalty used, SCAD or MCP.                         |

**Author(s)**

Ben Sherwood; Adam Maidman

**References**

- [1] Wang, L., Wu, Y. and Li, R. (2012). Quantile regression of analyzing heterogeneity in ultra-high dimension. *J. Am. Statist. Ass.*, **107**, 214–222.
- [2] Wu, Y. and Liu, Y. (2009). Variable selection in quantile regression. *Statistica Sinica*, **19**, 801–817.
- [3] Zou, H. and Li, R. (2008). One-step sparse estimates in nonconcave penalized likelihood models. *Ann. Statist.*, **36**, 1509–1533.
- [4] Peng, B. and Wang, L. (2015). An iterative coordinate-descent algorithm for high-dimensional nonconvex penalized quantile regression. *J. Comp. Graph.*, **24**, 676–694.

**Examples**

```
x <- matrix(rnorm(800),nrow=100)
y <- 1 + x[,1] - 3*x[,5] + rnorm(100)
scadModel <- rq.nc.fit(x,y,lambda=1)
```

---

scad

*scad*

---

**Description**

SCAD penalty function as described in Fan and Li (2001).

**Usage**

```
scad(x, lambda, a)
```

**Arguments**

|        |                         |
|--------|-------------------------|
| x      | Number to be evaluated  |
| lambda | Tuning parameter lambda |
| a      | Tuning parameter a      |

**Value**

SCAD penalty function with tuning parameters lambda and "a" evaluated at "x".

**Author(s)**

Ben Sherwood

**References**

[1] Fan, J. and Li, R. (2001). Variable selection via nonconcave penalized likelihood and its oracle properties, *J. Am. Statist. Ass.*, **96**, 1348–1360.

**Examples**

```
scad(3,1)
scad(-3,1)
scad(.001,2)
```

---

scad\_deriv

*SCAD Derivative*

---

**Description**

Derivative of SCAD penalty function as described in Fan and Li (2001).

**Usage**

```
scad_deriv(x, lambda, a)
```

**Arguments**

|        |                                                                            |
|--------|----------------------------------------------------------------------------|
| x      | Number to be evaluated                                                     |
| lambda | Tuning parameter lambda                                                    |
| a      | Tuning parameter a. Default value of 3.7 as suggested in Fan and Li (2001) |

**Value**

Derivative SCAD penalty function with tuning parameters lambda and "a" evaluated at "x".

**Author(s)**

Ben Sherwood

**References**

[1] Fan, J. and Li, R. (2001). Variable selection via nonconcave penalized likelihood and its oracle properties, *J. Am. Statist. Ass.*, **96**, 1348–1360.

**Examples**

```
scad_deriv(3,1)
scad_deriv(-3,1)
scad_deriv(.001,2)
```

---

square

*Square function*

---

**Description**

Square value of a number

**Usage**

```
square(x)
```

**Arguments**

x                    Number to be squared.

**Value**

$x^2$

**Author(s)**

Ben Sherwood

**Examples**

```
square(4)
square(-4)
square(2)
```

---

|                 |                                                      |
|-----------------|------------------------------------------------------|
| transform_coefs | <i>Transform coefficients back to original scale</i> |
|-----------------|------------------------------------------------------|

---

**Description**

Takes the coefficients fit after scaling the predictors to have mean zero and a standard deviation of one and transforms them back to the original scale of the predictors.

**Usage**

```
transform_coefs(coefs,mu_x,sigma_x, intercept=TRUE)
```

**Arguments**

|           |                                                 |
|-----------|-------------------------------------------------|
| coefs     | Coefficients to be transformed.                 |
| mu_x      | Means of the original predictors.               |
| sigma_x   | Standard deviations of the original predictors. |
| intercept | Whether an intercept is included in the model.  |

**Author(s)**

Ben Sherwood

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