

# Package ‘GJRM’

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**Type** Package

**Version** 0.2-6.8

**Title** Generalised Joint Regression Modelling

**Description** Routines for fitting various joint (and univariate) regression models, with several types of covariate effects, in the presence of equations' errors association.

**Author** Giampiero Marra [aut, cre],  
Rosalba Radice [aut]

**Maintainer** Giampiero Marra <giampiero.marra@ucl.ac.uk>

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## Description

This package provides a function for fitting various generalised joint regression models with several types of covariate effects and distributions. Many modelling options are supported and all parameters of the joint distribution can be specified as flexible functions of covariates.

The original name of this package was `SemiParBIVprobit` which was designed to fit flexible bivariate binary response models. However, since then the package has expanded so much that its original name no longer gave a clue about all modelling options available. The new name should more closely reflect past, current and future developments.

The main fitting functions are listed below.

`gjrm()` which fits bivariate regression models with binary responses (useful for fitting bivariate binary models in the presence of (i) non-random sample selection or (ii) associated responses/endogeneity or (iii) partial observability), bivariate models with binary/discrete/continuous/survival margins in the presence of associated responses/endogeneity, bivariate sample selection models with continuous/discrete response, trivariate binary models (with and without double sample selection). This function essentially merges all previously available fitting functions, namely `SemiParBIV()`, `SemiParTRIV()`, `copulaReg()` and `copulaSampleSel()`.

`gamllss()` fits flexible univariate regression models where the response can be binary (only the extreme value distribution is allowed for), continuous, discrete and survival. The purpose of this function was only to provide, in some cases, starting values for the above functions, but it has now been made available in the form of a proper function should the user wish to fit univariate models using the general estimation approach of this package.

We are currently working on several multivariate extensions.

## Details

GJRM provides functions for fitting general joint models in various situations. The estimation approach is based on a very generic penalized maximum likelihood based framework, where any (parametric) distribution can in principle be employed, and the smoothers (representing several types of covariate effects) are set up using penalised regression splines. Several marginal and copula distributions are available and the numerical routine carries out function minimization using a trust region algorithm in combination with an adaptation of an automatic multiple smoothing parameter estimation procedure for GAMs (see `mgcv` for more details on this last point). The smoothers supported by this package are those available in `mgcv`.

Confidence intervals for smooth components and nonlinear functions of the model parameters are derived using a Bayesian approach. P-values for testing individual smooth terms for equality to the zero function are also provided and based on the approach implemented in `mgcv`. The usual plotting and summary functions are also available. Model/variable selection is also possible via the use of shrinkage smoothers and/or information criteria.

**Author(s)**

Giampiero Marra (University College London, Department of Statistical Science) and Rosalba Radice (Bayes Business School, Faculty of Actuarial Science and Insurance, City, University of London)

with help and contributions from Panagiota Filippou (trivariate binary models), Francesco Donat (bivariate models with ordinal and continuous margins, and ordinal margins), Matteo Fasiolo (pdf and cdf, and related derivatives, of the Tweedie distribution), Alessia Eletti and Javier Rubio Alvarez (univariate survival models with mixed censoring and excess hazards), Kiron Das (Galambos copula), Eva Cantoni and William Aeberhard (robust gamlss).

Thanks to Bear Braumoeller for suggesting the implementation of bivariate models with partial observability, and Carmen Cadarso for suggesting the inclusion of various modelling extensions.

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

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**References**

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- For applied case studies see <https://www.homepages.ucl.ac.uk/~ucakgm0/pubs.htm>.

### See Also

[gjrm](#), [gamlss](#)

---

adjCov

*Adjustment for the covariance matrix from a fitted gjrm model*

---

### Description

adjCov can be used to adjust the covariance matrix of a fitted gjrm object.

### Usage

```
adjCov(x, id)
```

### Arguments

x	A fitted gjrm object as produced by the respective fitting function.
id	Cluster identifier.

**Details**

This adjustment can be made when dealing with clustered data and the cluster structure is neglected when fitting the model. The basic idea is that the model is fitted as though observations were independent, and subsequently adjust the covariance matrix of the parameter estimates. Using the terminology of Liang and Zeger (1986), this would correspond to using an independence structure within the context of generalized estimating equations. The parameter estimators are still consistent but are inefficient as compared to a model which accounts for the correct cluster dependence structure. The covariance matrix of the independence estimators can be adjusted as described in Liang and Zeger (1986, Section 2).

**Value**

This function returns a fitted object which is identical to that supplied in adjCov but with adjusted covariance matrix.

**WARNINGS**

This correction may not be appropriate for models fitted using penalties.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**References**

Liang K.-Y. and Zeger S. (1986), Longitudinal Data Analysis Using Generalized Linear Models. *Biometrika*, 73(1), 13-22.

**See Also**

[GJRM-package](#), [gjrm](#)

---

adjCovSD

*Adjustment for the covariance matrix from a gjrm model fitted to complex survey data.*

---

**Description**

adjCovSD can be used to adjust the covariance matrix of a fitted gjrm object.

**Usage**

```
adjCovSD(x, design)
```

**Arguments**

`x`                      A fitted `gjrm` object as produced by the respective fitting function.

`design`                 A `svydesign` object as produced by `svydesign()` from the survey package.

**Details**

This function has been extracted from the survey package and adapted to the class of this package's models. It computes the sandwich variance estimator for a copula model fitted to data from a complex sample survey (Lumley, 2004).

**Value**

This function returns a fitted object which is identical to that supplied in `adjCovSD` but with adjusted covariance matrix.

**WARNINGS**

This correction may not be appropriate for models fitted using penalties.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**References**

Lumley T. (2004), Analysis of Complex Survey Samples. *Journal of Statistical Software*, 9(8), 1-19.

**See Also**

[GJRM-package](#), `gjrm`

---

ATE

*Average Treatment Effect of a binary or continuous treatment variable*

---

**Description**

ATE can be used to calculate the causal average treatment effect of a binary or continuous Gaussian treatment variable, with corresponding interval obtained using posterior simulation.

**Usage**

```
ATE(x, trt, trt.val = NULL, int.var = NULL, eq = NULL, joint = TRUE, n.sim = 100,
    prob.lev = 0.05, length.out = NULL, percentage = FALSE)
```



**Arguments**

<code>x</code>	A fitted <code>gjrm</code> object as produced by the respective fitting function.
<code>trt</code>	Name of the treatment variable.
<code>trt.val</code>	Numeric value for the treatment variable. This is only required when the endogenous variable is Gaussian.
<code>int.var</code>	A vector made up of the name of the variable interacted with <code>trt</code> , and a value for it. It can also be a list.
<code>eq</code>	Number of equation containing the treatment variable. This is only used for trivariate models.
<code>joint</code>	If FALSE then the effect is obtained from the univariate model which neglects the presence of unobserved confounders. When TRUE, the effect is obtained from the simultaneous model which accounts for observed and unobserved confounders.
<code>n.sim</code>	Number of simulated coefficient vectors from the posterior distribution of the estimated model parameters. It may be increased if more precision is required.
<code>prob.lev</code>	Overall probability of the left and right tails of the AT distribution used for interval calculations.
<code>length.out</code>	Length of the sequence to be used when calculating the effect that a continuous treatment has on a binary outcome.
<code>percentage</code>	Only for the Roy model, when TRUE it provides results in terms of percentage.

**Details**

ATE measures the causal average difference in outcomes under treatment (the binary predictor or treatment assumes value 1) and under control (the binary treatment assumes value 0). Posterior simulation is used to obtain a confidence/credible interval. See the references below for details.

ATE can also calculate the effect that a continuous Gaussian endogenous variable has on a binary outcome. In this case the effect will depend on the unit increment chosen (as shown by the plot produced).

**Value**

<code>res</code>	It returns three values: lower confidence interval limit, estimated AT and upper interval limit.
<code>prob.lev</code>	Probability level used.
<code>sim.ATE</code>	It returns a vector containing simulated values of the average treatment effect. This is used to calculate intervals.
<code>Effects</code>	For the case of continuous/discrete endogenous variable and binary outcome, it returns a matrix made up of three columns containing the effects for each incremental value in the endogenous variable and respective intervals.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

## References

Marra G. and Radice R. (2011), Estimation of a Semiparametric Recursive Bivariate Probit in the Presence of Endogeneity. *Canadian Journal of Statistics*, 39(2), 259-279.

## See Also

[GJRM-package, gjrm](#)

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BCDF	<i>Internal Function</i>
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## Description

It evaluates the cdf of several copulae.

## Author(s)

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

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bcont	<i>Internal Function</i>
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## Description

This and other similar internal functions provide the log-likelihood, gradient and observed information matrix for penalized/unpenalized maximum likelihood optimization when copula models with continuous margins are employed.

## Author(s)

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

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bdisrcont	<i>Internal Function</i>
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## Description

This and other similar internal functions provide the log-likelihood, gradient and observed information matrix for penalized/unpenalized maximum likelihood optimization when copula models with discrete and continuous margins are employed.

## Author(s)

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

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**bdiscrdiscr***Internal Function*

---

**Description**

This and other similar internal functions provide the log-likelihood, gradient and observed information matrix for penalized/unpenalized maximum likelihood optimization when copula models with discrete margins are employed.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

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**bprobghs***Internal Function*

---

**Description**

It provides the log-likelihood, gradient and observed/Fisher information matrix for penalized/unpenalized maximum likelihood optimization when copula models with binary outcomes are employed.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

---

**bprobghsCont***Internal Function*

---

**Description**

It provides the log-likelihood, gradient and observed information matrix for penalized/unpenalized maximum likelihood optimization when copula models with binary and continuous margins are employed.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

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bprobHsContSS	<i>Internal Function</i>
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**Description**

It provides the log-likelihood, gradient and observed information matrix for penalized/unpenalized maximum likelihood optimization when copula sample selection models with continuous margins are employed.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

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bprobHsContUniv	<i>Internal Function</i>
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**Description**

It provides the log-likelihood, gradient and observed information matrix for penalized/unpenalized maximum likelihood optimization when fitting univariate models with discrete/continuous response.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

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bprobHsDiscr1	<i>Internal Function</i>
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**Description**

It provides the log-likelihood, gradient and observed information matrix for penalized/unpenalized maximum likelihood optimization when copula models with binary and discrete margins are employed.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

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bprobGHSdiscr1SS	<i>Internal Function</i>
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**Description**

It provides the log-likelihood, gradient and observed information matrix for penalized/unpenalized maximum likelihood optimization when copula sample selection models with discrete margins are employed.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

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bprobGHSPO	<i>Internal Function</i>
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**Description**

It provides the log-likelihood, gradient and observed or expected information matrix for penalized/unpenalized maximum likelihood optimization when bivariate probit models with partial observability are employed.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

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bprobGHSSS	<i>Internal Function</i>
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**Description**

It provides the log-likelihood, gradient and observed/Fisher information matrix for penalized/unpenalized maximum likelihood optimization when copula sample selection models with binary outcomes are employed.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

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clarke.test

*Clarke test*


---

### Description

The Clarke test is a likelihood-ratio-based test that can be used for choosing between two non-nested models.

### Usage

```
clarke.test(obj1, obj2, sig.lev = 0.05)
```

### Arguments

obj1, obj2	Objects of the two fitted bivariate non-nested models.
sig.lev	Significance level used for testing.

### Details

The Clarke (2007) test is a likelihood-ratio-based tests for model selection that use the Kullback-Leibler information criterion, and that can be employed for choosing between two bivariate models which are non-nested.

If the two models are statistically equivalent then the log-likelihood ratios of the observations should be evenly distributed around zero and around half of the ratios should be larger than zero. The test follows asymptotically a binomial distribution with parameters  $n$  and 0.5. Critical values can be obtained as shown in Clarke (2007). Intuitively, model obj1 is preferred over obj2 if the value of the test is significantly larger than its expected value under the null hypothesis ( $n/2$ ), and vice versa. If the value is not significantly different from  $n/2$  then obj1 can be thought of as equivalent to obj2.

### Value

It returns a decision.

### Author(s)

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

### References

Clarke K. (2007), A Simple Distribution-Free Test for Non-Nested Model Selection. *Political Analysis*, 15, 347-363.

### Examples

```
## see examples for gjrm
```

---

cond.mv*Conditional Mean/Variance from a Copula Model*

---

**Description**

Function `cond.mv` can be used to calculate conditional means/variances from a copula model, with corresponding interval obtained using posterior simulation.

**Usage**

```
cond.mv(x, eq, y1 = NULL, y2 = NULL, newdata, fun = "mean", n.sim = 100,  
        prob.lev = 0.05)
```

**Arguments**

<code>x</code>	A fitted <code>cond.mv</code> object as produced by the respective fitting function.
<code>eq</code>	Equation of interest. From this, conditioning is also deduced.
<code>y1, y2</code>	Values for <code>y1</code> and <code>y2</code> . Depending on the fitted model, one of them may be required.
<code>newdata</code>	A data frame with one row, which must be provided.
<code>fun</code>	Either mean or variance.
<code>n.sim</code>	Number of simulated coefficient vectors from the posterior distribution of the estimated model parameters.
<code>prob.lev</code>	Overall probability of the left and right tails of the simulated distribution used for interval calculations.

**Details**

`cond.mv()` calculates the conditional mean or variance of copula models. Posterior simulation is used to obtain a confidence/credible interval.

**Value**

<code>res</code>	It returns three values: lower confidence interval limit, estimated conditional mean or variance and upper interval limit.
<code>prob.lev</code>	Probability level used.
<code>sim.mv</code>	It returns a vector containing simulated values of the conditional mean or variance. This is used to calculate intervals.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**See Also**

[GJRM-package](#), [gjrm](#)

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conv.check	<i>Some convergence diagnostics</i>
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---

**Description**

It takes a fitted model object and produces some diagnostic information about the fitting procedure.

**Usage**

```
conv.check(x, blather = FALSE)
```

**Arguments**

x	gjrm object.
blather	If TRUE then more diagnostic information is provided.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**See Also**

[gamlss](#), [gjrm](#)

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copgHs	<i>Internal Function</i>
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**Description**

This and other similar internal functions evaluate the first and second derivatives with respect to the margins and association parameter of several copulae.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>



---

copula.prob	<i>Copula probabilities (joint and conditional) from a fitted simultaneous model</i>
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---

### Description

copula.prob can be used to calculate the joint or conditional copula probabilities from a fitted simultaneous model with intervals obtained via posterior simulation.

### Usage

```
copula.prob(x, y1, y2, y3 = NULL, newdata, joint = TRUE, cond = 0,
            intervals = FALSE, n.sim = 100, prob.lev = 0.05,
            theta = FALSE, tau = FALSE, min.pr = 1e-323, max.pr = 1)
```

### Arguments

x	A fitted gjrm object as produced by the respective fitting function.
y1	Value of response for first margin.
y2	Value of response for second margin.
y3	Value of response for third margin if a trivariate model is employed.
newdata	A data frame with one row, which must be provided.
joint	If TRUE then the calculation is done using the fitted joint model. If FALSE then the calculation is done from univariate fits.
cond	There are three possible values: 0 (joint probabilities are delivered), 1 (conditional probabilities are delivered and conditioning is with the respect to the first margin), 2 (as before but conditioning is with the respect to the second margin).
intervals	If TRUE then intervals for the probabilities are also produced.
n.sim	Number of simulated coefficient vectors from the posterior distribution of the estimated model parameters. This is used for interval calculations.
prob.lev	Overall probability of the left and right tails of the probabilities' distributions used for interval calculations.
theta	If TRUE the theta dependence parameter will be shown. This is especially useful for prediction purposes when theta is specified as a function of covariate effects.
tau	If TRUE the Kendall's tau will also be calculated and provided in output. Note that the calculation adopted here assumes continuous margins. In all other cases, this may provide a rough indication of dependence under certain assumptions. Note that, for the F, PL and J0 (and the related rotations), computing times may be longer than for the other cases. This is especially useful for prediction purposes when theta is specified as a function of covariate effects, with an interest in analysing a more interpretable measure of dependence for certain copulae.
min.pr, max.pr	Allowed minimum and maximum for estimated probabilities.

**Details**

This function calculates joint or conditional copula probabilities from a fitted simultaneous model or a model assuming independence, with intervals obtained via posterior simulation.

**Value**

res                    It returns several values including: estimated probabilities (p12), with lower and upper interval limits (CIpr) if intervals = TRUE, and p1, p2 and p3 (the marginal probabilities).

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**See Also**

[GJRM-package](#), [gjrm](#)

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CopulaCLM	<i>Internal fitting function</i>
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**Description**

Internal fitting and set up function.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

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copulaSampleSel	<i>Internal fitting function</i>
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---

**Description**

Internal fitting and set up function.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

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cv.inform	<i>Cross validation for informative censoring univariate survival models</i>
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---

**Description**

cv.inform carries out cross validation to help choosing the set of informative covariates.

**Usage**

```
cv.inform(x, K = 5, data, informative = "yes")
```

**Arguments**

x	A fitted gamlss object as produced by the respective fitting function.
K	No. of folds.
data	Data.
informative	If no then cv is carried out for the case of no informative censoring. This is useful for comparison purposes.

**Details**

cv.inform carries out cross validation to help choosing the set of informative covariates.

**Value**

s1	Overall sum of predicted likelihood contributions.
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**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**See Also**

[GJRM-package](#), [gamlss](#)

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distrHs	<i>Internal Function</i>
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**Description**

This and other similar internal functions evaluate the margins' derivatives needed in the likelihood function for the binary, discrete and continuous cases.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

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Dpens

*Differentiable penalties*


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**Description**

work in progress, temp function

**Usage**

```
Dpens(params, type = "lasso", lambda = 1, w.lasso = NULL,
      gamma = 1, a = 3.7, eps = 1e-08)
```

**Arguments**

params	coefficients.
type	lasso, alasso or scad.
lambda	smoothing parameter.
w.lasso	for alasso.
gamma	default 1.
a	for scad.
eps	tolerance.

**Details**

work in progress.

**Value**

The function returns a penalty.

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eta.tr

*Internal Function*


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**Description**

This and other similar internal functions map certain key quantities into a feasible parameter space. Some functions carry out some general consistency checks.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

g.tri

*Internal Function***Description**

This and other similar internal functions calculate the score for trivariate binary models.

**Author(s)**

Author: Panagiota Filippou

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

gamlss

*Generalised Additive Models for Location, Scale and Shape and Beyond***Description**

gamlss fits flexible univariate regression models for several continuous and discrete distributions as well as survival outcomes, and types of covariate effects. When first designed, the purpose of this function was only to provide, in some cases, starting values for the simultaneous models in the package. At a later stage, it was made available in the form of a proper function should the user wish to fit univariate models using the general estimation approach of this package. The continuous and discrete distributions used here are parametrised according to Rigby and Stasinopoulos (2005).

**Usage**

```
gamlss(formula, data = list(), weights = NULL, subset = NULL, offset = NULL,
       family = "N", cens = NULL, type.cens = "R", ub.t = NULL, left.trunc = 0,
       robust = FALSE, rc = 3, lB = NULL, uB = NULL, infl.fac = 1,
       rinit = 1, rmax = 100, iterlimsp = 50, tolsp = 1e-07,
       gc.l = FALSE, parscale, gev.par = -0.25,
       chunk.size = 10000, knots = NULL,
       informative = "no", inform.cov = NULL, family2 = "-cloglog",
       fp = FALSE, sp = NULL,
       drop.unused.levels = TRUE, siginit = NULL, shinit = NULL,
       sp.method = "perf", hrate = NULL, d.lchrates = NULL, d.rchrates = NULL,
       d.lchrates.td = NULL, d.rchrates.td = NULL, truncation.time = NULL,
       min.dn = 1e-40, min.pr = 1e-16, max.pr = 0.9999999, ygrid.tol = 1e-08)
```

**Arguments**

<code>formula</code>	List of equations. This should contain one or more equations.
<code>data</code>	A data frame.
<code>weights</code>	Optional vector of prior weights to be used in fitting.
<code>subset</code>	Optional vector specifying a subset of observations to be used in the fitting process.
<code>offset</code>	Optional vector specifying an offset for use in fitting. Option introduced for dealing with offset with discrete distributions.
<code>family</code>	Possible choices are Gaussian ("N"), truncated Gaussian ("tN"), Tweedie ("TW"), log-normal ("LN"), Gumbel ("GU"), reverse Gumbel ("rGU"), generalised Pareto ("GP"), generalised Pareto II ("GPII") where the shape parameter is forced to be $> -0.5$ , generalised Pareto (with orthogonal parametrisation) ("GPo") where the shape parameter is forced to be $> -0.5$ , discrete generalised Pareto ("DGP"), discrete generalised Pareto II ("DGPII") where the shape parameter is forced to be positive, discrete generalised Pareto derived under the scenario in which shape = 0 ("DGP0"), logistic ("LO"), Weibull ("WEI"), Inverse Gaussian ("IG"), gamma ("GA"), Dagum ("DAGUM"), Singh-Maddala ("SM"), beta ("BE"), Fisk ("FISK", also known as log-logistic), Poisson ("P"), truncated Poisson ("tP"), negative binomial - type I ("NBI"), negative binomial - type II ("NBII"), Poisson inverse Gaussian ("PIG"), truncated negative binomial - type I ("tNBI"), truncated negative binomial - type II ("tNBII"), truncated Poisson inverse Gaussian ("tPIG"), generalised extreme value link function ("GEVlink", this is used for binary responses and is more stable and faster than the R package bgeva). For survival models, family can be "-cloglog" (similar to generalised proportional hazards), "-logit" (similar to generalised proportional odds), "-probit" (generalised probit).
<code>cens</code>	This is required for a survival model. When <code>type.cens</code> is different from <code>mixed</code> , this variable can be equal to 1 if the event occurred and 0 otherwise. If <code>type.cens</code> = "mixed" then <code>cens</code> is a mixed factor variable (made up of four possible categories: I for interval, L for left, R for right, and U for uncensored).
<code>type.cens</code>	Type of censoring mechanism. This can be "R", "L", "I" or "mixed".
<code>ub.t</code>	Variable name of right/upper bound when <code>type.cens</code> = "I" or <code>type.cens</code> = "mixed" and interval censoring is present.
<code>left.trunc</code>	Value of truncation at left. Currently done for count distributions only.
<code>robust</code>	If TRUE then the robust version of the model is fitted.
<code>rc</code>	Robust constant.
<code>lB, uB</code>	Bounds for integral in robust case.
<code>infl.fac</code>	Inflation factor for the model degrees of freedom in the approximate AIC. Smoother models can be obtained setting this parameter to a value greater than 1.
<code>rinit</code>	Starting trust region radius. The trust region radius is adjusted as the algorithm proceeds.
<code>rmax</code>	Maximum allowed trust region radius. This may be set very large. If set small, the algorithm traces a steepest descent path.
<code>iterlimsp</code>	A positive integer specifying the maximum number of loops to be performed before the smoothing parameter estimation step is terminated.

<code>tolsp</code>	Tolerance to use in judging convergence of the algorithm when automatic smoothing parameter estimation is used.
<code>gc.l</code>	This is relevant when working with big datasets. If TRUE then the garbage collector is called more often than it is usually done. This keeps the memory footprint down but it will slow down the routine.
<code>parscale</code>	The algorithm will operate as if optimizing <code>objfun(x / parscale, ...)</code> where <code>parscale</code> is a scalar. If missing then no rescaling is done. See the documentation of <code>trust</code> for more details.
<code>gev.par</code>	GEV link parameter.
<code>chunk.size</code>	This is used for discrete robust models.
<code>knots</code>	Optional list containing user specified knot values to be used for basis construction.
<code>informative</code>	If "yes" then informative censoring is assumed when using a survival model.
<code>inform.cov</code>	If above is "yes" then a set of informative covariates must be provided.
<code>family2</code>	In the informative survival case, the family for the censored equation can be different from that of the survival equation. Choices are "-cloglog" (similar to generalised proportional hazards), "-logit" (similar to generalised proportional odds), "-probit" (generalised probit).
<code>fp</code>	If TRUE then a fully parametric model with unpenalised regression splines is fitted.
<code>sp</code>	A vector of smoothing parameters can be provided here. Smoothing parameters must be supplied in the order that the smooth terms appear in the model equation(s).
<code>drop.unused.levels</code>	By default unused levels are dropped from factors before fitting. For some smooths involving factor variables this may have to be turned off (only use if you know what you are doing).
<code>siginit, shinit</code>	For the GP and DGP distributions, initial values for sigma and shape may be provided.
<code>sp.method</code>	Multiple smoothing automatic parameter selection is <code>perf</code> . <code>efs</code> is an alternative and only sensible option for robust models.
<code>hrate</code>	Vector of population hazard rates computed at time of death of each uncensored patient. The length of <code>hrate</code> should be equal to the number of uncensored observations in the dataset. Needed in the context of excess hazard modelling when uncensored observations are present. Note that this includes left truncated uncensored observations as well.
<code>d.lchrates</code>	Vector of differences of population cumulative excess hazards computed at the age of the patient when the left censoring occurred and at the initial age of the patient. The length of <code>d.lchrates</code> should be equal to the number of left and/or interval censored observations in the dataset. Needed in the context of excess hazard modelling if left censored and/or interval censored observations are present. In the latter case, <code>d.rchrates</code> also need be provided.

<code>d.rchrte</code>	Vector of differences of population cumulative excess hazards computed at the age of the patient when the at the right interval censoring time and at the initial age of the patient. The length of <code>d.rchrte</code> should be equal to the number of right censored and/or interval censored observations in the dataset. Needed in the context of excess hazard modelling if right censored and/or interval censored observations are present. In the latter case, <code>d.lchrte</code> also need be provided.
<code>d.lchrte.td</code>	Vector of differences of population cumulative excess hazards computed at the age of the patient when the left censoring occurred and at the age of the patient when the truncation occurred. The length of <code>d.lchrte.td</code> should be equal to the number of left truncated left censored and/or left truncated interval censored observations in the dataset. Needed in the context of excess hazard modelling if left truncated left censored and/or left truncated interval censored observations are present. In the latter case, <code>d.rchrte.td</code> also need be provided.
<code>d.rchrte.td</code>	Vector of differences of population cumulative excess hazards computed at the age of the patient when the right censoring occurred and at the age of the patient when the truncation occurred. The length of <code>d.rchrte.td</code> should be equal to the number of left truncated right censored and/or left truncated interval censored observations in the dataset. Needed in the context of excess hazard modelling if left truncated right censored and/or left truncated interval censored observations are present. In the latter case, <code>d.lchrte.td</code> also need be provided.
<code>truncation.time</code>	Variable name of truncation time.
<code>min.dn, min.pr, max.pr</code>	These values are used to set, depending on the model used for modelling, the minimum and maximum allowed for the densities and probabilities. These parameters are employed to avoid potential overflows/underflows in the calculations and the default values seem to offer a good compromise. Function <code>conv.check()</code> provides some relevant diagnostic information which can be used, for example, to check whether the lower bounds of <code>min.dn</code> and <code>min.pr</code> have been reached. So based on this or if the user wishes to do some sensitivity analysis then this can be easily carried out using these three arguments. However, the user has to be cautious. For instance, it would not make much sense to choose for <code>min.dn</code> and <code>min.pr</code> values bigger than the default ones. Bear in mind that the bounds can be reached for ill-defined models. For certain distributions/models, if convergence failure occurs and the bounds have been reached then the user can try a sensitivity analysis as mentioned above.
<code>ygrid.tol</code>	Tolerance used to choose grid of response values for robust discrete models. Values smaller than $1e-160$ are not allowed for.

## Details

The underlying algorithm is described in ?gjrm.

There are many continuous/discrete distributions to choose from and we plan to include more options. Get in touch if you are interested in a particular distribution.

The "GEVlink" option is used for binary response additive models and is more stable and faster than the R package `bgeva`. This model has been incorporated into this package to take advantage



of the richer set of smoother choices, and of the estimation approach. Details on the model can be found in Calabrese, Marra and Osmetti (2016).

### Value

The function returns an object of class `gamlss` as described in `gamlssObject`.

### WARNINGS

Convergence can be checked using `conv.check` which provides some information about the score and information matrix associated with the fitted model. The former should be close to 0 and the latter positive definite. `gamlss()` will produce some warnings if there is a convergence issue.

Convergence failure may sometimes occur. This is not necessarily a bad thing as it may indicate specific problems with a fitted model. In such a situation, the user may use rescaling (see `parscale`). However, the user should especially consider re-specifying/simplifying the model, and/or checking that the chosen distribution fits the response well. In our experience, we found that convergence failure typically occurs when the model has been misspecified and/or the sample size is low compared to the complexity of the model. It is also worth bearing in mind that the use of three parameter distributions requires the data to be more informative than a situation in which two parameter distributions are used instead.

### Author(s)

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

### References

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**See Also**

[GJRM-package](#), [gamlssObject](#), [conv.check](#), [summary.gamlss](#)

**Examples**

```
## Not run:

library(GJRM)

set.seed(0)

n <- 400

x1 <- round(runif(n))
x2 <- runif(n)
x3 <- runif(n)
f1 <- function(x) cos(pi*2*x) + sin(pi*x)
y1 <- -1.55 + 2*x1 + f1(x2) + rnorm(n)

dataSim <- data.frame(y1, x1, x2, x3)
resp.check(y1, "N")

eq.mu <- y1 ~ x1 + s(x2) + s(x3)
eq.s   <-      ~ s(x3)
fl     <- list(eq.mu, eq.s)

out <- gamlss(fl, data = dataSim)

conv.check(out)
res.check(out)

plot(out, eq = 1, scale = 0, pages = 1, seWithMean = TRUE)
plot(out, eq = 2, seWithMean = TRUE)

summary(out)

AIC(out)
BIC(out)

#####
# Robust example
#####

eq.mu <- y1 ~ x1 + x2 + x3
fl     <- list(eq.mu)

out <- gamlss(fl, data = dataSim, family = "N", robust = TRUE,
              rc = 3, lB = -Inf, uB = Inf)

conv.check(out)
summary(out)
```

```

rob.const(out, 100)

##

eq.s <- ~ x3
fl <- list(eq.mu, eq.s)

out <- gamlss(fl, data = dataSim, family = "N", robust = TRUE)

conv.check(out)
summary(out)

##

eq.mu <- y1 ~ x1 + s(x2) + s(x3)
eq.s <- ~ s(x3)
fl <- list(eq.mu, eq.s)

out1 <- gamlss(fl, data = dataSim, family = "N", robust = TRUE,
               sp.method = "efs")

conv.check(out1)
summary(out1)
AIC(out, out1)

plot(out1, eq = 1, all.terms = TRUE, pages = 1, seWithMean = TRUE)
plot(out1, eq = 2, seWithMean = TRUE)

#####
## GEV link binary example
#####
# this incorporates the bgeva
# model implemented in the bgeva package
# however this implementation is more general,
# stable and efficient

set.seed(0)

n <- 400

x1 <- round(runif(n)); x2 <- runif(n); x3 <- runif(n)

f1 <- function(x) cos(pi*2*x) + sin(pi*x)
f2 <- function(x) x*exp(-30*(x-0.5)^2)

y <- ifelse(-3.55 + 2*x1 + f1(x2) + rnorm(n) > 0, 1, 0)

dataSim <- data.frame(y, x1, x2, x3)

out1 <- gamlss(list(y ~ x1 + x2 + x3), family = "GEVlink", data = dataSim)
out2 <- gamlss(list(y ~ x1 + s(x2) + s(x3)), family = "GEVlink", data = dataSim)

```

```

conv.check(out1)
conv.check(out2)
summary(out1)
summary(out2)
AIC(out1, out2)
BIC(out1, out2)

plot(out2, eq = 1, all.terms = TRUE, pages = 1, seWithMean = TRUE)

#####
# prediction of Pr
#####

# Calculate eta (that is, X*model.coef)
# For a new data set the argument newdata should be used

eta <- predict(out2, eq = 1, type = "link")

# extract gev tail parameter

gev.par <- out2$gev.par

# multiply gev tail parameter by eta

gevpeta <- gev.par*eta

# establish for which values the model is defined

gevpetaIND <- ifelse(gevpeta < -1, FALSE, TRUE)
gevpeta <- gevpeta[gevpetaIND]

# estimate probabilities

pr <- exp(-(1 + gevpeta)^(-1/gev.par))

#####
## Flexible survival model examples
#####

## Simulate proportional hazards data ##

set.seed(0)
n <- 2000
c <- runif(n, 3, 8)
u <- runif(n, 0, 1)
z1 <- rbinom(n, 1, 0.5)
z2 <- runif(n, 0, 1)
t <- rep(NA, n)

beta_0 <- -0.2357
beta_1 <- 1

```

```

f <- function(t, beta_0, beta_1, u, z1, z2){
  S_0 <- 0.7 * exp(-0.03*t^1.9) + 0.3*exp(-0.3*t^2.5)
  exp(-exp(log(-log(S_0))+beta_0*z1 + beta_1*z2))-u
}

for (i in 1:n){
  t[i] <- uniroot(f, c(0, 8), tol = .Machine$double.eps^0.5,
    beta_0 = beta_0, beta_1 = beta_1, u = u[i],
    z1 = z1[i], z2 = z2[i], extendInt = "yes" )$root
}

delta <- ifelse(t < c, 1, 0)
u <- apply(cbind(t, c), 1, min)
dataSim <- data.frame(u, delta, z1, z2)
1-mean(delta) # average censoring rate

# log(u) helps obtaining smoother hazards

out <- gamlss(list(u ~ s(log(u), bs = "mpi") + z1 + s(z2) ), data = dataSim,
  family = "-cloglog", cens = delta)
res.check(out)
summary(out)
AIC(out)
BIC(out)
plot(out, eq = 1, scale = 0, pages = 1)
haz.surv(out, newdata = data.frame(z1 = 0, z2 = 0), shade = TRUE,
  n.sim = 1000, baseline = TRUE)
haz.surv(out, type = "haz", newdata = data.frame(z1 = 0, z2 = 0),
  shade = TRUE, n.sim = 1000, baseline = TRUE)

# library(mgcv)
# out1 <- mgcv::gam(u ~ z1 + s(z2), family = cox.ph(),
#   data = dataSim, weights = delta)
# summary(out1)
# estimates of z1 and s(z2) are
# nearly identical between out and out1

#####
## Simulate proportional odds data ##
#####

set.seed(0)

n <- 2000
c <- runif(n, 4, 8)
u <- runif(n, 0, 1)
z <- rbinom(n, 1, 0.5)
beta_0 <- -1.05
t <- rep(NA, n)

f <- function(t, beta_0, u, z){
  S_0 <- 0.7 * exp(-0.03*t^1.9) + 0.3*exp(-0.3*t^2.5)

```

```

1/(1 + exp(log((1-S_0)/S_0)+beta_0*z))-u
}

for (i in 1:n){
  t[i] <- uniroot(f, c(0, 8), tol = .Machine$double.eps^0.5,
    beta_0 = beta_0, u = u[i], z = z[i],
    extendInt="yes" )$root
}

delta <- ifelse(t < c,1, 0)
u <- apply(cbind(t, c), 1, min)
dataSim <- data.frame(u, delta, z)
1-mean(delta) # average censoring rate

out <- gamlss(list(u ~ s(log(u), bs = "mpi") + z ), data = dataSim,
  family = "-logit", cens = delta)
res.check(out)
summary(out)
AIC(out)
BIC(out)
plot(out, eq = 1, scale = 0)
haz.surv(out, newdata = data.frame(z = 0), shade = TRUE, n.sim = 1000,
  baseline = TRUE)
haz.surv(out, type = "haz", newdata = data.frame(z = 0),
  shade = TRUE, n.sim = 1000)

#####
## Mixed censoring example ##
#####

f1 <- function(t, u, z1, z2, z3, z4, s1, s2){

  S_0 <- 0.7 * exp(-0.03*t^1.8) + 0.3*exp(-0.3*t^2.5)

  exp( -exp(log(-log(S_0)) + 1.3*z1 + 0.5*z2 + s1(z3) + s2(z4) ) ) - u

}

datagen <- function(n, z1, z2, z3, z4, s1, s2, f1){

  u <- runif(n, 0, 1)
  t <- rep(NA, n)

  for (i in 1:n) t[i] <- uniroot(f1, c(0, 100), tol = .Machine$double.eps^0.5,
    u = u[i], s1 = s1, s2 = s2, z1 = z1[i], z2 = z2[i],
    z3 = z3[i], z4 = z4[i], extendInt = "yes")$root

  c1 <- runif(n, 0, 2)
  c2 <- c1 + runif(n, 0, 6)

  df <- data.frame(u1 = t, u2 = t, cens = character(n), stringsAsFactors = FALSE)

```

```

for (i in 1:n){

  if(t[i] <= c1[i]) {
    df[i, 1] <- c1[i]
    df[i, 2] <- NA
    df[i, 3] <- "L"

  }else if(c1[i] < t[i] && t[i] <= c2[i]){
    df[i, 1] <- c1[i]
    df[i, 2] <- c2[i]
    df[i, 3] <- "I"

  }else if(t[i] > c2[i]){
    df[i, 1] <- c2[i]
    df[i, 2] <- NA
    df[i, 3] <- "R"}

}

uncens <- (df[, 3] %in% c("L", "I")) + (rbinom(n, 1, 0.2) == 1) == 2

df[uncens, 1] <- t[uncens]
df[uncens, 2] <- NA
df[uncens, 3] <- "U"

dataSim <- data.frame(u1 = df$u1, u2 = df$u2, cens = as.factor(df$cens), z1, z2, z3, z4, t)
dataSim

}

set.seed(0)

n      <- 1000
SigmaC <- matrix(0.5, 4, 4); diag(SigmaC) <- 1
cov     <- rmVN(n, rep(0,4), SigmaC)
cov     <- pnorm(cov)
z1      <- round(cov[, 1])
z2      <- round(cov[, 2])
z3      <- cov[, 3]
z4      <- cov[, 4]
s1      <- function(x) -0.075*exp(3.2 * x)
s2      <- function(x) sin(2*pi*x)

eq1     <- u1 ~ s(log(u1), bs = "mpi") + z1 + z2 + s(z3) + s(z4)

dataSim <- datagen(n, z1, z2, z3, z4, s1, s2, f1)

out <- gamlss(list(eq1), data = dataSim, family = "-cloglog",
               cens = cens, type.cen = "mixed", ub.t = "u2")

conv.check(out)
summary(out)

```

```

plot(out, eq = 1, scale = 0, pages = 1)

ndf <- data.frame(z1 = 1, z2 = 0, z3 = 0.2, z4 = 0.5)

haz.surv(out, eq = 1, newdata = ndf, type = "surv")
haz.surv(out, eq = 1, newdata = ndf, type = "haz", n.sim = 1000)

## End(Not run)

```

---

gamlssObject	<i>Fitted gamlssObject object</i>
--------------	-----------------------------------

---

## Description

A fitted gamlss object returned by function `gamlss` and of class "gamlss" and "SemiParBIV".

## Value

<code>fit</code>	List of values and diagnostics extracted from the output of the algorithm.
<code>gam1, gam2, gam3</code>	Univariate starting values' fits.
<code>coefficients</code>	The coefficients of the fitted model.
<code>weights</code>	Prior weights used during model fitting.
<code>sp</code>	Estimated smoothing parameters of the smooth components.
<code>iter.sp</code>	Number of iterations performed for the smoothing parameter estimation step.
<code>iter.if</code>	Number of iterations performed in the initial step of the algorithm.
<code>iter.inner</code>	Number of iterations performed within the smoothing parameter estimation step.
<code>n</code>	Sample size.
<code>X1, X2, X3, ...</code>	Design matrices associated with the linear predictors.
<code>X1.d2, X2.d2, X3.d2, ...</code>	Number of columns of X1, X2, X3, etc.
<code>l.sp1, l.sp2, l.sp3, ...</code>	Number of smooth components in the equations.
<code>He</code>	Penalized -hessian/Fisher. This is the same as HeSh for unpenalized models.
<code>HeSh</code>	Unpenalized -hessian/Fisher.
<code>Vb</code>	Inverse of He. This corresponds to the Bayesian variance-covariance matrix used for confidence/credible interval calculations.
<code>F</code>	This is obtained multiplying Vb by HeSh.
<code>t.edf</code>	Total degrees of freedom of the estimated bivariate model. It is calculated as <code>sum(diag(F))</code> .
<code>edf1, edf2, edf3, ...</code>	Degrees of freedom for the model's equations.



wor.c	Working model quantities.
eta1, eta2, eta3, ...	Estimated linear predictors.
y1	Response.
logLik	Value of the (unpenalized) log-likelihood evaluated at the (penalized or unpenalized) parameter estimates.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**See Also**

[gamlss](#), [summary.gamlss](#)

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ggmtrust	<i>ggmtrust for penalised network</i>
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**Description**

penalised network, work in progress.

**Usage**

```
ggmtrust(s, n, data = NULL, lambda = 1, pen = "lasso", params = NULL, method = "BHHH",
         w.lasso = NULL, gamma = 1, a = 3.7)
```

**Arguments**

s	Sample covariance matrix.
n	Sample size.
data	Data.
lambda	Regularisation parameter.
pen	Either "lasso" or "ridge".
params	If different from null then these are taken as the starting values.
method	Either "H" or "BHHH".
w.lasso	weight for alasso.
gamma	alasso param.
a	scad param.

## Details

penalised network, work in progress.

## Value

The function returns an object of class `ggmtrust`.

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<code>gjrm</code>	<i>Generalised Joint Regression Models with Binary/Continuous/Discrete/Survival Margins</i>
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## Description

`gjrm` fits flexible joint models with binary/continuous/discrete/survival margins, with several types of covariate effects, copula and marginal distributions.

## Usage

```
gjrm(formula, data = list(), weights = NULL, subset = NULL,
      offset1 = NULL, offset2 = NULL,
      copula = "N", copula2 = "N", margins, model, dof = 3, dof2 = 3,
      cens1 = NULL, cens2 = NULL, cens3 = NULL, dep.cens = FALSE,
      ub.t1 = NULL, ub.t2 = NULL, left.trunc1 = 0, left.trunc2 = 0,
      uni.fit = FALSE, fp = FALSE, infl.fac = 1,
      rinit = 1, rmax = 100, iterlimsp = 50, tols = 1e-07,
      gc.l = FALSE, parscale, knots = NULL,
      penCor = "unpen", sp.penCor = 3,
      Chol = FALSE, gamma = 1, w.lasso = NULL,
      drop.unused.levels = TRUE,
      min.dn = 1e-40, min.pr = 1e-16, max.pr = 0.999999,
      h.margins = FALSE)
```

## Arguments

<code>formula</code>	In the basic setup this will be a list of two (or three) formulas, one for equation 1, the other for equation 2 and another one for equation 3 if a trivariate model is fitted to the data. Otherwise, more equations can be used depending on the number of distributional parameters. <code>s</code> terms are used to specify smooth functions of predictors; see the documentation of <code>mgcv</code> for further details on formula specifications. Note that if a selection model is employed (that is, <code>model = "BSS"</code> or <code>model = "TSS"</code> ) then the first formula (and the second as well for trivariate models) MUST refer to the selection equation(s). When one outcome is binary and the other continuous/discrete then the first equation should refer to the binary outcome whereas the second to the continuous/discrete one. When one outcome is discrete and the other continuous then the first equation has to be the discrete one.
<code>data</code>	A data frame.

weights	Optional vector of prior weights to be used in fitting.
subset	Optional vector specifying a subset of observations to be used in the fitting process.
offset1, offset2	They can be used to supply model offsets for use in fitting. These have been introduced for dealing with offsets in the case of discrete marginal distributions.
copula	Type of bivariate error distribution employed. Possible choices are "N", "C0", "C90", "C180", "C270", "GAL0", "GAL90", "GAL180", "GAL270", "J0", "J90", "J180", "J270", "G0", "G90", "G180", "G270", "F", "AMH", "FGM", "T", "PL", "HO" which stand for bivariate normal, Clayton, rotated Clayton (90 degrees), survival Clayton, rotated Clayton (270 degrees), Galambos, rotated Galambos (90 degrees), survival Galambos, rotated Galambos (270 degrees), Joe, rotated Joe (90 degrees), survival Joe, rotated Joe (270 degrees), Gumbel, rotated Gumbel (90 degrees), survival Gumbel, rotated Gumbel (270 degrees), Frank, Ali-Mikhail-Haq, Farlie-Gumbel-Morgenstern, Student-t with dof, Plackett, Hougaard. Each of the Clayton, Galambos, Joe and Gumbel copulae is allowed to be mixed with a rotated version of the same family. The options are: "C0C90", "C0C270", "C180C90", "C180C270", "GAL0GAL90", "GAL0GAL270", "GAL180GAL90", "GAL180GAL270", "G0G90", "G0G270", "G180G90", "G180G270", "J0J90", "J0J270", "J180J90" and "J180J270". This allows the user to model negative and positive tail dependencies.
copula2	As above but used only for Roy models.
margins	It indicates the distributions used for margins. Possible distributions are Gaussian ("N"), truncated Gaussian ("tN"), Tweedie ("TW"), log-normal ("LN"), Gumbel ("GU"), reverse Gumbel ("rGU"), logistic ("LO"), Weibull ("WEI"), Inverse Gaussian ("IG"), gamma ("GA"), Dagum ("DAGUM"), Singh-Maddala ("SM"), beta ("BE"), Fisk ("FISK", also known as log-logistic distribution), Poisson ("P"), truncated Poisson ("tP"), negative binomial - type I ("NBI"), negative binomial - type II ("NBII"), Poisson inverse Gaussian ("PIG"), truncated negative binomial - type I ("tNBI"), truncated negative binomial - type II ("tNBII"), truncated Poisson inverse Gaussian ("tPIG"). If the responses are binary then possible link functions are "probit", "logit", "cloglog". For survival models, the margins can be "-cloglog" (similar to generalised proportional hazards), "-logit" (similar to generalised proportional odds), "-probit" (generalised probit). For ordinal marginals, the choices are "ord.probit" and "ord.logit". For extreme value models, there are also options we are working on, which are already implemented in the univariate gamlss() function. These are the generalised Pareto ("GP"), generalised Pareto II ("GPII") where the shape parameter is forced to be > -0.5, generalised Pareto (with orthogonal parametrisation) ("GPo") where the shape parameter is forced to be > -0.5, discrete generalised Pareto ("DGP"), discrete generalised Pareto II ("DGPII") where the shape parameter is forced to be positive, discrete generalised Pareto derived under the scenario in which shape = 0 ("DGP0"). Regarding the Tweedie, this margin can currently only be used together with a binary margin; we are working on the discrete/continuous margin extension.
model	Possible values are "B" (bivariate model), "T" (trivariate model), "BSS" (bivariate model with non-random sample selection), "TSS" (trivariate model with double non-random sample selection), "TESS" (trivariate model with endogeneity

and non-random sample selection), "BPO" (bivariate model with partial observability) and "BPO0" (bivariate model with partial observability and zero correlation). Options "T", "TESS" and "TSS" are currently for trivariate binary models only. "BPO" and "BPO0" are for bivariate binary models only. "SWITCH" is for the switching regression model.

dof	If <code>copula = "T"</code> then the degrees of freedom can be set to a value greater than 2 and smaller than 249. Only for continuous margins, this will be taken as a starting value and the dof estimated from the data.
dof2	As above but used only for Roy models.
cens1	Censoring indicator for the first equation. For the case of right censored data only, this variable can be equal to 1 if the event occurred and 0 otherwise. However, if there are several censoring mechanisms then <code>cens</code> will have to be specified as a factor variable made up of four possible categories: I for interval, L for left, R for right, and U for uncensored.
cens2	Same as above but for the second equation.
cens3	Binary censoring indicator employed only when <code>dep.cens = TRUE</code> and administrative censoring is present.
dep.cens	If TRUE then the dependence censored model is employed.
ub.t1, ub.t2	Variable names of right/upper bounds when interval censoring is present.
left.trunc1, left.trunc2	Values of truncation at left. Currently done for count distributions only.
uni.fit	If <code>uni.fit = TRUE</code> then <code>gamlss</code> or <code>gam</code> univariate models are also fitted. This is useful for obtaining starting values, for instance.
fp	If TRUE then a fully parametric model with unpenalised regression splines is fitted. See the Example 2 below.
infl.fac	Inflation factor for the model degrees of freedom in the approximate AIC. Smoother models can be obtained setting this parameter to a value greater than 1.
rinit	Starting trust region radius. The trust region radius is adjusted as the algorithm proceeds. See the documentation of <code>trust</code> for further details.
rmax	Maximum allowed trust region radius. This may be set very large. If set small, the algorithm traces a steepest descent path.
iterlimsp	A positive integer specifying the maximum number of loops to be performed before the smoothing parameter estimation step is terminated.
tolsp	Tolerance to use in judging convergence of the algorithm when automatic smoothing parameter estimation is used.
gc.l	This is relevant when working with big datasets. If TRUE then the garbage collector is called more often than it is usually done. This keeps the memory footprint down but it will slow down the routine.
parscale	The algorithm will operate as if optimizing <code>objfun(x / parscale, ...)</code> where <code>parscale</code> is a scalar. If missing then no rescaling is done. See the documentation of <code>trust</code> for more details.
knots	Optional list containing user specified knot values to be used for basis construction.

penCor	This and the arguments below are only for trivariate binary models. Type of penalty for correlation coefficients. Possible values are "unpen", "lasso", "ridge", "alasso".
sp.penCor	Starting value for smoothing parameter of penCor.
Chol	If TRUE then the Cholesky method instead of the eigenvalue method is employed for the correlation matrix.
gamma	Inflation factor used only for the alasso penalty.
w. alasso	When using the alasso penalty a weight vector made up of three values must be provided.
drop.unused.levels	By default unused levels are dropped from factors before fitting. For some smooths involving factor variables this may have to be turned off (only use if you know what you are doing).
min.dn, min.pr, max.pr	These values are used to set, depending on the model used for modelling, the minimum and maximum allowed for the densities and probabilities; recall that the margins of copula models have to be in the range (0,1). These parameters are employed to avoid potential overflows/underflows in the calculations and the default values seem to offer a good compromise. Function <code>conv.check()</code> provides some relevant diagnostic information which can be used, for example, to check whether the lower bounds of <code>min.dn</code> and <code>min.pr</code> have been reached. So based on this or if the user wishes to do some sensitivity analysis then this can be easily carried out using these three arguments. However, the user has to be cautious. For instance, it would not make much sense to choose for <code>min.dn</code> and <code>min.pr</code> values bigger than the default ones. Bear in mind that the bounds can be reached for ill-defined models. For certain distributions/models, if convergence failure occurs and the bounds have been reached then the user can try a sensitivity analysis as mentioned above.
h.margins	If TRUE then the marginal distributions are treated as copula h-functions. This is still experimental.

## Details

The joint models considered by this function consist of two or three model equations which depend on flexible linear predictors and whose dependence between the responses is modelled through one or more parameters of a chosen multivariate distribution. The additive predictors of the equations are flexibly specified using parametric components and smooth functions of covariates. The same can be done for the dependence parameter(s) if it makes sense. Estimation is achieved within a penalized likelihood framework with integrated automatic multiple smoothing parameter selection. The use of penalty matrices allows for the suppression of that part of smooth term complexity which has no support from the data. The trade-off between smoothness and fitness is controlled by smoothing parameters associated with the penalty matrices. Smoothing parameters are chosen to minimise an approximate AIC.

For sample selection models, if there are factors in the model then before fitting the user has to ensure that the numbers of factor variables' levels in the selected sample are the same as those in the complete dataset. Even if a model could be fitted in such a situation, the model may produce fits which are not coherent with the nature of the correction sought. As an example consider the

situation in which the complete dataset contains a factor variable with five levels and that only three of them appear in the selected sample. For the outcome equation (which is the one of interest) only three levels of such variable exist in the population, but their effects will be corrected for non-random selection using a selection equation in which five levels exist instead. Having differing numbers of factors' levels between complete and selected samples will also make prediction not feasible (an aspect which may be particularly important for selection models); clearly it is not possible to predict the response of interest for the missing entries using a dataset that contains all levels of a factor variable but using an outcome model estimated using a subset of these levels.

There are many continuous/discrete/survival distributions and copula functions to choose from and we plan to include more options. Get in touch if you are interested in a particular distribution.

## Value

The function returns an object of class `gjrm` as described in `gjrmObject`.

## WARNINGS

Convergence can be checked using `conv.check` which provides some information about the score and information matrix associated with the fitted model. The former should be close to 0 and the latter positive definite. `gjrm()` will produce some warnings if there is a convergence issue.

Convergence failure may sometimes occur. This is not necessarily a bad thing as it may indicate specific problems with a fitted model. In such a situation, the user may use rescaling (see `parscale`). Using `uni.fit = TRUE` is typically more effective than the first two options as this will provide better calibrated starting values as compared to those obtained from the default starting value procedure. The default option is, however, `uni.fit = FALSE` only because it tends to be computationally cheaper and because the default procedure has typically been found to do a satisfactory job in most cases. (The results obtained when using `uni.fit = FALSE` and `uni.fit = TRUE` could also be compared to check if starting values make any difference.)

The above suggestions may help, especially the latter option. However, the user should also consider re-specifying/simplifying the model, and/or using a different dependence structure and/or checking that the chosen marginal distributions fit the responses well. In our experience, we found that convergence failure typically occurs when the model has been misspecified and/or the sample size is low compared to the complexity of the model. Examples of misspecification include using a Clayton copula rotated by 90 degrees when a positive association between the margins is present instead, using marginal distributions that do not fit the responses, and employing a copula which does not accommodate the type and/or strength of the dependence between the margins (e.g., using AMH when the association between the margins is strong). When using smooth functions, if the covariate's values are too sparse then convergence may be affected by this. It is also worth bearing in mind that the use of three parameter marginal distributions requires the data to be more informative than a situation in which two parameter distributions are used instead.

In the contexts of endogeneity and non-random sample selection, extra attention is required when specifying the dependence parameter as a function of covariates. This is because in these situations the dependence parameter mainly models the association between the unobserved confounders in the two equations. Therefore, this option would make sense when it is believed that the strength of the association between the unobservables in the two equations varies based on some grouping factor or across geographical areas, for instance. In any case, a clear rationale is typically needed in such cases.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**References**

See `help("GJRM-package")`.

**See Also**

[adjCov](#), [vuong.test](#), [clarke.test](#), [GJRM-package](#), [gjrmObject](#), [conv.check](#), [summary.gjrm](#)

**Examples**

```
library(GJRM)

#####
# JOINT MODELS WITH BINARY MARGINS #
#####

#####
## EXAMPLE 1 ##

set.seed(0)

n <- 400

Sigma <- matrix(0.5, 2, 2); diag(Sigma) <- 1
u <- rMVN(n, rep(0,2), Sigma)

x1 <- round(runif(n)); x2 <- runif(n); x3 <- runif(n)

f1 <- function(x) cos(pi*2*x) + sin(pi*x)
f2 <- function(x) x*exp(-30*(x-0.5)^2)

y1 <- ifelse(-1.55 + 2*x1 + f1(x2) + u[,1] > 0, 1, 0)
y2 <- ifelse(-0.25 - 1.25*x1 + f2(x2) + u[,2] > 0, 1, 0)

dataSim <- data.frame(y1, y2, x1, x2, x3)

## CLASSIC BIVARIATE PROBIT

out <- gjrm(list(y1 ~ x1 + x2 + x3,
                y2 ~ x1 + x2 + x3),
            data = dataSim,
            margins = c("probit", "probit"),
            model = "B")

conv.check(out)
summary(out)
AIC(out)
BIC(out)
```

```
## Not run:

## BIVARIATE PROBIT with Splines

out <- gjrm(list(y1 ~ x1 + s(x2) + s(x3),
               y2 ~ x1 + s(x2) + s(x3)),
            data = dataSim,
            margins = c("probit", "probit"),
            model = "B")
conv.check(out)
summary(out)
AIC(out)

## estimated smooth function plots

plot(out, eq = 1, pages = 1, seWithMean = TRUE, scale = 0)
plot(out, eq = 2, pages = 1, seWithMean = TRUE, scale = 0)

## BIVARIATE PROBIT with Splines and
## varying dependence parameter

eq.mu.1 <- y1 ~ x1 + s(x2)
eq.mu.2 <- y2 ~ x1 + s(x2)
eq.theta <- ~ x1 + s(x2)

fl <- list(eq.mu.1, eq.mu.2, eq.theta)

outD <- gjrm(fl, data = dataSim,
             margins = c("probit", "probit"),
             model = "B")

conv.check(outD)
summary(outD)
summary(outD$theta)

plot(outD, eq = 1, seWithMean = TRUE)
plot(outD, eq = 2, seWithMean = TRUE)
plot(outD, eq = 3, seWithMean = TRUE)
graphics.off()

#####
## EXAMPLE 2 ##

## Generate data with one endogenous variable
## and exclusion restriction (or instrument)

set.seed(0)

n <- 400
```



```

Sigma <- matrix(0.5, 2, 2); diag(Sigma) <- 1
u      <- rMVN(n, rep(0,2), Sigma)

cov     <- rMVN(n, rep(0,2), Sigma)
cov     <- pnorm(cov)
x1 <- round(cov[,1]); x2 <- cov[,2]

f1 <- function(x) cos(pi*2*x) + sin(pi*x)
f2 <- function(x) x*exp(-30*(x-0.5)^2)

y1 <- ifelse(-1.55 + 2*x1 + f1(x2) + u[,1] > 0, 1, 0)
y2 <- ifelse(-0.25 - 1.25*y1 + f2(x2) + u[,2] > 0, 1, 0)

dataSim <- data.frame(y1, y2, x1, x2)

#
## Testing the hypothesis of absence of endogeneity...
#

LM.bpm(list(y1 ~ x1 + s(x2), y2 ~ y1 + s(x2)), dataSim, model = "B")

## CLASSIC RECURSIVE BIVARIATE PROBIT

out <- gfrm(list(y1 ~ x1 + x2,
                y2 ~ y1 + x2),
            data = dataSim,
            margins = c("probit", "probit"), model = "B")
conv.check(out)
summary(out)

## FLEXIBLE RECURSIVE BIVARIATE PROBIT

out <- gfrm(list(y1 ~ x1 + s(x2),
                y2 ~ y1 + s(x2)),
            data = dataSim,
            margins = c("probit", "probit"),
            model = "B")
conv.check(out)
summary(out)

#
## Testing the hypothesis of absence of endogeneity post estimation...

gt.bpm(out)

#
## Causal effects
## average treatment effect, risk ratio and odds ratio with CIs

mb(y1, y2, model = "B")
ATE(out, trt = "y1")

```

```

RR(out, trt = "y1")
OR(out, trt = "y1")
ATE(out, trt = "y1", joint = FALSE)

## try a Clayton copula model...

outC <- gjrm(list(y1 ~ x1 + s(x2),
                 y2 ~ y1 + s(x2)),
             data = dataSim, copula = "C0",
             margins = c("probit", "probit"),
             model = "B")
conv.check(outC)
summary(outC)
ATE(outC, trt = "y1")

## try a Joe copula model...

outJ <- gjrm(list(y1 ~ x1 + s(x2),
                 y2 ~ y1 + s(x2)),
             data = dataSim, copula = "J0",
             margins = c("probit", "probit"),
             model = "B")
conv.check(outJ)
summary(outJ)
ATE(outJ, "y1")

vuong.test(out, outJ)
clarke.test(out, outJ)

#
## recursive bivariate probit modelling with unpenalized splines
## can be achieved as follows

outFP <- gjrm(list(y1 ~ x1 + s(x2, bs = "cr", k = 5),
                  y2 ~ y1 + s(x2, bs = "cr", k = 6)),
              fp = TRUE, data = dataSim,
              margins = c("probit", "probit"),
              model = "B")
conv.check(outFP)
summary(outFP)

# in the above examples a third equation could be introduced
# as illustrated in Example 1

#####
## EXAMPLE 3 ##

## Generate data with a non-random sample selection mechanism
## and exclusion restriction

set.seed(0)

```

```

n <- 2000

Sigma <- matrix(0.5, 2, 2); diag(Sigma) <- 1
u      <- rMVN(n, rep(0,2), Sigma)

SigmaC <- matrix(0.5, 3, 3); diag(SigmaC) <- 1
cov     <- rMVN(n, rep(0,3), SigmaC)
cov     <- pnorm(cov)
bi <- round(cov[,1]); x1 <- cov[,2]; x2 <- cov[,3]

f11 <- function(x) -0.7*(4*x + 2.5*x^2 + 0.7*sin(5*x) + cos(7.5*x))
f12 <- function(x) -0.4*( -0.3 - 1.6*x + sin(5*x))
f21 <- function(x) 0.6*(exp(x) + sin(2.9*x))

ys <- 0.58 + 2.5*bi + f11(x1) + f12(x2) + u[, 1] > 0
y  <- -0.68 - 1.5*bi + f21(x1) +          + u[, 2] > 0
yo <- y*(ys > 0)

dataSim <- data.frame(y, ys, yo, bi, x1, x2)

#
## Testing the hypothesis of absence of non-random sample selection...

LM.bpm(list(ys ~ bi + s(x1) + s(x2), yo ~ bi + s(x1)), dataSim, model = "BSS")

# p-value suggests presence of sample selection

#
## SEMIPARAMETRIC SAMPLE SELECTION BIVARIATE PROBIT
## the first equation MUST be the selection equation

out <- gjrm(list(ys ~ bi + s(x1) + s(x2),
                yo ~ bi + s(x1)),
            data = dataSim, model = "BSS",
            margins = c("probit", "probit"))

conv.check(out)
gt.bpm(out)

## compare the two summary outputs below
## the second output produces a summary of the results obtained when
## selection bias is not accounted for

summary(out)
summary(out$gam2)

## corrected predicted probability that 'yo' is equal to 1

mb(ys, yo, model = "BSS")
prev(out)
prev(out, joint = FALSE)

## estimated smooth function plots
## the red line is the true curve

```

```

## the blue line is the univariate model curve not accounting for selection bias

x1.s <- sort(x1[dataSim$ys>0])
f21.x1 <- f21(x1.s)[order(x1.s)]-mean(f21(x1.s))

plot(out, eq = 2, ylim = c(-1.65,0.95)); lines(x1.s, f21.x1, col="red")
par(new = TRUE)
plot(out$gam2, se = FALSE, col = "blue", ylim = c(-1.65,0.95),
      ylab = "", rug = FALSE)

#
#
## try a Clayton copula model...

outC <- gjrm(list(ys ~ bi + s(x1) + s(x2),
                  yo ~ bi + s(x1)),
              data = dataSim, model = "BSS", copula = "C0",
              margins = c("probit", "probit"))
conv.check(outC)
summary(outC)
prev(outC)

#####
## EXAMPLE 4 ##

## Generate data with partial observability

set.seed(0)

n <- 1000

Sigma <- matrix(0.5, 2, 2); diag(Sigma) <- 1
u <- rMVN(n, rep(0,2), Sigma)

x1 <- round(runif(n)); x2 <- runif(n); x3 <- runif(n)

y1 <- ifelse(-1.55 + 2*x1 + x2 + u[,1] > 0, 1, 0)
y2 <- ifelse( 0.45 - x3 + u[,2] > 0, 1, 0)
y <- y1*y2

dataSim <- data.frame(y, x1, x2, x3)

## BIVARIATE PROBIT with Partial Observability

out <- gjrm(list(y ~ x1 + x2,
                 y ~ x3),
              data = dataSim, model = "BP0",
              margins = c("probit", "probit"))
conv.check(out)
summary(out)

# first ten estimated probabilities for the four events from object out

```

```

cbind(out$p11, out$p10, out$p00, out$p01)[1:10,]

# case with smooth function

f1 <- function(x) cos(pi*2*x) + sin(pi*x)

y1 <- ifelse(-1.55 + 2*x1 + f1(x2) + u[,1] > 0, 1, 0)
y2 <- ifelse( 0.45 - x3          + u[,2] > 0, 1, 0)
y  <- y1*y2

dataSim <- data.frame(y, x1, x2, x3)

out <- gjrm(list(y ~ x1 + s(x2),
                 y ~ x3),
            data = dataSim, model = "BP0",
            margins = c("probit", "probit"))

conv.check(out)
summary(out)

plot(out, eq = 1, scale = 0)

#####
# JOINT MODELS WITH BINARY AND/OR CONTINUOUS MARGINS #
#####

#####
## EXAMPLE 5 ##

## Generate data
## Correlation between the two equations 0.5 - Sample size 400

set.seed(0)

n <- 400

Sigma <- matrix(0.5, 2, 2); diag(Sigma) <- 1
u      <- rMVN(n, rep(0,2), Sigma)

x1 <- round(runif(n)); x2 <- runif(n); x3 <- runif(n)

f1 <- function(x) cos(pi*2*x) + sin(pi*x)
f2 <- function(x) x*exp(-30*(x-0.5)^2)

y1 <- -1.55 + 2*x1      + f1(x2) + u[,1]
y2 <- -0.25 - 1.25*x1 + f2(x2) + u[,2]

dataSim <- data.frame(y1, y2, x1, x2, x3)

resp.check(y1, "N")
resp.check(y2, "N")

```

```

eq.mu.1    <- y1 ~ x1 + s(x2) + s(x3)
eq.mu.2    <- y2 ~ x1 + s(x2) + s(x3)
eq.sigma1  <- ~ 1
eq.sigma2  <- ~ 1
eq.theta   <- ~ x1

fl <- list(eq.mu.1, eq.mu.2, eq.sigma1, eq.sigma2, eq.theta)

# the order above is the one to follow when
# using more than two equations

out <- gjrm(fl, data = dataSim, margins = c("N", "N"),
            model = "B")

conv.check(out)
res.check(out)
summary(out)
AIC(out)
BIC(out)

nd <- data.frame(x1 = 1, x2 = 0.4, x3 = 0.6)
copula.prob(out, y1 = 1.4, y2 = 2.3, newdata = nd, intervals = TRUE)

#####
## EXAMPLE 6 ##

## Generate data with one endogenous binary variable
## and continuous outcome

set.seed(0)

n <- 1000

Sigma <- matrix(0.5, 2, 2); diag(Sigma) <- 1
u      <- rMVN(n, rep(0,2), Sigma)

cov    <- rMVN(n, rep(0,2), Sigma)
cov    <- pnorm(cov)
x1 <- round(cov[,1]); x2 <- cov[,2]

f1 <- function(x) cos(pi*2*x) + sin(pi*x)
f2 <- function(x) x*exp(-30*(x-0.5)^2)

y1 <- ifelse(-1.55 + 2*x1 + f1(x2) + u[,1] > 0, 1, 0)
y2 <- -0.25 - 1.25*y1 + f2(x2) + u[,2]

dataSim <- data.frame(y1, y2, x1, x2)

## RECURSIVE Model

out <- gjrm(list(y1 ~ x1 + x2,
```

```

        y2 ~ y1 + x2),
        data = dataSim, margins = c("probit","N"),
        model = "B")

conv.check(out)
summary(out)
res.check(out)

## SEMIPARAMETRIC RECURSIVE Model

eq.mu.1 <- y1 ~ x1 + s(x2)
eq.mu.2 <- y2 ~ y1 + s(x2)
eq.sigma <- ~ 1
eq.theta <- ~ 1

f1 <- list(eq.mu.1, eq.mu.2, eq.sigma, eq.theta)

out <- gjrm(f1, data = dataSim,
            margins = c("probit","N"), uni.fit = TRUE,
            model = "B")
conv.check(out)
summary(out)
res.check(out)
ATE(out, trt = "y1")
ATE(out, trt = "y1", joint = FALSE)

#
#

#####
## EXAMPLE 7 ##

## Generate data with one endogenous continuous exposure
## and binary outcome

set.seed(0)

n <- 1000

Sigma <- matrix(0.5, 2, 2); diag(Sigma) <- 1
u <- rMVN(n, rep(0,2), Sigma)

cov <- rMVN(n, rep(0,2), Sigma)
cov <- pnorm(cov)
x1 <- round(cov[,1]); x2 <- cov[,2]

f1 <- function(x) cos(pi*2*x) + sin(pi*x)
f2 <- function(x) x*exp(-30*(x-0.5)^2)

y1 <- -0.25 - 2*x1 + f2(x2) + u[,2]
y2 <- ifelse(-0.25 - 0.25*y1 + f1(x2) + u[,1] > 0, 1, 0)

dataSim <- data.frame(y1, y2, x1, x2)

```

```

eq.mu.1 <- y2 ~ y1 + s(x2)
eq.mu.2 <- y1 ~ x1 + s(x2)
eq.sigma <- ~ 1
eq.theta <- ~ 1

fl <- list(eq.mu.1, eq.mu.2, eq.sigma, eq.theta)

out <- gjrm(fl, data = dataSim,
            margins = c("probit", "N"),
            model = "B")
conv.check(out)
summary(out)
res.check(out)
ATE(out, trt = "y1", trt.val = 1)
ATE(out, trt = "y1", trt.val = 1, joint = FALSE)
RR(out, trt = "y1", trt.val = 1)
RR(out, trt = "y1", trt.val = 1, joint = FALSE)
OR(out, trt = "y1", trt.val = 1)
OR(out, trt = "y1", trt.val = 1, joint = FALSE)

#
#

#####
## EXAMPLE 8      ##
## SURVIVAL MODELS ##

set.seed(0)

n <- 2000
c <- runif(n, 3, 8)
u <- runif(n, 0, 1)
z1 <- rbinom(n, 1, 0.5)
z2 <- runif(n, 0, 1)
t <- rep(NA, n)

beta_0 <- -0.2357
beta_1 <- 1

f <- function(t, beta_0, beta_1, u, z1, z2){
  S_0 <- 0.7 * exp(-0.03*t^1.9) + 0.3*exp(-0.3*t^2.5)
  exp(-exp(log(-log(S_0))+beta_0*z1 + beta_1*z2))-u
}

for (i in 1:n){
  t[i] <- uniroot(f, c(0, 8), tol = .Machine$double.eps^0.5,
                beta_0 = beta_0, beta_1 = beta_1, u = u[i],
                z1 = z1[i], z2 = z2[i], extendInt = "yes" )$root
}

delta1 <- ifelse(t < c, 1, 0)
u1 <- apply(cbind(t, c), 1, min)

```



```

dataSim <- data.frame(u1, delta1, z1, z2)

c <- runif(n, 4, 8)
u <- runif(n, 0, 1)
z <- rbinom(n, 1, 0.5)
beta_0 <- -1.05
t <- rep(NA, n)

f <- function(t, beta_0, u, z){
  S_0 <- 0.7 * exp(-0.03*t^1.9) + 0.3*exp(-0.3*t^2.5)
  1/(1 + exp(log((1-S_0)/S_0)+beta_0*z))-u
}

for (i in 1:n){
  t[i] <- uniroot(f, c(0, 8), tol = .Machine$double.eps^0.5,
    beta_0 = beta_0, u = u[i], z = z[i],
    extendInt="yes" )$root
}

delta2 <- ifelse(t < c, 1, 0)
u2 <- apply(cbind(t, c), 1, min)
dataSim$delta2 <- delta2
dataSim$u2 <- u2
dataSim$z <- z

eq1 <- u1 ~ s(log(u1), bs = "mpi") + z1 + s(z2)
eq2 <- u2 ~ s(log(u2), bs = "mpi") + z
eq3 <- ~ s(z2)

out <- gjrm(list(eq1, eq2), data = dataSim,
  margins = c("-cloglog", "-logit"),
  cens1 = delta1, cens2 = delta2, model = "B")

# PH margin fit can also be compared with cox.ph from mgcv

conv.check(out)
res <- res.check(out)

## martingale residuals
mr1 <- out$cens1 - res$qr1
mr2 <- out$cens2 - res$qr2

# can be plotted against covariates
# obs index, survival time, rank order of
# surv times

# to determine func form, one may use
# res from null model against covariate

```

```

# to test for PH, use:
# library(survival)
# fit <- coxph(Surv(u1, delta1) ~ z1 + z2, data = dataSim)
# temp <- cox.zph(fit)
# print(temp)
# plot(temp, resid = FALSE)

summary(out)
AIC(out); BIC(out)
plot(out, eq = 1, scale = 0, pages = 1)
plot(out, eq = 2, scale = 0, pages = 1)

haz.surv(out, eq = 1, newdata = data.frame(z1 = 0, z2 = 0),
        shade = TRUE, n.sim = 100, baseline = TRUE)
haz.surv(out, eq = 1, newdata = data.frame(z1 = 0, z2 = 0),
        shade = TRUE, n.sim = 100, type = "haz", baseline = TRUE,
        intervals = FALSE)
haz.surv(out, eq = 2, newdata = data.frame(z = 0),
        shade = FALSE, n.sim = 100, baseline = TRUE)
haz.surv(out, eq = 2, newdata = data.frame(z = 0),
        shade = TRUE, n.sim = 100, type = "haz", baseline = TRUE)

newd0 <- newd1 <- data.frame(z = 0, z1 = mean(dataSim$z1),
                             z2 = mean(dataSim$z2),
                             u1 = mean(dataSim$u1) + 1,
                             u2 = mean(dataSim$u2) + 1)

newd1$z <- 1

copula.prob(out, newdata = newd0, intervals = TRUE)
copula.prob(out, newdata = newd1, intervals = TRUE)

out1 <- gjrm(list(eq1, eq2, eq3), data = dataSim,
              margins = c("-cloglog", "-logit"),
              cens1 = delta1, cens2 = delta2, uni.fit = TRUE,
              model = "B")

#####
## Joint continuous and survival outcomes
#####
# this is complete, just testing, get in touch if interested
#
# eq1 <- z2 ~ z1
# eq2 <- u2 ~ s(u2, bs = "mpi") + z
# eq3 <- ~ s(z2)
# eq4 <- ~ s(z2)
#
# f.l <- list(eq1, eq2, eq3, eq4)
#
# out3 <- gjrm(f.l, data = dataSim,
#             margins = c("N", "-logit"),

```

```

#          cens1 = NULL, cens2 = delta2,
#          uni.fit = TRUE, model = "B")
#
# conv.check(out3)
# res.check(out3)
# summary(out3)
# AIC(out3); BIC(out3)
# plot(out3, eq = 2, scale = 0, pages = 1)
# plot(out3, eq = 3, scale = 0, pages = 1)
# plot(out3, eq = 4, scale = 0, pages = 1)
#
# newd <- newd1 <- data.frame(z = 0, z1 = mean(dataSim$z1),
#                             z2 = mean(dataSim$z2),
#                             u2 = mean(dataSim$u2) + 1)
#
# copula.prob(out3, y1 = 0.6, newdata = newd, intervals = TRUE)

#####
# JOINT MODELS WITH THREE BINARY MARGINS #
#####

#####
## EXAMPLE 9 ##

## Generate data
## Correlation between the two equations 0.5 - Sample size 400

set.seed(0)

n <- 400

Sigma <- matrix(0.5, 3, 3); diag(Sigma) <- 1
u <- rmVN(n, rep(0,3), Sigma)

x1 <- round(runif(n)); x2 <- runif(n); x3 <- runif(n)

f1 <- function(x) cos(pi*2*x) + sin(pi*x)
f2 <- function(x) x*exp(-30*(x-0.5)^2)

y1 <- ifelse(-1.55 + 2*x1 - f1(x2) + u[,1] > 0, 1, 0)
y2 <- ifelse(-0.25 - 1.25*x1 + f2(x2) + u[,2] > 0, 1, 0)
y3 <- ifelse(-0.75 + 0.25*x1 + u[,3] > 0, 1, 0)

dataSim <- data.frame(y1, y2, y3, x1, x2)

f.l <- list(y1 ~ x1 + s(x2),
            y2 ~ x1 + s(x2),
            y3 ~ x1)

margs <- c("probit", "probit", "probit")

out <- gjrm(f.l, data = dataSim, model = "T", margins = margs)
out1 <- gjrm(f.l, data = dataSim, Chol = TRUE, model = "T", margins = margs)

```

```

conv.check(out)
summary(out)
plot(out, eq = 1)
plot(out, eq = 2)
AIC(out)
BIC(out)

margs <- c("probit","logit","cloglog")

out <- gjrm(f.l, data = dataSim, model = "T", margins = margs)
out1 <- gjrm(f.l, data = dataSim, Chol = TRUE, model = "T", margins = margs)
conv.check(out)
summary(out)
plot(out, eq = 1)
plot(out, eq = 2)

margs <- c("probit", "probit", "probit")

f.l <- list(y1 ~ x1 + s(x2),
            y2 ~ x1 + s(x2),
            y3 ~ x1,
            ~ 1, ~ 1, ~ 1)

out1 <- gjrm(f.l, data = dataSim, Chol = TRUE, model = "T", margins = margs)

f.l <- list(y1 ~ x1 + s(x2),
            y2 ~ x1 + s(x2),
            y3 ~ x1,
            ~ 1, ~ s(x2), ~ 1)

out2 <- gjrm(f.l, data = dataSim, Chol = TRUE, model = "T", margins = margs)

f.l <- list(y1 ~ x1 + s(x2),
            y2 ~ x1 + s(x2),
            y3 ~ x1,
            ~ x1, ~ s(x2), ~ x1 + s(x2))

out2 <- gjrm(f.l, data = dataSim, Chol = TRUE, model = "T", margins = margs)

f.l <- list(y1 ~ x1 + s(x2),
            y2 ~ x1 + s(x2),
            y3 ~ x1,
            ~ x1, ~ x1, ~ s(x2))

out2 <- gjrm(f.l, data = dataSim, Chol = TRUE, model = "T", margins = margs)

f.l <- list(y1 ~ x1 + s(x2),
            y2 ~ x1 + s(x2),
            y3 ~ x1,
            ~ x1, ~ x1 + x2, ~ s(x2))

```

```

out2 <- gjrm(f.l, data = dataSim, Chol = TRUE, model = "T", margins = margs)

f.l <- list(y1 ~ x1 + s(x2),
            y2 ~ x1 + s(x2),
            y3 ~ x1,
            ~ x1 + x2, ~ x1 + x2, ~ x1 + x2)

out2 <- gjrm(f.l, data = dataSim, Chol = TRUE, model = "T", margins = margs)

nw <- data.frame( x1 = 0, x2 = 0.7 )

copula.prob(out2, 1, 1, 1, newdata = nw, cond = 0, intervals = TRUE, n.sim = 100)

# with endogenous variable

f.l <- list(y1 ~ x1 + s(x2),
            y2 ~ y1 + x1 + s(x2),
            y3 ~ x1)

margs <- c("probit", "probit", "probit")

out <- gjrm(f.l, data = dataSim, model = "T", margins = margs)

conv.check(out)
summary(out)

ATE(out, trt = "y1", eq = 2, joint = TRUE)
ATE(out, trt = "y1", eq = 2, joint = FALSE)

#####
## EXAMPLE 10 ##

## Generate data
## with double sample selection

set.seed(0)

n <- 5000

Sigma <- matrix(c(1, 0.5, 0.4,
                  0.5, 1, 0.6,
                  0.4, 0.6, 1 ), 3, 3)

u <- rmVN(n, rep(0,3), Sigma)

f1 <- function(x) cos(pi*2*x) + sin(pi*x)
f2 <- function(x) x*exp(-30*(x-0.5)^2)

x1 <- runif(n)
x2 <- runif(n)
x3 <- runif(n)
x4 <- runif(n)

```

```

y1 <- 1 + 1.5*x1 - x2 + 0.8*x3 - f1(x4) + u[, 1] > 0
y2 <- 1 - 2.5*x1 + 1.2*x2 + x3 + u[, 2] > 0
y3 <- 1.58 + 1.5*x1 - f2(x2) + u[, 3] > 0

dataSim <- data.frame(y1, y2, y3, x1, x2, x3, x4)

f.l <- list(y1 ~ x1 + x2 + x3 + s(x4),
            y2 ~ x1 + x2 + x3,
            y3 ~ x1 + s(x2))

out <- gjrm(f.l, data = dataSim, model = "TSS",
            margins = c("probit", "probit", "probit"))
conv.check(out)
summary(out)
plot(out, eq = 1)
plot(out, eq = 3)
prev(out)
prev(out, joint = FALSE)

#####
## EXAMPLE 11

set.seed(0)

n <- 2000

rh <- 0.5

sigmau <- matrix(c(1, rh, rh, 1), 2, 2)
u <- rMVN(n, rep(0,2), sigmau)

sigmac <- matrix(rh, 3, 3); diag(sigmac) <- 1
cov <- rMVN(n, rep(0,3), sigmac)
cov <- pnorm(cov)

bi <- round(cov[,1]); x1 <- cov[,2]; x2 <- cov[,3]

f11 <- function(x) -0.7*(4*x + 2.5*x^2 + 0.7*sin(5*x) + cos(7.5*x))
f12 <- function(x) -0.4*( -0.3 - 1.6*x + sin(5*x))
f21 <- function(x) 0.6*(exp(x) + sin(2.9*x))

ys <- 0.58 + 2.5*bi + f11(x1) + f12(x2) + u[, 1] > 0
y <- -0.68 - 1.5*bi + f21(x1) + u[, 2]
yo <- y*(ys > 0)

dataSim <- data.frame(ys, yo, bi, x1, x2)

## CLASSIC SAMPLE SELECTION MODEL
## the first equation MUST be the selection equation

resp.check(yo[ys > 0], "N")

```

```

out <- gjrm(list(ys ~ bi + x1 + x2,
                yo ~ bi + x1),
            data = dataSim, model = "BSS",
            margins = c("probit", "N"))
conv.check(out)
res.check(out)
summary(out)

AIC(out)
BIC(out)

## SEMIPARAMETRIC SAMPLE SELECTION MODEL

out <- gjrm(list(ys ~ bi + s(x1) + s(x2),
                yo ~ bi + s(x1)),
            data = dataSim, model = "BSS",
            margins = c("probit", "N"))
conv.check(out)
res.check(out)
AIC(out)

## compare the two summary outputs
## the second output produces a summary of the results obtained when only
## the outcome equation is fitted, i.e. selection bias is not accounted for

summary(out)
summary(out$gam2)

## estimated smooth function plots
## the red line is the true curve
## the blue line is the naive curve not accounting for selection bias

x1.s <- sort(x1[dataSim$ys>0])
f21.x1 <- f21(x1.s)[order(x1.s)] - mean(f21(x1.s))

plot(out, eq = 2, ylim = c(-1, 0.8)); lines(x1.s, f21.x1, col = "red")
par(new = TRUE)
plot(out$gam2, se = FALSE, lty = 3, lwd = 2, ylim = c(-1, 0.8),
     ylab = "", rug = FALSE)

##

## SEMIPARAMETRIC SAMPLE SELECTION MODEL with association
## and dispersion parameters
## depending on covariates as well

eq.mu.1 <- ys ~ bi + s(x1) + s(x2)
eq.mu.2 <- yo ~ bi + s(x1)
eq.sigma <- ~ bi
eq.theta <- ~ bi + x1

```

```

fl <- list(eq.mu.1, eq.mu.2, eq.sigma, eq.theta)

out <- gjrm(fl, data = dataSim, model = "BSS",
           margins = c("probit", "N"))
conv.check(out)
res.check(out)
summary(out)
summary(out$sigma)
summary(out$theta)

nd <- data.frame(bi = 0, x1 = 0.2, x2 = 0.8)
copula.prob(out, 0, 0.3, newdata = nd, intervals = TRUE)

outC0 <- gjrm(fl, data = dataSim, copula = "C0", model = "BSS",
             margins = c("probit", "N"))
conv.check(outC0)
res.check(outC0)

## End(Not run)

```

---

girmObject

*Fitted gjrm object*


---

## Description

A fitted joint model returned by function `gjrm` and of class "gjrm", "SemiParBIV", "SemiParTRIV", etc.

## Value

<code>fit</code>	List of values and diagnostics extracted from the output of the algorithm.
<code>gam1</code>	Univariate fit for equation 1. See the documentation of <code>mgcv</code> for full details.
<code>gam2, gam3, ...</code>	Univariate fit for equation 2, equation 3, etc.
<code>coefficients</code>	The coefficients of the fitted model.
<code>weights</code>	Prior weights used during model fitting.
<code>sp</code>	Estimated smoothing parameters of the smooth components.
<code>iter.sp</code>	Number of iterations performed for the smoothing parameter estimation step.
<code>iter.if</code>	Number of iterations performed in the initial step of the algorithm.
<code>iter.inner</code>	Number of iterations performed within the smoothing parameter estimation step.
<code>theta</code>	Estimated dependence parameter linking the two equations.
<code>n</code>	Sample size.
<code>X1, X2, X3, ...</code>	Design matrices associated with the linear predictors.



X1.d2, X2.d2, X3.d2, ...	Number of columns of X1, X2, X3, etc.
l.sp1, l.sp2, l.sp3, ...	Number of smooth components in the equations.
He	Penalized -hessian/Fisher. This is the same as HeSh for unpenalized models.
HeSh	Unpenalized -hessian/Fisher.
Vb	Inverse of He. This corresponds to the Bayesian variance-covariance matrix used for confidence/credible interval calculations.
F	This is obtained multiplying Vb by HeSh.
t.edf	Total degrees of freedom of the estimated bivariate model. It is calculated as <code>sum(diag(F))</code> .
edf1, edf2, edf3, ...	Degrees of freedom for the two equations of the fitted bivariate model (and for the third and fourth equations if present. They are calculated when splines are used.
bs.mgfit	List of values and diagnostics extracted from <code>magic</code> in <code>mgcv</code> .
conv.sp	If TRUE then the smoothing parameter selection algorithm stopped before reaching the maximum number of iterations allowed.
wor.c	Working model quantities.
eta1, eta2, eta3, ...	Estimated linear predictors for the two equations (as well as the third and fourth equations if present).
y1, y2	Responses of the two equations.
logLik	Value of the (unpenalized) log-likelihood evaluated at the (penalized or unpenalized) parameter estimates.
respvec	List containing response vectors.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**See Also**

[gjrm](#), [summary.gjrm](#)

---

gt.bpm

*Gradient test*


---

**Description**

gt.bpm can be used to test the hypothesis of absence of endogeneity, correlated model equations/errors or non-random sample selection in binary bivariate probit models.

**Usage**

```
gt.bpm(x)
```

**Arguments**

x                      A fitted gjrm object.

**Details**

The gradient test was first proposed by Terrell (2002) and it is based on classic likelihood theory. See Marra et al. (2017) for full details.

**Value**

It returns a numeric p-value corresponding to the null hypothesis that the correlation,  $\theta$ , is equal to 0.

**WARNINGS**

This test's implementation is only valid for bivariate binary probit models with normal errors.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**References**

Marra G., Radice R. and Filippou P. (2017), Regression Spline Bivariate Probit Models: A Practical Approach to Testing for Exogeneity. *Communications in Statistics - Simulation and Computation*, 46(3), 2283-2298.

Terrell G. (2002), The Gradient Statistic. *Computing Science and Statistics*, 34, 206-215.

**Examples**

```
## see examples for gjrm
```

---

H.tri

*Internal Function*


---

**Description**

This and other similar internal functions calculate the Hessian for trivariate binary models.

**Author(s)**

Author: Panagioti Filippou

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

---

haz.surv	<i>Post-estimation calculation of hazard, cumulative hazard and survival functions</i>
----------	--

---

## Description

This function produces estimated values, intervals and plots for the hazard, cumulative hazard and survival functions.

## Usage

```
haz.surv(x, eq, newdata, type = "surv", t.range = NULL, t.vec = NULL,
         intervals = TRUE, n.sim = 100, prob.lev = 0.05, shade = FALSE,
         bars = FALSE, ylim, ylab, xlab, pch, ls = 100, baseline = FALSE,
         min.dn = 1e-200, min.pr = 1e-200, max.pr = 1, plot = TRUE,
         print.progress = TRUE, ...)
```

## Arguments

x	A fitted gamlss/gjrm object.
eq	Equation number. This can be ignored for univariate models.
newdata	<p>A data frame or list containing the values of the model covariates at which predictions are required. This must always be provided.</p> <p>For the individual survival/hazard/cumulative hazard function, the data frame must have one row containing the values of the model covariates corresponding to the individual of interest.</p> <p>For the (sub-)population survival/hazard/cumulative hazard function, the data frame must have as many rows as there are individuals in the (sub-)population of interest. Each row must contain the values of the model covariates of the corresponding individual.</p>
type	Either "surv", "haz" or "cum.haz". In the excess hazard setting these are, respectively, the net survival, the excess hazard and the cumulative excess hazard.
t.range	Time variable range. This must be a vector with only two elements: the minimum and maximum of the time range. If NULL then it is determined automatically based on the observed data.
t.vec	Vector of time values. This can also be a single time. Note you cannot provide both t.range and t.vec as they are two mutually exclusive ways of defining the time variable. If NULL then it is determined automatically based on the observed data.
intervals	If TRUE then intervals are also produced.
n.sim	Number of simulated coefficient vectors from the posterior distribution of the estimated model parameters. This is used for interval calculations.

prob.lev	Overall probability of the left and right tails of the probabilities' distributions used for interval calculations.
shade	If TRUE then it produces shaded regions as confidence bands.
bars	If TRUE then the confidence intervals are plotted as bars rather than continuous curves. If t.vec is used and only one time value is provided, this is the only possible plotting option for the confidence intervals. Note shade and bars are mutually exclusive.
ylim, ylab, xlab, pch	Usual plot arguments.
ls	Length of sequence to use for time variable.
baseline	If baseline is desired; this will set all covariate/smooth effects to zero.
min.dn, min.pr, max.pr	Allowed minimum and maximum for estimated probabilities and densities for survival, hazard and cumulative hazard calculations.
plot	If FALSE then the function does not produce a plot. The default is TRUE.
print.progress	If FALSE then the function does not print progress made. The default is TRUE.
...	Other arguments to pass to plot.

**Value**

It produces estimated values, intervals and plots for the hazard, cumulative hazard and survival functions.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

---

k.tau	<i>Kendall's tau a fitted joint model</i>
-------	---

---

**Description**

k.tau can be used to calculate the Kendall's tau from a fitted joint model with intervals obtained via posterior simulation.

**Usage**

```
k.tau(x, prob.lev = 0.05)
```

**Arguments**

x	A fitted gjrm object as produced by the respective fitting function.
prob.lev	Overall probability of the left and right tails of the probabilities' distributions used for interval calculations.

**Details**

This function calculates the Kendall's tau a fitted simultaneous model, with intervals obtained via posterior simulation. Note that this is derived under the assumption of continuous margins.

**Value**

`res` It returns the estimated tau with lower and upper interval limits.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**See Also**

[GJRM-package](#), [gjrm](#)

---

llpsi

*Internal Function*


---

**Description**

Log-logistic robust function.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

---

LM.bpm

*Lagrange Multiplier Test (Score Test)*


---

**Description**

Before fitting a bivariate probit model, LM.bpm can be used to test the hypothesis of absence of endogeneity, correlated model equations/errors or non-random sample selection.

**Usage**

```
LM.bpm(formula, data = list(), weights = NULL, subset = NULL, model, hess = TRUE)
```

**Arguments**

formula	A list of two formulas, one for equation 1 and the other for equation 2. $s$ terms are used to specify smooth functions of predictors. Note that if <code>model = "BSS"</code> then the first formula MUST refer to the selection equation.
data	An optional data frame, list or environment containing the variables in the model. If not found in data, the variables are taken from <code>environment(formula)</code> .
weights	Optional vector of prior weights to be used in fitting.
subset	Optional vector specifying a subset of observations to be used in the fitting process.
model	It indicates the type of model to be used in the analysis. Possible values are "B" (bivariate model) and "BSS" (bivariate model with sample selection). The two marginal equations have probit links.
hess	If FALSE then the expected (rather than observed) information matrix is employed.

**Details**

This Lagrange multiplier test (also known as score test) is used here for testing the null hypothesis that  $\theta$  is equal to 0 (i.e. no endogeneity, non-random sample selection or correlated model equations/errors, depending on the model being fitted). Its main advantage is that it does not require an estimate of the model parameter vector under the alternative hypothesis. Asymptotically, it takes a Chi-squared distribution with one degree of freedom. Full details can be found in Marra et al. (2014) and Marra et al. (2017).

**Value**

It returns a numeric p-value corresponding to the null hypothesis that the correlation,  $\theta$ , is equal to 0.

**WARNINGS**

This test's implementation is ONLY valid for bivariate binary probit models with normal errors.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**References**

Marra G., Radice R. and Filippou P. (2017), Regression Spline Bivariate Probit Models: A Practical Approach to Testing for Exogeneity. *Communications in Statistics - Simulation and Computation*, 46(3), 2283-2298.

Marra G., Radice R. and Missiroli S. (2014), Testing the Hypothesis of Absence of Unobserved Confounding in Semiparametric Bivariate Probit Models. *Computational Statistics*, 29(3-4), 715-741.

**See Also**[gjrm](#)**Examples**

```
## see examples for gjrm
```

---

`lmc`*Linear Model Fitting with Constraints*

---

**Description**

Linear model fitting with positivity and sum-to-one constraints on the model's coefficients.

**Usage**

```
lmc(y, X, start.v = NULL, lambda = 1, pen = "none", gamma = 1, a = 3.7)
```

**Arguments**

<code>y</code>	Response vector.
<code>X</code>	Design matrix.
<code>start.v</code>	Starting values.
<code>lambda</code>	Tuning parameter.
<code>pen</code>	Type of penalty. Choices are: none, ridge, lasso, alasso, scad.
<code>gamma</code>	Power parameter of adaptive lasso.
<code>a</code>	Scad parameter.

**Details**

Linear model fitting with positivity and sum-to-one constraints on the model's coefficients.

**Value**

The function returns an object of class `lmc`.

**Examples**

```
## Not run:

library(GJRM)

set.seed(1)

n    <- 1000
beta <- c(0.07, 0.08, 0.21, 0.12, 0.15, 0.17, 0.2)
l    <- length(beta)
X    <- matrix(runif(n*l), n, l)

y    <- X%*%beta + rnorm(n)

out <- lmc(y, X)
conv.check(out)

out1 <- lmc(y, X, start.v = beta)
conv.check(out1)

coef(out)          # estimated coefficients
round(out$c.coefficients, 3) # constrained coefficients
sum(out$c.coefficients)

round(out1$c.coefficients, 3)
sum(out1$c.coefficients)

# penalised estimation

out1 <- lmc(y, X, pen = "alasso", lambda = 0.02)
conv.check(out1)

coef(out1)
round(out1$c.coefficients, 3)
sum(out1$c.coefficients)

AIC(out, out1)
BIC(out, out1)

round(cbind(out$c.coefficients, out1$c.coefficients), 3)

# scad

n    <- 10000
beta <- c(0.2, 0, 0, 0.02, 0.01, 0.01, 0.01, 0.08, 0.21, 0.12, 0.15, 0.17, 0.02)
l    <- length(beta)
X    <- matrix(runif(n*l), n, l)

y    <- X%*%beta + rnorm(n)
```



```
out1 <- lmc(y, X, pen = "scad", lambda = 0.01)
conv.check(out1)

coef(out1)
sum(out1$c.coefficients)

round(cbind(beta, out1$c.coefficients), 2)

## End(Not run)
```

---

logLik.SemiParBIV	<i>Extract the log likelihood for a fitted copula model</i>
-------------------	---

---

### Description

It extracts the log-likelihood for a fitted gjrm model.

### Usage

```
## S3 method for class 'SemiParBIV'
logLik(object, ...)
```

### Arguments

object	A fitted gjrm object.
...	Un-used for this function.

### Details

Modification of the classic logLik which accounts for the estimated degrees of freedom used in gjrm. This function is provided so that information criteria work correctly by using the correct number of degrees of freedom.

### Value

Standard [logLik](#) object.

### Author(s)

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

### See Also

[AIC](#), [BIC](#)

---

marg.mv	<i>Marginal Mean/Variance</i>
---------	-------------------------------

---

## Description

Function `marg.mv` can be used to calculate marginal means/variances, with corresponding interval obtained using posterior simulation.

## Usage

```
marg.mv(x, eq, newdata, fun = "mean", n.sim = 100, prob.lev = 0.05, bin.model = NULL)
```

## Arguments

<code>x</code>	A fitted <code>marg.mv</code> object as produced by the respective fitting function.
<code>eq</code>	Number of equation of interest.
<code>newdata</code>	A data frame with one row, which must be provided.
<code>fun</code>	Either mean or variance.
<code>n.sim</code>	Number of simulated coefficient vectors from the posterior distribution of the estimated model parameters.
<code>prob.lev</code>	Overall probability of the left and right tails of the simulated distribution used for interval calculations.
<code>bin.model</code>	If a two part or hurdle model is used then this is the object of a binary regression model fitted using <code>gam()</code> from <code>mgcv</code> .

## Details

`marg.mv()` calculates the marginal mean or variance. Posterior simulation is used to obtain a confidence/credible interval.

## Value

<code>res</code>	It returns three values: lower confidence interval limit, estimated marginal mean or variance and upper interval limit.
<code>prob.lev</code>	Probability level used.
<code>sim.mv</code>	It returns a vector containing simulated values of the marginal mean or variance. This is used to calculate intervals.

## Author(s)

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

## See Also

[GJRM-package](#), [gjrm](#)

mb

*Nonparametric (worst-case and IV) Manski's bounds***Description**

mb can be used to calculate the (worst-case and IV) Manski's bounds and confidence interval covering the true effect of interest with a fixed probability.

**Usage**

```
mb(treat, outc, IV = NULL, model, B = 100, sig.lev = 0.05)
```

**Arguments**

treat	Binary treatment/selection variable.
outc	Binary outcome variable.
IV	An instrumental binary variable can be used if available.
model	Possible values are "B" (model with endogenous variable) and "BSS" (model with non-random sample selection).
B	Number of bootstrap replicates. This is used to obtain some components needed for confidence interval calculations.
sig.lev	Significance level.

**Details**

Based on Manski (1990), this function returns the nonparametric lower and upper (worst-case) Manski's bounds for the average treatment effect (ATE) when model = "B" or prevalence when model = "BSS". When an IV is employed the function returns IV Manski bounds.

For comparison, it also returns the estimated effect assuming random assignment (i.e., the treatment received or selection relies on the assumption of ignorable observed and unobserved selection). Note that this is equivalent to what provided by [ATE](#) or [prev](#) when type = "naive", and is different from what obtained by [ATE](#) or [prev](#) when type = "univariate" as observed confounders are accounted for and the assumption here is of ignorable unobserved selection.

A confidence interval covering the true ATE/prevalence with a fixed probability is also provided. This is based on the approach described in Imbens and Manski (2004). NOTE that this interval is typically very close (if not identical) to the lower and upper bounds.

The ATE can be at most 1 (or 100 in percentage) and the worst-case Manski's bounds have width 1. This means that 0 is always included within the possibilities of these bounds. Nevertheless, this may be useful to check whether the effect from a bivariate recursive model is included within the possibilities of the bounds.

When estimating a prevalence the worst-case Manski's bounds have width equal to the non-response probability, which provides a measure of the uncertainty about the prevalence caused by non-response. Again, this may be useful to check whether the prevalence from a bivariate non-random sample selection model is included within the possibilities of the bounds.

See [gjrm](#) for some examples.

**Value**

LB, UP	Lower and upper bounds for the true effect of interest.
CI	Confidence interval covering the true effect of interest with a fixed probability.
ate.ra	Estimated effect of interest assuming random assignment.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**References**

Manski C.F. (1990), Nonparametric Bounds on Treatment Effects. *American Economic Review, Papers and Proceedings*, 80(2), 319-323.

Imbens G.W. and Manski C.F. (2004), Confidence Intervals for Partially Identified Parameters. *Econometrica*, 72(6), 1845-1857.

**See Also**

[gjrm](#)

**Examples**

```
## see examples for gjrm
```

---

numgh

---

*Internal Function*


---

**Description**

This and other similar internal functions calculate numerical derivatives.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

---

OR	<i>Causal odds ratio of a binary/continuous treatment variable</i>
----	--

---

### Description

OR can be used to calculate the causal odds ratio of a binary/continuous treatment variable, with corresponding interval obtained using posterior simulation.

### Usage

```
OR(x, trt, trt.val = NULL, int.var = NULL, joint = TRUE, n.sim = 100, prob.lev = 0.05,
  length.out = NULL)
```

### Arguments

x	A fitted gjrm object.
trt	Name of the treatment variable.
trt.val	Numeric value for the treatment variable. This is only required when the endogenous variable is Gaussian.
int.var	A vector made up of the name of the variable interacted with trt, and a value for it. It can also be a list.
joint	If FALSE then the effect is obtained from the univariate model which neglects the presence of unobserved confounders. When TRUE, the effect is obtained from the simultaneous model which accounts for observed and unobserved confounders.
n.sim	Number of simulated coefficient vectors from the posterior distribution of the estimated model parameters. This is used when delta = FALSE. It may be increased if more precision is required.
prob.lev	Overall probability of the left and right tails of the OR distribution used for interval calculations.
length.out	Desired length of the sequence to be used when calculating the effect that a continuous treatment has on a binary outcome.

### Details

OR calculates the causal odds ratio for a binary/continuous Gaussian treatment. Posterior simulation is used to obtain a confidence/credible interval.

### Value

prob.lev	Probability level used.
sim.OR	It returns a vector containing simulated values of the average OR. This is used to calculate intervals.
Ratios	For the case of continuous endogenous treatment and binary outcome, it returns a matrix made up of three columns containing the odds ratios for each incremental value in the endogenous variable and respective intervals.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**See Also**

[GJRM-package](#), [gjrm](#)

---

 PE

---

*Partial effect from a binary bivariate model*


---

**Description**

PE can be used to calculate the sample treatment effect from a binary bivariate model, with corresponding interval obtained using posterior simulation.

**Usage**

```
PE(x1, idx, n.sim = 100, prob.lev = 0.05,
  plot = FALSE,
  main = "Histogram of Simulated Average Effects",
  xlab = "Simulated Average Effects", ...)
```

**Arguments**

<code>x1</code>	A fitted <code>gjrm</code> object.
<code>idx</code>	This is useful to pick a particular individual and must be provided.
<code>n.sim</code>	Number of simulated coefficient vectors from the posterior distribution of the estimated model parameters. This is used when <code>delta = FALSE</code> . It may be increased if more precision is required.
<code>prob.lev</code>	Overall probability of the left and right tails of the AT distribution used for interval calculations.
<code>plot</code>	If TRUE then a plot of the histogram and kernel density estimate of the simulated average effects is produced.
<code>main</code>	Title for the plot.
<code>xlab</code>	Title for the x axis.
<code>...</code>	Other graphics parameters to pass on to plotting commands. These are used only when <code>hd.plot = TRUE</code> .

**Details**

PE measures the sample average effect from a binary bivariate model when a binary response (associated with a continuous outcome) takes values 0 and 1. Posterior simulation is used to obtain a confidence/credible interval.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**See Also**

[GJRM-package, gjrm](#)

---

 pen

---

*Internal Function*


---

**Description**

It provides an overall penalty matrix in a format suitable for estimation conditional on smoothing parameters.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

---

 plot.SemiParBIV

---

*Plotting function*


---

**Description**

It takes a fitted `gjrm` object produced by `gjrm()` and plots the estimated smooth functions on the scale of the linear predictors. This function is a wrapper of `plot.gam()` in `mgcv`. Please see the documentation of `plot.gam()` for full details.

**Usage**

```
## S3 method for class 'SemiParBIV'
plot(x, eq, ...)
```

**Arguments**

<code>x</code>	A fitted <code>gjrm</code> object.
<code>eq</code>	The equation from which smooth terms should be considered for printing.
<code>...</code>	Other graphics parameters to pass on to plotting commands, as described for <code>plot.gam()</code> in <code>mgcv</code> .

**Details**

This function produces plots showing the smooth terms of a fitted semiparametric bivariate probit model. In the case of 1-D smooths, the x axis of each plot is labelled using the name of the regressor, while the y axis is labelled as `s(regr, edf)` where `regr` is the regressor's name, and `edf` the effective degrees of freedom of the smooth. For 2-D smooths, perspective plots are produced with the x axes labelled with the first and second variable names and the y axis is labelled as `s(var1, var2, edf)`, which indicates the variables of which the term is a function and the `edf` for the term.

If `seWithMean = TRUE` then the intervals include the uncertainty about the overall mean. Note that the smooths are still shown centred. The theoretical arguments and simulation study of Marra and Wood (2012) suggest that `seWithMean = TRUE` results in intervals with close to nominal frequentist coverage probabilities.

**Value**

The function generates plots.

**WARNING**

The function can not deal with smooths of more than 2 variables.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**References**

Marra G. and Wood S.N. (2012), Coverage Properties of Confidence Intervals for Generalized Additive Model Components. *Scandinavian Journal of Statistics*, 39(1), 53-74.

**See Also**

[gjrm](#)

---

polys.map

*Geographic map with regions defined as polygons*

---

**Description**

This function produces a map with geographic regions defined by polygons. It is essentially the same function as `polys.plot()` in `mgcv` but with added arguments `zlim` and `rev.col` and a wider set of choices for `scheme`.

**Usage**

```
polys.map(lm, z, scheme = "gray", lab = "", zlim, rev.col = FALSE, ...)
```



**Arguments**

lm	Named list of matrices where each matrix has two columns. The matrix rows each define the vertex of a boundary polygon.
z	A vector of values associated with each area (item) of lm.
scheme	Possible values are "heat", "terrain", "topo", "cm" and "gray", indicating how to fill the polygons in accordance with the value of z.
lab	label for plot.
zlim	If missing then the range of z will be chosen using pretty(z) otherwise the range provided will be used.
rev.col	If TRUE then coloring scheme is reversed.
...	other arguments to pass to plot.

**Details**

See help file of polys.plot in mgcv.

**Value**

It produces a plot.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

---

polys.setup

*Set up geographic polygons*


---

**Description**

This function creates geographic polygons in a format suitable for smoothing.

**Usage**

```
polys.setup(object)
```

**Arguments**

object	An RDS file object as extracted from <a href="http://www.gadm.org">http://www.gadm.org</a> .
--------	--

**Value**

It produces a list with polygons (polys), and various names (names0, names1 - first level of aggregation, names2 - second level of aggregation).

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

Thanks to Guy Harling for suggesting the implementation of this function.

**Examples**

```
?hiv
```

---

pred.gp

*Function to predict quantiles from GP and DGP distributions*

---

**Description**

It takes a fitted `gamlss` object produced by `gamlss()` and produces the desired quantities and respective intervals.

**Usage**

```
pred.gp(x, p = 0.5, newdata, n.sim = 100, prob.lev = 0.05)
```

**Arguments**

<code>x</code>	A fitted <code>gamlss</code> object.
<code>p</code>	Value of $p$ .
<code>newdata</code>	A data frame or list containing the values of the model covariates at which predictions are required. If not provided then predictions corresponding to the original data are returned. When <code>newdata</code> is provided, it should contain all the variables needed for prediction.
<code>n.sim</code>	The number of simulated coefficient vectors from the posterior distribution of the estimated model parameters. This is used to calculate intervals. It may be increased if more precision is required.
<code>prob.lev</code>	Probability of the left and right tails of the posterior distribution used for interval calculations.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**See Also**

[gamlss](#)

---

predict.CopulaCLM	<i>Prediction function</i>
-------------------	----------------------------

---

**Description**

It takes a fitted `gjrm` object for the ordinal-continuous case and, for each equation, produces predictions for a new set of values of the model covariates or the original values used for the model fit. Standard errors of predictions can be produced and are based on the posterior distribution of the model coefficients.

**Usage**

```
## S3 method for class 'CopulaCLM'  
predict(object, eq, type = "link", ...)
```

**Arguments**

<code>object</code>	A fitted <code>gjrm</code> object.
<code>eq</code>	The equation to be considered for prediction.
<code>type</code>	Type of prediction.
<code>...</code>	Other arguments as in <code>predict.gam()</code> in <code>mgcv</code> .

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**See Also**

[gjrm](#)

---

predict.SemiParBIV	<i>Prediction function</i>
--------------------	----------------------------

---

**Description**

It takes a fitted `gjrm` object and, for each equation, produces predictions for a new set of values of the model covariates or the original values used for the model fit. Standard errors of predictions can be produced and are based on the posterior distribution of the model coefficients. This function is a wrapper for `predict.gam()` in `mgcv`. Please see the documentation of `predict.gam()` for full details.

**Usage**

```
## S3 method for class 'SemiParBIV'
predict(object, eq, ...)
```

**Arguments**

object	A fitted <code>gjrm</code> object.
eq	The equation to be considered for prediction.
...	Other arguments as in <code>predict.gam()</code> in <code>mgcv</code> .

**WARNINGS**

When `type = "response"` this function will provide prediction assuming that the identity link function is adopted. This means that `type = "link"` and `type = "response"` will produce the same results, which for some distributions is fine. This is because, for internal reasons, the model object used always assumes an identity link. There are other functions in the package which will produce predictions for the response correctly and we are currently working on extending them to all models in the package. For all the other `type` values the function will produce the correct results.

When predicting based on a new data set, this function can not return correct predictions for models based on a copula value of "C0C90", "C0C270", "C180C90", "C180C270", "G0G90", "G0G270", "G180G90", "G180G270", "J0J90", "J0J270", "J180J90" or "J180J270".

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**See Also**

[gjrm](#)

---

prev

*Estimated overall prevalence from a sample selection model*

---

**Description**

`prev` can be used to calculate the overall estimated prevalence from a sample selection model with binary outcome, with corresponding interval obtained using posterior simulation.

**Usage**

```
prev(x, sw = NULL, joint = TRUE, n.sim = 100, prob.lev = 0.05)
```

**Arguments**

x	A fitted gjrm object.
sw	Survey weights.
joint	If FALSE then the prevalence is obtained from the univariate model which neglects the presence of unobserved confounders. When TRUE, the prevalence is obtained from the simultaneous model which accounts for observed and unobserved confounders.
n.sim	Number of simulated coefficient vectors from the posterior distribution of the estimated model parameters. It may be increased if more precision is required.
prob.lev	Overall probability of the left and right tails of the prevalence distribution used for interval calculations.

**Details**

prev estimates the overall prevalence of a disease (e.g., HIV) when there are missing values that are not at random. An interval for the estimated prevalence can be obtained using posterior simulation.

**Value**

res	It returns three values: lower confidence interval limit, estimated prevalence and upper confidence interval limit.
prob.lev	Probability level used.
sim.prev	Vector containing simulated values of the prevalence. This is used to calculate an interval.

**Author(s)**

Authors: Giampiero Marra, Rosalba Radice, Guy Harling, Mark E McGovern

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**References**

Marra G., Radice R., Barnighausen T., Wood S.N. and McGovern M.E. (2017), A Simultaneous Equation Approach to Estimating HIV Prevalence with Non-Ignorable Missing Responses. *Journal of the American Statistical Association*, 112(518), 484-496.

**See Also**

[GJRM-package](#), [gjrm](#)

---

print.ATE	<i>Print an ATE object</i>
-----------	----------------------------

---

**Description**

The print method for an ATE object.

**Usage**

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

**Arguments**

x	ATE object produced by ATE().
...	Other arguments.

**Details**

print.ATE prints the lower confidence interval limit, estimated ATE and upper confidence interval limit.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**See Also**

[ATE](#)

---

print.cond.mv	<i>Print a cond.mv object</i>
---------------	-------------------------------

---

**Description**

The print method for a cond.mv object.

**Usage**

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

**Arguments**

x	cond.mv object produced by cond.mv().
...	Other arguments.

**Details**

print.cond.mv prints the lower confidence interval limit, estimated conditonal mean or variance and upper confidence interval limit.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**See Also**

[cond.mv](#)

---

print.copulaSampleSel *Print a copulaSampleSel object*

---

**Description**

The print method for a copulaSampleSel object.

**Usage**

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

**Arguments**

x	copulaSampleSel object.
...	Other arguments.

**Details**

It prints out the family, model equations, total number of observations, estimated association coefficient, etc for the penalized or unpenalized model.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

---

print.gamlss	<i>Print a gamlss object</i>
--------------	------------------------------

---

**Description**

The print method for a gamlss object.

**Usage**

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

**Arguments**

x	gamlss object produced by gamlss().
...	Other arguments.

**Details**

print.gamlss prints out the family, model equations, total number of observations, etc for the penalized or unpenalized model.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**See Also**

[gamlss](#)

---

print.gjrm	<i>Print a gjrm object</i>
------------	----------------------------

---

**Description**

The print method for a gjrm object.

**Usage**

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



**Arguments**

x                    gjrm object produced by gjrm().  
 ...                Other arguments.

**Details**

print.gjrm prints out the family, model equations, total number of observations, estimated association coefficient, etc for the penalized or unpenalized model.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**See Also**

[gjrm](#)

---

print.marg.mv	<i>Print a marg.mv object</i>
---------------	-------------------------------

---

**Description**

The print method for a marg.mv object.

**Usage**

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

**Arguments**

x                    marg.mv object produced by marg.mv().  
 ...                Other arguments.

**Details**

print.marg.mv prints the lower confidence interval limit, estimated conditonal mean or variance and upper confidence interval limit.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**See Also**

[marg.mv](#)

---

print.mb	<i>Print an mb object</i>
----------	---------------------------

---

**Description**

The print method for an mb object.

**Usage**

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

**Arguments**

x	mb object produced by mb().
...	Other arguments.

**Details**

print.mb prints the lower and upper bounds, confidence interval, and effect assuming random assignment.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**See Also**

[mb](#)

---

print.OR	<i>Print an OR object</i>
----------	---------------------------

---

**Description**

The print method for an OR object.

**Usage**

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

**Arguments**

x                    OR object produced by OR().  
...                  Other arguments.

**Details**

print.OR prints the lower confidence interval limit, estimated OR and upper confidence interval limit.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**See Also**

[OR](#)

---

print.PE	<i>Print an PE object</i>
----------	---------------------------

---

**Description**

The print method for an PE object.

**Usage**

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

**Arguments**

x                    PE object produced by PE().  
...                  Other arguments.

**Details**

print.PE prints the lower confidence interval limit, estimated PE and upper confidence interval limit.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**See Also**

[PE](#)

---

print.prev	<i>Print an prev object</i>
------------	-----------------------------

---

**Description**

The print method for an prev object.

**Usage**

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

**Arguments**

x	prev object produced by prev().
...	Other arguments.

**Details**

print.prev prints the lower interval limit, estimated prevalence and upper interval limit.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**See Also**

[prev](#)

---

print.RR	<i>Print an RR object</i>
----------	---------------------------

---

**Description**

The print method for an RR object.

**Usage**

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

**Arguments**

x                   RR object produced by `RR()`.  
...                 Other arguments.

**Details**

`print.RR` prints the lower confidence interval limit, estimated RR and upper confidence interval limit.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**See Also**

[RR](#)

---

print.SATE	<i>Print an SATE object</i>
------------	-----------------------------

---

**Description**

The print method for a SATE object.

**Usage**

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

**Arguments**

x                   SATE object produced by `SATE()`.  
...                 Other arguments.

**Details**

`print.SATE` prints the lower confidence interval limit, estimated SATE and upper confidence interval limit.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**See Also**

[SATE](#)

---

<code>print.SemiParBIV</code>	<i>Print a SemiParBIV object</i>
-------------------------------	----------------------------------

---

**Description**

The print method for a SemiParBIV object.

**Usage**

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

**Arguments**

<code>x</code>	SemiParBIV object.
<code>...</code>	Other arguments.

**Details**

It prints out the family, model equations, total number of observations, estimated association coefficient and total effective degrees of freedom for the penalized or unpenalized model.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

---

<code>print.SemiParROY</code>	<i>Print a SemiParROY object</i>
-------------------------------	----------------------------------

---

**Description**

The print method for a SemiParROY object.

**Usage**

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

**Arguments**

x	SemiParROY object.
...	Other arguments.

**Details**

It prints out the family, model equations, total number of observations, estimated association coefficient, etc for the penalized or unpenalized model.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

---

print.SemiParTRIV	<i>Print a SemiParTRIV object</i>
-------------------	-----------------------------------

---

**Description**

The print method for a SemiParTRIV object.

**Usage**

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

**Arguments**

x	SemiParTRIV object.
...	Other arguments.

**Details**

It prints out the family, model equations, total number of observations, estimated association coefficient and total effective degrees of freedom for the penalized or unpenalized model.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

---

probm	<i>Internal Function</i>
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---

**Description**

Internal fitting function.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

---

regH	<i>Internal Function</i>
------	--------------------------

---

**Description**

It applies one of two regularisations on the information matrix if desired. These are based on the Cholesky and eigen decompositions.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

---

res.check	<i>Diagnostic plots for discrete/continuous response margins</i>
-----------	--

---

**Description**

It produces diagnostic plots based on (randomised) quantile residuals.

**Usage**

```
res.check(x, intervals = FALSE, n.sim = 100, prob.lev = 0.05)
```

**Arguments**

x	A fitted gjrm object.
intervals	If TRUE then intervals for the qqplots are produced.
n.sim	Number of replicate datasets used to simulate quantiles of the residual distribution.
prob.lev	Overall probability of the left and right tails of the probabilities' distributions used for interval calculations.



**Details**

If the model fits the response well then the plots should look normally distributed. When fitting models with discrete and/or continuous margins, four plots will be produced. In this case, the arguments `main2` and `xlab2` come into play and allow for different labelling across the plots.

**Value**

<code>qr</code>	It returns the (randomised) quantile residuals for the continuous or discrete margin when fitting a model that involves a binary response.
<code>qr1</code>	As above but for first equation (this applies when fitting models with continuous/discrete margins).
<code>qr2</code>	As above but for second equation.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**See Also**

[gjrm](#)

---

<code>resp.check</code>	<i>Diagnostic plot for a variable</i>
-------------------------	---------------------------------------

---

**Description**

It produces a normal Q-Q plot for the (randomised) normalised quantile response. It also provides the log-likelihood for AIC calculation, for instance. It is also used for internal purposes.

**Usage**

```
resp.check(y, margin = "N", print.par = FALSE, plots = TRUE,
           loglik = FALSE, os = FALSE, i.f = FALSE,
           min.dn = 1e-40, min.pr = 1e-16, max.pr = 0.999999,
           left.trunc = 0)
```

**Arguments**

<code>y</code>	Response.
<code>margin</code>	The distributions allowed are: normal ("N"), log-normal ("LN"), generalised Pareto ("GP"), discrete generalised Pareto ("DGP"), Gumbel ("GU"), reverse Gumbel ("rGU"), logistic ("LO"), Weibull ("WEI"), inverse Gaussian ("iG"), gamma ("GA"), Dagum ("DAGUM"), Singh-Maddala ("SM"), beta ("BE"), Fisk ("FISK"), Poisson ("P"), zero truncated Poisson ("ZTP"), negative binomial - type I ("NBI"), negative binomial - type II ("NBII"), Poisson inverse Gaussian ("PIG").

<code>print.par</code>	If TRUE then the estimated parameters used to construct the plot are returned.
<code>plots</code>	If FALSE then no plot is produced and only parameter estimates returned.
<code>loglik</code>	If TRUE then it returns the logLik.
<code>os</code>	If TRUE then the estimated parameters are returned on the original scale.
<code>i.f</code>	Internal fitting option. This is not for user purposes.
<code>min.dn, min.pr, max.pr</code>	Allowed minimum and maximum for estimated probabilities and densities for parameter estimation.
<code>left.trunc</code>	Value of truncation at left. Currently done for count distributions only.

### Details

Prior to fitting a model with discrete and/or continuous margins, the distributions for the outcome variables may be chosen by checking the normalised quantile responses. These will provide a rough guide to the adequacy of the chosen distribution. The latter are defined as the quantile standard normal function of the cumulative distribution function of the response with scale and location estimated by MLE. These should behave approximately as normally distributed variables (even though the original observations are not). Therefore, a normal Q-Q plot is appropriate here.

If `loglik = TRUE` then this function also provides the log-likelihood for AIC calculation, for instance.

### Author(s)

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

### See Also

[gjrm](#)

---

rMVN

*Multivariate Normal Variates*

---

### Description

This function simply generates random multivariate normal variates.

### Author(s)

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

---

rob.const	<i>Bootstrap procedure to help select the robust constant in a GAMLSS</i>
-----------	---

---

## Description

It helps finding the robust constant for a GAMLSS.

## Usage

```
rob.const(x, B = 100, left.trunc = 0)
```

## Arguments

x	A fitted gjrm object.
B	Number of bootstrap replicates.
left.trunc	If a truncated count distribution is employed then this is the left truncation point.

## Details

It helps finding the robust constant for a GAMLSS based on the mean or median.

## Value

rc	Robust constant used in fitting.
sw	Sum of weights for each bootstrap replicate.
m1	Mean.
m2	Median.

## Author(s)

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

## See Also

[gamlss](#)

---

`rob.int`*Tool for tuning bounds of integral in robust models*

---

**Description**

Tool for tuning bounds of integral in robust GAMLSS with continuous distribution.

**Usage**

```
rob.int(x, rc, l.grid = 1000, tol = 1e-4, var.range = NULL)
```

**Arguments**

<code>x</code>	A fitted <code>gjrm</code> object, typically from a non-robust fit.
<code>rc</code>	Robust tuning constant.
<code>l.grid</code>	Length of grid.
<code>tol</code>	Tolerance
<code>var.range</code>	Range of values, min and max, to use in calculations.

**Details**

Tool for tuning bounds of integral in robust GAMLSS.

**Value**

`lB`, `uB` Lower and upper bounds.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**See Also**

[gamlss](#)

---

RR	<i>Causal risk ratio of a binary/continuous treatment variable</i>
----	--

---

## Description

RR can be used to calculate the causal risk ratio of a binary/continuous treatment variable, with corresponding interval obtained using posterior simulation.

## Usage

```
RR(x, trt, trt.val = NULL, int.var = NULL, joint = TRUE, n.sim = 100, prob.lev = 0.05,
   length.out = NULL)
```

## Arguments

<code>x</code>	A fitted <code>gjrm</code> object.
<code>trt</code>	Name of the treatment variable.
<code>trt.val</code>	Numeric value for the treatment variable. This is only required when the endogenous variable is Gaussian.
<code>int.var</code>	A vector made up of the name of the variable interacted with <code>trt</code> , and a value for it. It can also be a list.
<code>joint</code>	If <code>FALSE</code> then the effect is obtained from the univariate model which neglects the presence of unobserved confounders. When <code>TRUE</code> , the effect is obtained from the simultaneous model which accounts for observed and unobserved confounders.
<code>n.sim</code>	Number of simulated coefficient vectors from the posterior distribution of the estimated model parameters. This is used when <code>delta = FALSE</code> . It may be increased if more precision is required.
<code>prob.lev</code>	Overall probability of the left and right tails of the RR distribution used for interval calculations.
<code>length.out</code>	Desired length of the sequence to be used when calculating the effect that a continuous treatment has on a binary outcome.

## Details

RR calculates the causal risk ratio of the probabilities of positive outcome under treatment (the binary predictor or treatment assumes value 1) and under control (the binary treatment assumes value 0). Posterior simulation is used to obtain a confidence/credible interval.

RR works also for the case of continuous Gaussian endogenous treatment variable.

**Value**

<code>prob.lev</code>	Probability level used.
<code>sim.RR</code>	It returns a vector containing simulated values of the average RR. This is used to calculate intervals.
<code>Ratios</code>	For the case of continuous endogenous variable and binary outcome, it returns a matrix made up of three columns containing the risk ratios for each incremental value in the endogenous variable and respective intervals.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**See Also**

[GJRM-package](#), [gjrm](#)

---

S.m

*Internal Function*

---

**Description**

It provides penalty matrices in a format suitable for automatic multiple smoothing parameter estimation.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

---

SATE

*Survival Average Treatment Effects of a binary treatment variable*

---

**Description**

SATE can be used to calculate the survival treatment effects of a binary treatment variable, with corresponding interval obtained using posterior simulation.

**Usage**

```
SATE(x, trt, surv.t = NULL, int.var = NULL, joint = TRUE,
      n.sim = 100, prob.lev = 0.05, ls = 10, plot.type = "none", ...)
```

**Arguments**

<code>x</code>	A fitted <code>gjrm</code> object as produced by the respective fitting function.
<code>trt</code>	Name of the treatment variable.
<code>surv.t</code>	Numeric value or vector for time. If not provided, the function will calculate the SATE for each time point of a grid of length <code>ls</code> , calculated from the observed outcome.
<code>int.var</code>	A vector made up of the name of the variable interacted with <code>trt</code> , and a value for it. It can also be a list.
<code>joint</code>	If FALSE then the effects are obtained from the univariate model which neglects the presence of unobserved confounders. When TRUE, the effects are obtained from the simultaneous model which accounts for observed and unobserved confounders.
<code>n.sim</code>	Number of simulated coefficient vectors from the posterior distribution of the estimated model parameters. It may be increased if more precision is required.
<code>prob.lev</code>	Overall probability of the left and right tails of the SAT distribution used for interval calculations.
<code>ls</code>	Length of sequence to use for time variable. Only used when <code>surv.t = NULL</code> .
<code>plot.type</code>	Values allowed are: "none", "survival" (for survival plots under treatment = 0 (grey lines) and treatment = 1 (black lines)) and "sate" (SATE evaluated at several time points).
<code>...</code>	Other graphics parameters to pass on to plotting commands.

**Details**

SATE measures the average survival difference in outcomes under treatment (the binary predictor or treatment assumes value 1) and under control (the binary treatment assumes value 0). Posterior simulation is used to obtain a confidence/credible interval.

**Value**

<code>res</code>	It returns three values: lower interval limit(s), estimated SATE(s) and upper interval limit(s).
<code>prob.lev</code>	Probability level used.
<code>sim.SATE</code>	It returns a vector containing simulated values of the survival average treatment effect for the case in which a specific time is chosen. This is used to calculate intervals.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**See Also**

[GJRM-package](#), [gjrm](#)

---

SemiParBIV	<i>Internal fitting function</i>
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---

**Description**

Internal fitting set up function.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

---

SemiParBIV.fit	<i>Internal Function</i>
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---

**Description**

Wrapper of core algorithm.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

---

SemiParBIV.fit.post	<i>Internal Function</i>
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---

**Description**

This and other similar internal functions calculate useful post estimation quantities.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

---

SemiParROY	<i>Internal fitting function</i>
------------	----------------------------------

---

**Description**

Internal fitting set up function.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>



SemiParTRIV

*Internal fitting function***Description**

Internal fitting set up function.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

summary.copulaSampleSel

*copulaSampleSel summary***Description**

It takes a fitted copulaSampleSel object and produces some summaries from it.

**Usage**

```
## S3 method for class 'copulaSampleSel'
summary(object, n.sim = 100, prob.lev = 0.05, ...)

## S3 method for class 'summary.copulaSampleSel'
print(x, digits = max(3, getOption("digits") - 3),
      signif.stars = getOption("show.signif.stars"), ...)
```

**Arguments**

object	A fitted copulaSampleSel object.
x	summary.copulaSampleSel object produced by summary.copulaSampleSel().
n.sim	The number of simulated coefficient vectors from the posterior distribution of the estimated model parameters. This is used to calculate intervals for the association parameter, dispersion coefficient, for instance It may be increased if more precision is required.
prob.lev	Probability of the left and right tails of the posterior distribution used for interval calculations.
digits	Number of digits printed in output.
signif.stars	By default significance stars are printed alongside output.
...	Other arguments.

**Details**

print.summary.copulaSampleSel prints model term summaries.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**Examples**

```
## see examples for gjrm
```

---

summary.gamlss	<i>gamlss summary</i>
----------------	-----------------------

---

**Description**

It takes a fitted gamlss object and produces some summaries from it.

**Usage**

```
## S3 method for class 'gamlss'
summary(object, n.sim = 100, prob.lev = 0.05, ...)

## S3 method for class 'summary.gamlss'
print(x, digits = max(3, getOption("digits") - 3),
      signif.stars = getOption("show.signif.stars"), ...)
```

**Arguments**

object	A fitted gamlss object.
x	summary.gamlss object produced by summary.gamlss().
n.sim	The number of simulated coefficient vectors from the posterior distribution of the estimated model parameters. This is used to calculate intervals for various parameters. It may be increased if more precision is required.
prob.lev	Probability of the left and right tails of the posterior distribution used for interval calculations.
digits	Number of digits printed in output.
signif.stars	By default significance stars are printed alongside output.
...	Other arguments.

**Details**

print.summary.gamlss prints model term summaries.

**Value**

tableP1	Table containing parametric estimates, their standard errors, z-values and p-values for equation 1.
tableP2, tableP3	As above but for equations 2 and 3 if present.
tableNP1	Table of nonparametric summaries for each smooth component including effective degrees of freedom, estimated rank, approximate Wald statistic for testing the null hypothesis that the smooth term is zero and corresponding p-value, for equation 1.
tableNP2, tableNP3	As above but for equations 2 and 3.
n	Sample size.
sigma, nu	Estimated distribution specific parameters.
formula1, formula2, formula3	Formulas used for the model equations.
l.sp1, l.sp2, l.sp3	Number of smooth components in model equation.
t.edf	Total degrees of freedom of the estimated bivariate model.
CI.sig, CI.nu	Intervals for distribution specific parameters.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**Examples**

```
## see examples for gamlss
```

---

summary.gjrm	<i>gjrm summary</i>
--------------	---------------------

---

**Description**

It takes a fitted gjrm object and produces some summaries from it.

**Usage**

```
## S3 method for class 'gjrm'
summary(object, n.sim = 100, prob.lev = 0.05, ...)

## S3 method for class 'summary.gjrm'
print(x, digits = max(3, getOption("digits") - 3),
      signif.stars = getOption("show.signif.stars"), ...)
```

**Arguments**

<code>object</code>	A fitted <code>gjrm</code> object.
<code>x</code>	<code>summary.gjrm</code> object produced by <code>summary.gjrm()</code> .
<code>n.sim</code>	The number of simulated coefficient vectors from the posterior distribution of the estimated model parameters. This is used to calculate intervals for the association parameter, dispersion coefficient etc. It may be increased if more precision is required.
<code>prob.lev</code>	Probability of the left and right tails of the posterior distribution used for interval calculations.
<code>digits</code>	Number of digits printed in output.
<code>signif.stars</code>	By default significance stars are printed alongside output.
<code>...</code>	Other arguments.

**Details**

`print.summary.gjrm` prints model term summaries.

**Value**

<code>tableP1</code>	Table containing parametric estimates, their standard errors, z-values and p-values for equation 1.
<code>tableP2, tableP3, ...</code>	As above but for equation 2 and equations 3 and 4 if present.
<code>tableNP1</code>	Table of nonparametric summaries for each smooth component including effective degrees of freedom, estimated rank, approximate Wald statistic for testing the null hypothesis that the smooth term is zero and corresponding p-value, for equation 1.
<code>tableNP2, tableNP3, ...</code>	As above but for equation 2 and equations 3 and 4 if present.
<code>n</code>	Sample size.
<code>theta</code>	Estimated dependence parameter linking the two equations.
<code>sigma1, sigma2</code>	Estimated distribution specific parameters for equations 1 and 2.
<code>nu1, nu2</code>	Estimated distribution specific parameters for equations 1 and 2.
<code>formula1, formula2, formula3, ...</code>	Formulas used for the model equations.
<code>l.sp1, l.sp2, l.sp3, ...</code>	Number of smooth components in model equations.
<code>t.edf</code>	Total degrees of freedom of the estimated bivariate model.
<code>CItheta</code>	Interval(s) for $\theta$ .
<code>CSig1, CSig2, CInu1, CInu2</code>	Intervals for distribution specific parameters

**WARNINGS**

Note that the Kendall's tau (and related interval), as implemented here, is a valid measure of dependence for continuous margins and it will only provide a crude indication of dependence in other cases.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

---

summary.SemiParBIV	<i>SemiParBIV summary</i>
--------------------	---------------------------

---

**Description**

It takes a fitted SemiParBIV object and produces some summaries from it.

**Usage**

```
## S3 method for class 'SemiParBIV'
summary(object, n.sim = 100, prob.lev = 0.05, gm = FALSE, ...)

## S3 method for class 'summary.SemiParBIV'
print(x, digits = max(3, getOption("digits") - 3),
      signif.stars = getOption("show.signif.stars"), ...)
```

**Arguments**

object	A fitted SemiParBIV object.
x	summary.SemiParBIV object produced by summary.SemiParBIV().
n.sim	The number of simulated coefficient vectors from the posterior distribution of the estimated model parameters. This is used to calculate intervals for the association parameter, dispersion coefficient and other measures (e.g., gamma measure). It may be increased if more precision is required.
prob.lev	Probability of the left and right tails of the posterior distribution used for interval calculations.
gm	If TRUE then intervals for the gamma measure and odds ratio are calculated.
digits	Number of digits printed in output.
signif.stars	By default significance stars are printed alongside output.
...	Other arguments.

## Details

Using some low level functions in `mgcv`, based on the results of Marra and Wood (2012), ‘Bayesian p-values’ are returned for the smooth terms. These have better frequentist performance than their frequentist counterpart. See the help file of `summary.gam` in `mgcv` for further details. Covariate selection can also be achieved using a single penalty shrinkage approach as shown in Marra and Wood (2011).

Posterior simulation is used to obtain intervals of nonlinear functions of parameters, such as the association and dispersion parameters as well as the odds ratio and gamma measure discussed by Tajar et al. (2001) if `gm = TRUE`.

`print.summary.SemiParBIV` prints model term summaries.

## Value

<code>tableP1</code>	Table containing parametric estimates, their standard errors, z-values and p-values for equation 1.
<code>tableP2, tableP3, ...</code>	As above but for equation 2 and equations 3 and 4 if present.
<code>tableNP1</code>	Table of nonparametric summaries for each smooth component including effective degrees of freedom, estimated rank, approximate Wald statistic for testing the null hypothesis that the smooth term is zero and corresponding p-value, for equation 1.
<code>tableNP2, tableNP3, ...</code>	As above but for equation 2 and equations 3 and 4 if present.
<code>n</code>	Sample size.
<code>theta</code>	Estimated dependence parameter linking the two equations.
<code>formula1, formula2, formula3, ...</code>	Formulas used for the model equations.
<code>l.sp1, l.sp2, l.sp3, ...</code>	Number of smooth components in model equations.
<code>t.edf</code>	Total degrees of freedom of the estimated bivariate model.
<code>CItheta</code>	Interval(s) for $\theta$ .
<code>n.sel</code>	Number of selected observations in the sample selection case.
<code>OR, CIor</code>	Odds ratio and related CI. The odds ratio is a measure of association between binary random variables and is defined as $p_{00}p_{11}/p_{10}p_{01}$ . In the case of independence this ratio is equal to 1. It can take values in the range $(-\infty, \infty)$ and it does not depend on the marginal probabilities (Tajar et al., 2001). Interval is calculated using posterior simulation.
<code>GM, CIgm</code>	Gamma measure and related CI. This measure of association was proposed by Goodman and Kruskal (1954). It is defined as $(OR - 1)/(OR + 1)$ , can take values in the range $(-1, 1)$ and does not depend on the marginal probabilities. Interval is calculated using posterior simulation.

**WARNINGS**

Note that the Kendall's tau (and related interval), as implemented here, is a valid measure of dependence for continuous margins and it will only provide a crude indication of dependence in other cases.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**References**

Marra G. and Wood S.N. (2011), Practical Variable Selection for Generalized Additive Models. *Computational Statistics and Data Analysis*, 55(7), 2372-2387.

Marra G. and Wood S.N. (2012), Coverage Properties of Confidence Intervals for Generalized Additive Model Components. *Scandinavian Journal of Statistics*, 39(1), 53-74.

Tajar M., Denuit M. and Lambert P. (2001), Copula-Type Representation for Random Couples with Bernoulli Margins. Discussion Paper 0118, Universite Catholique De Louvain.

**See Also**

[ATE](#), [prev](#)

---

summary.SemiParROY	<i>SemiParROY summary</i>
--------------------	---------------------------

---

**Description**

It takes a fitted SemiParROY object and produces some summaries from it.

**Usage**

```
## S3 method for class 'SemiParROY'
summary(object, n.sim = 100, prob.lev = 0.05, ...)

## S3 method for class 'summary.SemiParROY'
print(x, digits = max(3, getOption("digits") - 3),
      signif.stars = getOption("show.signif.stars"), ...)
```

**Arguments**

object	A fitted SemiParROY object.
x	summary.SemiParROY object produced by summary.SemiParROY().
n.sim	The number of simulated coefficient vectors from the posterior distribution of the estimated model parameters. This is used to calculate intervals for the association parameter, dispersion coefficient, for instance It may be increased if more precision is required.

prob.lev	Probability of the left and right tails of the posterior distribution used for interval calculations.
digits	Number of digits printed in output.
signif.stars	By default significance stars are printed alongside output.
...	Other arguments.

### Details

print.summary.SemiParROY prints model term summaries.

### Author(s)

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

### Examples

```
## see examples for gjrm
```

---

```
summary.SemiParTRIV    SemiParTRIV summary
```

---

### Description

It takes a fitted SemiParTRIV object and produces some summaries from it.

### Usage

```
## S3 method for class 'SemiParTRIV'
summary(object, n.sim = 100, prob.lev = 0.05, ...)

## S3 method for class 'summary.SemiParTRIV'
print(x, digits = max(3, getOption("digits") - 3),
      signif.stars = getOption("show.signif.stars"), ...)
```

### Arguments

object	A fitted SemiParTRIV object.
x	summary.SemiParTRIV object produced by summary.SemiParTRIV().
n.sim	The number of simulated coefficient vectors from the posterior distribution of the estimated model parameters. This is used to calculate intervals for the association parameter and other measures. It may be increased if more precision is required.
prob.lev	Probability of the left and right tails of the posterior distribution used for interval calculations.
digits	Number of digits printed in output.
signif.stars	By default significance stars are printed alongside output.
...	Other arguments.



**Details**

```
print.summary.SemiParTRIV prints model term summaries.
```

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

**Examples**

```
## see examples for gjrm
```

---

TRIapprox

*Internal Function*

---

**Description**

It approximates the trivariate normal integral.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

---

triprobGhs

*Internal Function*

---

**Description**

It provides score and Hessian for trivariate binary models.

**Author(s)**

Author: Panagioti Filippou

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

---

 vuong.test

*Vuong test*


---

### Description

The Vuong test is likelihood-ratio-based tests that can be used for choosing between two non-nested models.

### Usage

```
vuong.test(obj1, obj2, sig.lev = 0.05)
```

### Arguments

obj1, obj2	Objects of the two fitted bivariate non-nested models.
sig.lev	Significance level used for testing.

### Details

The Vuong test is a likelihood-ratio-based tests for model selection that use the Kullback-Leibler information criterion, and that can be employed for choosing between two bivariate models which are non-nested.

The null hypothesis is that the two models are equally close to the actual model, whereas the alternative is that one model is closer. The test follows asymptotically a standard normal distribution under the null. Assume that the critical region is  $(-c, c)$ , where  $c$  is typically set to 1.96. If the value of the test is higher than  $c$  then we reject the null hypothesis that the models are equivalent in favor of model obj1. Viceversa if the value is smaller than  $c$ . If the value falls in  $[-c, c]$  then we cannot discriminate between the two competing models given the data.

### Value

It returns a decision.

### Author(s)

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

### References

Vuong Q.H. (1989), Likelihood Ratio Tests for Model Selection and Non-Nested Hypotheses. *Econometrica*, 57(2), 307-333.

### Examples

```
## see examples for gjrm
```

---

working.comp*Internal Function*

---

**Description**

It efficiently calculates the working model quantities needed to implement the automatic multiple smoothing parameter estimation procedure by exploiting a result which leads to very fast and stable calculations.

**Author(s)**

Maintainer: Giampiero Marra <giampiero.marra@ucl.ac.uk>

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