

# Package: amen (via r-universe)

September 10, 2024

**Title** Additive and Multiplicative Effects Models for Networks and Relational Data

**Version** 1.4.4

**Description** Analysis of dyadic network and relational data using additive and multiplicative effects (AME) models. The basic model includes regression terms, the covariance structure of the social relations model (Warner, Kenny and Stoto (1979) <DOI:10.1037/0022-3514.37.10.1742>, Wong (1982) <DOI:10.2307/2287296>), and multiplicative factor models (Hoff(2009) <DOI:10.1007/s10588-008-9040-4>). Several different link functions accommodate different relational data structures, including binary/network data, normal relational data, zero-inflated positive outcomes using a tobit model, ordinal relational data and data from fixed-rank nomination schemes. Several of these link functions are discussed in Hoff, Fosdick, Volfovsky and Stovel (2013) <DOI:10.1017/nws.2013.17>. Development of this software was supported in part by NIH grant R01HD067509.

**Maintainer** Peter Hoff <peter.hoff@duke.edu>

**URL** <https://github.com/pdhoff/amen>

**BugReports** <https://github.com/pdhoff/amen/issues>

**License** GPL-3

**Date** 2020-12-01

**LazyData** true

**Depends** R (>= 3.5.0)

**Suggests** coda,network,knitr,rmarkdown

**VignetteBuilder** knitr

**RoxygenNote** 7.1.1

**Repository** <https://pdhoff.r-universe.dev>

**RemoteUrl** <https://github.com/pdhoff/amen>

**RemoteRef** HEAD

**RemoteSha** aa6ca84d0452bdda093e7c12f3f6d9374d9aff8

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amen-package	<i>Additive and Multiplicative Effects Models for Networks and Relational Data</i>
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### Description

Analysis of network and relational data using additive and multiplicative effects (AME) models. The basic model includes regression terms, the covariance structure of the social relations model (Warner, Kenny and Stoto (1979), Wong (1982)), and multiplicative factor effects (Hoff(2009)). Four different link functions accommodate different relational data structures, including binary/network data (bin), normal relational data (nrm), ordinal relational data (ord) and data from fixed-rank nomination schemes (frn). Several of these link functions are discussed in Hoff, Fosdick, Volfovsky and Stovel (2013). Development of this software was supported in part by NICHD grant R01HD067509.

### Details

Package: amen  
 Type: Package  
 Version: 1.4.4  
 Date: 2020-12-01  
 License: GPL-3

**Author(s)**

Peter Hoff, Bailey Fosdick, Alex Volfovsky, Yanjun He

Maintainer: Peter Hoff <peter.hoff@duke.edu>

**Examples**

```
data(YX_frn)
fit<-ame(YX_frn$Y,YX_frn$X,burn=5,nscan=5,odens=1,family="frn")

summary(fit)

plot(fit)
```

---

addhealthc3

*AddHealth community 3 data*

---

**Description**

A valued sociomatrix (Y) and matrix of nodal attributes (X) for students in community 3 of the AddHealth study.

- Y: A sociomatrix in which the value of the edge corresponds to an ad-hoc measure of intensity of the relation. Note that students were only allowed to nominate up to 5 male friends and 5 female friends.
- X: Matrix of students attributes, including sex, race (1=white, 2=black, 3=hispanic, 4=asian, 5=mixed/other) and grade.

**Usage**

```
data(addhealthc3)
```

**Format**

list

---

addhealthc9	<i>AddHealth community 9 data</i>
-------------	-----------------------------------

---

**Description**

A valued sociomatrix (Y) and matrix of nodal attributes (X) for students in community 9 of the AddHealth study.

- Y: A sociomatrix in which the value of the edge corresponds to an ad-hoc measure of intensity of the relation. Note that students were only allowed to nominate up to 5 male friends and 5 female friends.
- X: Matrix of students attributes, including sex, race (1=white, 2=black, 3=hispanic, 4=asian, 5=mixed/other) and grade.

**Usage**

```
data(addhealthc9)
```

**Format**

```
list
```

---

addlines	<i>Add lines</i>
----------	------------------

---

**Description**

Add lines to a network plot

**Usage**

```
addlines(Y,X,col="lightblue",alength=0,...)
```

**Arguments**

Y	a sociomatrix
X	coordinates of nodes
col	color of lines. Can be a vector of length equal to the number of edges to be drawn
alength	length of arrows to be drawn
...	additional plotting parameters

**Author(s)**

Peter Hoff

**Examples**

```
data(addhealthc3)
Y<-addhealthc3$Y
X<-xnet(Y)
netplot(Y,X)
addlines(Y,X,col=Y[!=0])
```

ame

*AME model fitting routine***Description**

An MCMC routine providing a fit to an additive and multiplicative effects (AME) regression model to relational data of various types

**Usage**

```
ame(Y, Xdyad=NULL, Xrow=NULL, Xcol=NULL, family, R=0, rvar = !(family=="rrl") ,
cvar = TRUE, dcor = !symmetric, nvar=TRUE,
intercept=!is.element(family,c("rrl","ord")),
symmetric=FALSE,
odmax=rep(max(apply(Y>0,1,sum,na.rm=TRUE)),nrow(Y)), seed = 1, nscan =
10000, burn = 500, odens = 25, plot=TRUE, print = TRUE, gof=TRUE,
prior=list())
```

**Arguments**

Y	an n x n square relational matrix of relations. See family below for various data types.
Xdyad	an n x n x pd array of covariates
Xrow	an n x pr matrix of nodal row covariates
Xcol	an n x pc matrix of nodal column covariates
family	character: one of "nrm","tob","bin","ord","cbin","frn","rrl" - see the details below
R	integer: dimension of the multiplicative effects (can be zero)
rvar	logical: fit row random effects (asymmetric case)?
cvar	logical: fit column random effects (asymmetric case)?
dcor	logical: fit a dyadic correlation (asymmetric case)?
nvar	logical: fit nodal random effects (symmetric case)?
intercept	logical: fit model with an intercept?
symmetric	logical: Is the sociomatrix symmetric by design?
odmax	a scalar integer or vector of length n giving the maximum number of nominations that each node may make - used for "frn" and "cbin" families

seed	random seed
nscan	number of iterations of the Markov chain (beyond burn-in)
burn	burn in for the Markov chain
odens	output density for the Markov chain
plot	logical: plot results while running?
print	logical: print results while running?
gof	logical: calculate goodness of fit statistics?
prior	list: A list of hyperparameters for the prior distribution

### Details

This command provides posterior inference for parameters in AME models of relational data, assuming one of six possible data types/models:

"nrm": A normal AME model.

"tob": A tobit AME model.

"bin": A binary probit AME model.

"ord": An ordinal probit AME model. An intercept is not identifiable in this model.

"cbin": An AME model for censored binary data. The value of 'odmax' specifies the maximum number of links each row may have.

"frn": An AME model for fixed rank nomination networks. A higher value of the rank indicates a stronger relationship. The value of 'odmax' specifies the maximum number of links each row may have.

"rrl": An AME model based on the row ranks. This is appropriate if the relationships across rows are not directly comparable in terms of scale. An intercept, row random effects and row regression effects are not estimable for this model.

### Value

BETA	posterior samples of regression coefficients
VC	posterior samples of the variance parameters
APM	posterior mean of additive row effects a
BPM	posterior mean of additive column effects b
U	posterior mean of multiplicative row effects u
V	posterior mean of multiplicative column effects v (asymmetric case)
UVPM	posterior mean of UV (asymmetric case)
ULUPM	posterior mean of ULU (symmetric case)
L	posterior mean of L (symmetric case)
EZ	estimate of expectation of Z matrix
YPM	posterior mean of Y (for imputing missing values)
GOF	observed (first row) and posterior predictive (remaining rows) values of four goodness-of-fit statistics

**Author(s)**

Peter Hoff

**Examples**

```
data(YX_frn)
fit<-ame(YX_frn$Y,YX_frn$X,burn=5,nscan=5,odens=1,family="frn")
# you should run the Markov chain much longer than this
```

ame\_rep

*AME model fitting routine for replicated relational data***Description**

An MCMC routine providing a fit to an additive and multiplicative effects (AME) regression model to replicated relational data of various types.

**Usage**

```
ame_rep(Y,Xdyad=NULL, Xrow=NULL, Xcol=NULL, family, R=0, rvar = !(family=="rrl"),
cvar = TRUE, dcor = !symmetric, nvar=TRUE,
intercept=!is.element(family,c("rrl","ord")),
symmetric=FALSE,
odmax=rep(max(apply(Y>0,c(1,3),sum,na.rm=TRUE)),nrow(Y[, ,1])), seed = 1,
nscan = 10000, burn = 500, odens = 25, plot=TRUE, print = TRUE, gof=TRUE)
```

**Arguments**

Y	an n x n x T array of relational matrix, where the third dimension corresponds to replicates (over time, for example). See family below for various data types.
Xdyad	an n x n x pd x T array of covariates
Xrow	an n x pr x T array of nodal row covariates
Xcol	an n x pc x T array of nodal column covariates
family	character: one of "nrm", "bin", "ord", "cbin", "frn", "rrl" - see the details below
R	integer: dimension of the multiplicative effects (can be zero)
rvar	logical: fit row random effects (asymmetric case)?
cvar	logical: fit column random effects (asymmetric case)?
dcor	logical: fit a dyadic correlation (asymmetric case)?
nvar	logical: fit nodal random effects (symmetric case)?
intercept	logical: fit model with an intercept?
symmetric	logical: Is the sociomatrix symmetric by design?

odmax	a scalar integer or vector of length n giving the maximum number of nominations that each node may make - used for "frn" and "cbin" families
seed	random seed
nscan	number of iterations of the Markov chain (beyond burn-in)
burn	burn in for the Markov chain
odens	output density for the Markov chain
plot	logical: plot results while running?
print	logical: print results while running?
gof	logical: calculate goodness of fit statistics?

### Details

This command provides posterior inference for parameters in AME models of independent replicated relational data, assuming one of six possible data types/models:

"nrm": A normal AME model.

"bin": A binary probit AME model.

"ord": An ordinal probit AME model. An intercept is not identifiable in this model.

"cbin": An AME model for censored binary data. The value of 'odmax' specifies the maximum number of links each row may have.

"frn": An AME model for fixed rank nomination networks. A higher value of the rank indicates a stronger relationship. The value of 'odmax' specifies the maximum number of links each row may have.

"rrl": An AME model based on the row ranks. This is appropriate if the relationships across rows are not directly comparable in terms of scale. An intercept, row random effects and row regression effects are not estimable for this model.

### Value

BETA	posterior samples of regression coefficients
VC	posterior samples of the variance parameters
APM	posterior mean of additive row effects a
BPM	posterior mean of additive column effects b
U	posterior mean of multiplicative row effects u
V	posterior mean of multiplicative column effects v (asymmetric case)
UVPM	posterior mean of UV
ULUPM	posterior mean of ULU (symmetric case)
L	posterior mean of L (symmetric case)
EZ	estimate of expectation of Z matrix
YPM	posterior mean of Y (for imputing missing values)
GOF	observed (first row) and posterior predictive (remaining rows) values of four goodness-of-fit statistics

**Author(s)**

Peter Hoff, Yanjun He

**Examples**

```
data(YX_bin_long)
fit<-ame_rep(YX_bin_long$Y,YX_bin_long$X,burn=5,nscan=5,odens=1,family="bin")
# you should run the Markov chain much longer than this
```

---

cirplot

*Circular network plot*

---

**Description**

Produce a circular network plot.

**Usage**

```
cirplot(
  Y,
  U = NULL,
  V = NULL,
  row.names = rownames(Y),
  col.names = colnames(Y),
  plotnames = TRUE,
  vscale = 0.8,
  pscale = 1.75,
  mscale = 0.3,
  lcol = "gray",
  rcol = "brown",
  ccol = "blue",
  pch = 16,
  lty = 3,
  jitter = 0.1 * (nrow(Y)/(1 + nrow(Y))),
  bty = "n",
  add = FALSE
)
```

**Arguments**

Y	(matrix) m by n relational matrix.
U	(matrix) m by 2 matrix of row factors of Y.
V	(matrix) n by 2 matrix of column factors of Y.
row.names	(character vector) names of the row objects.
col.names	(character vector) names of the columns objects.

plotnames	(logical) plot row and column names.
vscale	(scalar) scaling factor for V coordinates.
pscale	(scalar) scaling factor for plotting characters.
mscale	(scalar) scaling factor for plotting characters.
lcol	(scalar or vector) line color(s) for the nonzero elements of Y.
rcol	(scalar or vector) node color(s) for the rows.
ccol	(scalar or vector) node color(s) for the columns.
pch	(integer) plotting character.
lty	(integer) line type.
jitter	(scalar) a number to control jittering of nodes.
bty	(character) bounding box type.
add	(logical) add to existing plot

### Details

This function creates a circle plot of a relational matrix or social network. If not supplied via U and V, two-dimensional row factors and column factors are computed from the SVD of Y, scaled versions of which are used to plot positions on the outside edge (U) and inside edge (V) of the circle plot. The magnitudes of the plotting characters are determined by the magnitudes of the rows of U and V. Segments are drawn between each row object *i* and column object *j* for which  $Y[i, j] \neq 0$ .

### Author(s)

Peter Hoff

### Examples

```
data(IR90s)
circplot(IR90s$dyadvars[, , 1])
```

---

coldwar

*Cold War data*

---

### Description

Positive and negative relations between countries during the cold war

### Format

A list including the following dyadic and nodal variables:

- cc: a socioarray of ordinal levels of military cooperation (positive) and conflict (negative), every 5 years;
- distance: between-country distance (in thousands of kilometers);
- gdp: country gdp in dollars every 5 years;
- polity: country polity every 5 years.

**Source**

Xun Cao : <https://polisci.la.psu.edu/people/xuc11>

---

comtrade

*Comtrade data*

---

**Description**

Eleven years of import and export data between 229 countries. The data use the SITC Rev. 1 commodity classification, aggregated at the first level (AG1).

**Format**

A list consisting of a socioarray Trade and a vector dollars2010 of inflation rates. The socioarray gives yearly trade volume (exports and imports) in dollars for 10 different commodity classes for eleven years between 229 countries. This gives a five-way array. The first index is the reporting country, so Trade[i, j, t, k, 1] is what i reports for exports to j, but in general this is not the same as Trade[j, i, t, k, 2], what j reports as importing from i.

**Source**

<https://comtrade.un.org/>, <https://www.measuringworth.com/>

---

design\_array

*Computes the design socioarray of covariate values*

---

**Description**

Computes the design socioarray of covariate values for an AME fit

**Usage**

```
design_array(Xrow=NULL, Xcol=NULL, Xdyad=NULL, intercept=TRUE, n)
```

**Arguments**

Xrow	an n x pr matrix of row covariates
Xcol	an n x pc matrix of column covariates
Xdyad	an n x n x pd array of dyadic covariates
intercept	logical
n	number of rows/columns

**Value**

an n x n x (pr+pc+pd+intercept) 3-way array

**Author(s)**

Peter Hoff

dutchcollege

*Dutch college data***Description**

Longitudinal relational measurements and nodal characteristics of Dutch college students, described in van de Bunt, van Duijn, and Snijders (1999). The time interval between the first four measurements was three weeks, whereas the interval between the last three was six weeks.

**Format**

A list consisting of a socioarray  $Y$  and a matrix  $X$  of static nodal attributes. The relational measurements range from -1 to 4, indicating the following:

- -1 a troubled or negative relationship
- 0 don't know
- 1 neutral relationship
- 2 friendly
- 3 friendship
- 4 best friends

**Source**

Linton Freeman

el2sm

*Edgelist to sociomatrix***Description**

Construction of a sociomatrix from an edgelist

**Usage**

```
e12sm(e1,directed=TRUE,nadiag=all(e1[,1]!=e1[,2]))
```

**Arguments**

e1	a matrix in which each row contains the indices of an edge and possibly the weight for the edge
directed	if FALSE, then a relation is placed in both entry ij and ji of the sociomatrix, for each edge ij (or ji)
nadiag	put NAs on the diagonal

**Value**

a sociomatrix

**Author(s)**

Peter Hoff

**Examples**

```
Y<-matrix(rpois(10*10,.5),10,10) ; diag(Y)<-NA
E<-sm2el(Y)
e12sm(E) - Y
```

---

gofstats

*Goodness of fit statistics*

---

**Description**

Goodness of fit statistics evaluating second and third-order dependence patterns

**Usage**

```
gofstats(Y)
```

**Arguments**

Y                    a relational data matrix

**Value**

a vector of gof statistics

**Author(s)**

Peter Hoff

**Examples**

```
data(YX_nrm)
gofstats(YX_nrm$Y)
```

---

IR90s

*International relations in the 90s*

---

### **Description**

A relational dataset recording a variety of nodal and dyadic variables on countries in the 1990s, including information on conflicts, trade and other variables. Except for the conflict variable, the variables are averages across the decade.

### **Format**

A list consisting of a socioarray dyadvars of dyadic variables and matrix nodevars of nodal variables. The dyadic variables include

- total number of conflicts;
- exports (in billions of dollars);
- distance (in thousands of kilometers);
- number of shared IGOs (averages across the years);
- polity interaction.

The nodal variables include

- population (in millions);
- gdp (in billions of dollars);
- polity

### **Source**

Michael Ward.

---

lazegalaw

*Lazega's law firm data*

---

### **Description**

Several nodal and dyadic variables measured on 71 attorneys in a law firm.

**Format**

A list consisting of a socioarray  $Y$  and a nodal attribute matrix  $X$ .

The dyadic variables in  $Y$  include three binary networks: advice, friendship and co-worker status.

The categorical nodal attributes in  $X$  are coded as follows:

- status (1=partner, 2=associate)
- office (1=Boston, 2=Hartford, 3=Providence)
- practice (1=litigation, 2=corporate)
- law school (1=Harvard or Yale, 2=UConn, 3=other)

seniority and age are given in years, and female is a binary indicator.

**Source**

Linton Freeman

---

ldZgbme	<i>log density for GBME models</i>
---------	------------------------------------

---

**Description**

Calculation of the log conditional density of the latent AMEN matrix  $Z$  given observed data  $Y$ .

**Usage**

```
ldZgbme(Z, Y, l1YZ, EZ, rho, s2 = 1)
```

**Arguments**

$Z$	$n \times n$ latent relational matrix following an AMEN model
$Y$	$n \times n$ observed relational matrix
$l1YZ$	a vectorizable function taking two arguments, $y$ and $z$ . See details below.
$EZ$	$n \times n$ mean matrix for $Z$ based on AMEN model (including additive effects)
$\rho$	dyadic correlation in AMEN model for $Z$
$s2$	residual variance in AMEN model for $Z$

**Details**

This function is used for updating dyadic pairs of the latent variable matrix  $Z$  based on  $Y$  and an AMEN model for  $Z$ . The function  $l1YZ$  specifies the log likelihood for each single  $z[i, j]$  based on  $y[i, j]$ , that is,  $l1YZ$  gives the log probability density (or mass function) of  $y[i, j]$  given  $z[i, j]$ .

**Value**

a symmetric matrix where entry  $i, j$  is proportional to the log conditional bivariate density of  $z[i, j], z[j, i]$ .

**Author(s)**

Peter Hoff

**Examples**

```
## For (overdispersed) Poisson regression, use  
llYZ<-function(y,z){ dpois(y,z,log=TRUE) }
```

---

llsrmRho	<i>SRM log likelihood evaluated on a grid of rho-values</i>
----------	---

---

**Description**

Calculation of the SRM log-likelihood over a grid of rho-values

**Usage**

```
llsrmRho(Y, Sab, rhos, s2 = 1)
```

**Arguments**

Y	sociomatrix assumed to follow a mean-zero SRM distribution
Sab	covariance matrix of additive effects
rhos	vector of rho-values at which to calculate the log-likelihood
s2	current value of s2

**Value**

a vector of log-likelihood values

**Author(s)**

Peter Hoff

---

mhalf	<i>Symmetric square root of a matrix</i>
-------	--

---

**Description**

Computes the symmetric square root of a positive definite matrix

**Usage**

```
mhalf(M)
```

**Arguments**

M                    a positive definite matrix

**Value**

a matrix H such that  $H^2$  equals M

**Author(s)**

Peter Hoff

---

netplot	<i>Network plotting</i>
---------	-------------------------

---

**Description**

Plot the graph of a sociomatrix

**Usage**

```
netplot(Y,X=NULL,xaxt="n",yaxt="n",xlab="",ylab="",
  lcol="gray",ncol="black",lwd=1,lty=1,pch=16,bty="n",plotnames=FALSE,
  seed=1,
  plot.iso=TRUE,directed=NULL,add=FALSE,...)
```

**Arguments**

Y                    a sociomatrix  
 X                    coordinates for plotting the nodes  
 yaxt                x-axis type  
 yaxt                y-axis type  
 xlab                x-axis label

ylab	y-axis label
lcol	edge color
ncol	node color (can be node-specific)
lwd	line width
lty	line type
pch	plotting character for nodes (can be node-specific)
bty	bounding box type
plotnames	plot rownames of Y as node labels
seed	random seed
plot.iso	include isolates in plot
directed	draw arrows
add	add to an existing plot region
...	additional plotting parameters

**Author(s)**

Peter Hoff

**Examples**

```
data(addhealthc3)
Y<-addhealthc3$Y
X<-xnet(Y)
netplot(Y,X)
```

---

plot.ame

*Plot results of an AME object*


---

**Description**

A set of plots summarizing the MCMC routine for an AME fit, as well as some posterior predictive checks.

**Usage**

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

**Arguments**

x	the result of fitting an AME model
...	additional parameters (not used)

**Value**

a series of plots

**Author(s)**

Peter Hoff

---

```
precomputeX
```

*Precomputation of design matrix quantities.*

---

**Description**

Computation of a variety of quantities from the design array to be used in MCMC model fitting algorithms.

**Usage**

```
precomputeX(X)
```

**Arguments**

X                    a three way array, the design array for an AME model

**Value**

the same three-way array but with derived quantities as attributes.

**Author(s)**

Peter Hoff

---

```
raSab_bin_fc
```

*Simulate a and Sab from full conditional distributions under bin likelihood*

---

**Description**

Simulate a and Sab from full conditional distributions under bin likelihood

**Usage**

```
raSab_bin_fc(Z, Y, a, b, Sab, Sab0=NULL, eta0=NULL, SS = round(sqrt(nrow(Z))))
```

**Arguments**

Z	a square matrix, the current value of Z
Y	square binary relational matrix
a	current value of row effects
b	current value of column effects
Sab	current value of Cov(a,b)
Sab0	prior (inverse) scale matrix for the prior distribution
eta0	prior degrees of freedom for the prior distribution
SS	number of iterations

**Value**

Z	new value of Z
Sab	new value of Sab
a	new value of a

**Author(s)**

Peter Hoff

---

raSab_cbin_fc	<i>Simulate a and Sab from full conditional distributions under the cbin likelihood</i>
---------------	---

---

**Description**

Simulate a and Sab from full conditional distributions under the cbin likelihood

**Usage**

```
raSab_cbin_fc(Z, Y, a, b, Sab, odmax, odobs, Sab0=NULL, eta0=NULL, SS = round(sqrt(nrow(Z))))
```

**Arguments**

Z	a square matrix, the current value of Z
Y	square matrix of ranked nomination data
a	current value of row effects
b	current value of column effects
Sab	current value of Cov(a,b)
odmax	a scalar or vector giving the maximum number of nominations for each individual
odobs	observed outdegree
Sab0	prior (inverse) scale matrix for the prior distribution
eta0	prior degrees of freedom for the prior distribution
SS	number of iterations

**Value**

Z	new value of Z
Sab	new value of Sab
a	new value of a

**Author(s)**

Peter Hoff

---

raSab_frn_fc	<i>Simulate a and Sab from full conditional distributions under frn likelihood</i>
--------------	--

---

**Description**

Simulate a and Sab from full conditional distributions under frn likelihood

**Usage**

```
raSab_frn_fc(Z, Y, YL, a, b, Sab, odmax, odobs, Sab0=NULL, eta0=NULL,
SS=round(sqrt(nrow(Z))))
```

**Arguments**

Z	a square matrix, the current value of Z
Y	square matrix of ranked nomination data
YL	list of ranked individuals, from least to most preferred in each row
a	current value of row effects
b	current value of column effects
Sab	current value of Cov(a,b)
odmax	a scalar or vector giving the maximum number of nominations for each individual
odobs	observed outdegree
Sab0	prior (inverse) scale matrix for the prior distribution
eta0	prior degrees of freedom for the prior distribution
SS	number of iterations

**Value**

Z	new value of Z
Sab	new value of Sab
a	new value of a

**Author(s)**

Peter Hoff

---

 rbeta\_ab\_fc

*Conditional simulation of additive effects and regression coefficients*


---

**Description**

Simulates from the joint full conditional distribution of (beta,a,b) in a social relations regression model

**Usage**

```
rbeta_ab_fc(
  Z,
  Sab,
  rho,
  X = NULL,
  s2 = 1,
  offset = 0,
  iV0 = NULL,
  m0 = NULL,
  g = length(Z)
)
```

**Arguments**

Z	n X n normal relational matrix
Sab	row and column covariance
rho	dyadic correlation
X	n x n x p covariate array
s2	dyadic variance
offset	a matrix of the same dimension as Z. It is assumed that Z-offset follows a SRRM, so the offset should contain any multiplicative effects (such as $U \otimes t(V)$ )
iV0	prior precision matrix for regression parameters
m0	prior mean vector for regression parameters
g	prior variance scale for g-prior when iV0 is unspecified

**Value**

beta	regression coefficients
a	additive row effects
b	additive column effects

**Author(s)**

Peter Hoff

---

rbeta_ab_rep_fc	<i>Gibbs sampling of additive row and column effects and regression coefficient with independent replicate relational data</i>
-----------------	--

---

**Description**

Simulates from the joint full conditional distribution of (a,b,beta), assuming same additive row and column effects and regression coefficient across replicates.

**Usage**

```
rbeta_ab_rep_fc(Z.T, Sab, rho, X.T, s2=1)
```

**Arguments**

Z.T	n x n x T array, with the third dimension for replicates. Each slice of the array is a (latent) normal relational matrix, with multiplicative effects subtracted out
Sab	row and column covariance
rho	dyadic correlation
X.T	n x n x p x T covariate array
s2	dyadic variance

**Value**

beta	regression coefficients
a	additive row effects
b	additive column effects

**Author(s)**

Peter Hoff, Yanjun He

---

rmvnorm	<i>Simulation from a multivariate normal distribution</i>
---------	---

---

**Description**

Simulates a matrix where the rows are i.i.d. samples from a multivariate normal distribution

**Usage**

```
rmvnorm(n, mu, Sigma, Sigma.chol = chol(Sigma))
```

**Arguments**

n	sample size
mu	multivariate mean vector
Sigma	covariance matrix
Sigma.chol	Cholesky factorization of Sigma

**Value**

a matrix with n rows

**Author(s)**

Peter Hoff

---

 rrho\_fc

*Griddy Gibbs update for dyadic correlation*


---

**Description**

Simulation of dyadic correlation from its approximate full conditional distribution using griddy Gibbs sampling

**Usage**

```
rrho_fc(Z, Sab, s2 = 1, offset = 0, ngp = 100, asp = NULL)
```

**Arguments**

Z	n X n normal relational matrix
Sab	covariance of additive effects
s2	residual variance
offset	matrix of the same dimension as Z. It is assumed that Z-offset follows an SRM distribution, so the offset should contain any regression terms and multiplicative effects (such as $X\beta + U * t(V)$ )
ngp	the number of points for an unevenly-spaced grid on which to approximate the full conditional distribution
asp	use arc sine prior (TRUE) or uniform prior (FALSE)

**Value**

a value of rho

**Author(s)**

Peter Hoff

---

rrho_mh	<i>Metropolis update for dyadic correlation</i>
---------	---

---

**Description**

Metropolis update for dyadic correlation

**Usage**

```
rrho_mh(Z, rho, s2 = 1, offset=0, asp=NULL)
```

**Arguments**

Z	n X n normal relational matrix
rho	current value of rho
s2	current value of s2
offset	matrix of the same dimension as Z. It is assumed that Z-offset is equal to dyadic noise, so the offset should contain any additive and multiplicative effects (such as $X\beta + U\%*t(V) + \text{outer}(a, b, "+")$ )
asp	use arc sine prior (TRUE) or uniform prior (FALSE)

**Value**

a new value of rho

**Author(s)**

Peter Hoff

---

rrho_mh_rep	<i>Metropolis update for dyadic correlation with independent replicate data</i>
-------------	---

---

**Description**

Metropolis update for dyadic correlation with independent replicate data.

**Usage**

```
rrho_mh_rep(E.T, rho, s2 = 1)
```

**Arguments**

E.T	Array of square residual relational matrix series. The third dimension of the array is for different replicates. Each slice of the array according to the third dimension is a square residual relational matrix.
rho	current value of rho
s2	current value of s2

**Value**

a new value of rho

**Author(s)**

Peter Hoff, Yanjun He

---

rs2_fc	<i>Gibbs update for dyadic variance</i>
--------	---

---

**Description**

Gibbs update for dyadic variance

**Usage**

```
rs2_fc(Z, rho, offset=0, nu0=NULL, s20=NULL)
```

**Arguments**

Z	n X n normal relational matrix
rho	current value of rho
offset	matrix of the same dimension as Z. It is assumed that Z-offset is equal to dyadic noise, so the offset should contain any additive and multiplicative effects (such as $X\beta + U\%*t(V) + \text{outer}(a, b, "+")$ )
nu0	prior degrees of freedom
s20	prior estimate of s2

**Value**

a new value of s2

**Author(s)**

Peter Hoff

---

rs2_rep_fc	<i>Gibbs update for dyadic variance with independent replicate relational data</i>
------------	--

---

**Description**

Gibbs update for dyadic variance with independent replicate relational data

**Usage**

```
rs2_rep_fc(E.T, rho)
```

**Arguments**

E.T	Array of square residual relational matrix series. The third dimension of the array is for different replicates. Each slice of the array according to the third dimension is a square residual relational matrix
rho	current value of rho

**Value**

a new value of s2

**Author(s)**

Peter Hoff, Yanjun He

---

rSab_fc	<i>Gibbs update for additive effects covariance</i>
---------	---

---

**Description**

Gibbs update for additive effects covariance

**Usage**

```
rSab_fc(a, b, Sab0=NULL, eta0=NULL)
```

**Arguments**

a	vector of row random effects
b	vector of row random effects
Sab0	prior (inverse) scale matrix for the prior distribution
eta0	prior degrees of freedom for the prior distribution

**Author(s)**

Peter Hoff

---

rSuv_fc	<i>Gibbs update for multiplicative effects covariance</i>
---------	---

---

**Description**

Gibbs update for multiplicative effects covariance

**Usage**

```
rSuv_fc(U,V, Suv0=NULL,kappa0=NULL)
```

**Arguments**

U	matrix of row random effects
V	matrix of row random effects
Suv0	prior (inverse) scale matrix for the prior distribution
kappa0	prior degrees of freedom for the prior distribution

**Author(s)**

Peter Hoff

---

rUV_fc	<i>Gibbs sampling of U and V</i>
--------	----------------------------------

---

**Description**

A Gibbs sampler for updating the multiplicative effect matrices U and V

**Usage**

```
rUV_fc(Z, U, V, Suv, rho, s2 = 1, offset = 0)
```

**Arguments**

Z	n X n normal relational matrix
U	current value of U
V	current value of V
Suv	covariance of (U V)
rho	dyadic correlation
s2	dyadic variance
offset	a matrix of the same dimension as Z. It is assumed that Z-offset is equal to the multiplicative effects plus dyadic noise, so the offset should contain any additive effects (such as $X\beta + \text{outer}(a,b, "+")$ )

**Value**

U	a new value of U
V	a new value of V

**Author(s)**

Peter Hoff

---

rUV\_rep\_fc

*Gibbs sampling of U and V*

---

**Description**

A Gibbs sampler for updating the multiplicative effect matrices U and V, assuming they are the same across replicates.

**Usage**

```
rUV_rep_fc(E.T,U,V,rho,s2=1,shrink=TRUE)
```

**Arguments**

E.T	Array of square residual relational matrix series with additive effects and covariates subtracted out. The third dimension of the array is for different replicates. Each slice of the array according to the third dimension is a square residual relational matrix.
U	current value of U
V	current value of V
rho	dyadic correlation
s2	dyadic variance
shrink	adaptively shrink the factors with a hierarchical prior

**Value**

U	a new value of U
V	a new value of V

**Author(s)**

Peter Hoff, Yanjun He

---

rUV_sym_fc	<i>Gibbs sampling of U and V</i>
------------	----------------------------------

---

**Description**

A Gibbs sampler for updating the multiplicative effect matrices  $U$  and  $V$  in the symmetric case. In this case  $U\%*\%t(V)$  is symmetric, so this is parameterized as  $V=U\%*\%L$  where  $L$  is the diagonal matrix of eigenvalues of  $U\%*\%t(V)$ .

**Usage**

```
rUV_sym_fc(E, U, V, s2 = 1, shrink=TRUE)
```

**Arguments**

E	square residual relational matrix
U	current value of U
V	current value of V
s2	dyadic variance
shrink	adaptively shrink the factors with a hierarchical prior

**Value**

U	a new value of U
V	a new value of V

**Author(s)**

Peter Hoff

**Examples**

```
U0<-matrix(rnorm(30,2),30,2) ; V0<-U0%*\%diag(c(3,-2))
E<- U0%*\%t(V0) + matrix(rnorm(30^2),30,30)
rUV_sym_fc
```

---

rwish

*Simulation from a Wishart distribution*

---

### Description

Simulates a random Wishart-distributed matrix

### Usage

```
rwish(S0, nu = dim(S0)[1] + 2)
```

### Arguments

`S0` a positive definite matrix  
`nu` a positive integer

### Value

a positive definite matrix

### Author(s)

Peter Hoff

### Examples

```
## The expectation is S0*nu  
S0<-rwish(diag(3))  
  
SS<-matrix(0,3,3)  
for(s in 1:1000) { SS<-SS+rwish(S0,5) }  
  
SS/s  
  
S0*5
```

---

rZ_bin_fc	<i>Simulate Z based on a probit model</i>
-----------	---

---

**Description**

Simulates a random latent matrix  $Z$  given its expectation, dyadic correlation and a binary relational matrix  $Y$

**Usage**

`rZ_bin_fc(Z, EZ, rho, Y)`

**Arguments**

$Z$	a square matrix, the current value of $Z$
$EZ$	expected value of $Z$
$\rho$	dyadic correlation
$Y$	square binary relational matrix

**Value**

a square matrix , the new value of  $Z$

**Author(s)**

Peter Hoff

---

rZ_cbin_fc	<i>Simulate Z given fixed rank nomination data</i>
------------	--

---

**Description**

Simulates a random latent matrix  $Z$  given its expectation, dyadic correlation and censored binary nomination data

**Usage**

`rZ_cbin_fc(Z, EZ, rho, Y, odmax, odoobs)`

**Arguments**

Z	a square matrix, the current value of Z
EZ	expected value of Z
rho	dyadic correlation
Y	square matrix of ranked nomination data
odmax	a scalar or vector giving the maximum number of nominations for each individual
odobs	observed outdegree

**Details**

simulates Z under the constraints (1)  $Y[i,j]=1, Y[i,k]=0 \Rightarrow Z[i,j]>Z[i,k]$  , (2)  $Y[i,j]=1 \Rightarrow Z[i,j]>0$  , (3)  $Y[i,j]=0 \ \& \ odobs[i]<odmax[i] \Rightarrow Z[i,j]<0$

**Value**

a square matrix, the new value of Z

**Author(s)**

Peter Hoff

---

rZ\_frn\_fc

*Simulate Z given fixed rank nomination data*

---

**Description**

Simulates a random latent matrix Z given its expectation, dyadic correlation and fixed rank nomination data

**Usage**

rZ\_frn\_fc(Z, EZ, rho, Y, YL, odmax, odobs)

**Arguments**

Z	a square matrix, the current value of Z
EZ	expected value of Z
rho	dyadic correlation
Y	square matrix of ranked nomination data
YL	list of ranked individuals, from least to most preferred in each row
odmax	a scalar or vector giving the maximum number of nominations for each individual
odobs	observed outdegree

**Details**

simulates Z under the constraints (1)  $Y[i,j] > Y[i,k] \Rightarrow Z[i,j] > Z[i,k]$  , (2)  $Y[i,j] > 0 \Rightarrow Z[i,j] > 0$  , (3)  $Y[i,j] = 0 \ \& \ odobs[i] < odmax[i] \Rightarrow Z[i,j] < 0$

**Value**

a square matrix, the new value of Z

**Author(s)**

Peter Hoff

---

rZ\_nrm\_fc

*Simulate missing values in a normal AME model*


---

**Description**

Simulates missing values of a sociomatrix under a normal AME model

**Usage**

```
rZ_nrm_fc(Z, EZ, rho, s2, Y)
```

**Arguments**

Z	a square matrix, the current value of Z
EZ	expected value of Z
rho	dyadic correlation
s2	dyadic variance
Y	square relational matrix

**Value**

a square matrix, equal to Y at non-missing values

**Author(s)**

Peter Hoff

---

rZ\_ord\_fc                      *Simulate Z given the partial ranks*

---

### Description

Simulates a random latent matrix  $Z$  given its expectation, dyadic correlation and partial rank information provided by  $W$

### Usage

rZ\_ord\_fc( $Z$ ,  $EZ$ ,  $\rho$ ,  $Y$ )

### Arguments

$Z$	a square matrix, the current value of $Z$
$EZ$	expected value of $Z$
$\rho$	dyadic correlation
$Y$	matrix of ordinal data

### Value

a square matrix, the new value of  $Z$

### Author(s)

Peter Hoff

---

rZ\_rrl\_fc                      *Simulate Z given relative rank nomination data*

---

### Description

Simulates a random latent matrix  $Z$  given its expectation, dyadic correlation and relative rank nomination data

### Usage

rZ\_rrl\_fc( $Z$ ,  $EZ$ ,  $\rho$ ,  $Y$ ,  $YL$ )

### Arguments

$Z$	a square matrix, the current value of $Z$
$EZ$	expected value of $Z$
$\rho$	dyadic correlation
$Y$	square matrix of ranked nomination data
$YL$	list of ranked individuals, from least to most preferred in each row

**Details**

simulates  $Z$  under the constraints (1)  $Y[i,j] > Y[i,k] \Rightarrow Z[i,j] > Z[i,k]$

**Value**

a square matrix, the new value of  $Z$

**Author(s)**

Peter Hoff

---

 rZ\_tob\_fc

*Simulate Z based on a tobit model*


---

**Description**

Simulates a random latent matrix  $Z$  given its expectation, dyadic correlation and a nonnegative relational matrix  $Y$

**Usage**

`rZ_tob_fc(Z, EZ, rho, s2, Y)`

**Arguments**

$Z$	a square matrix, the current value of $Z$
$EZ$	expected value of $Z$
$\rho$	dyadic correlation
$s2$	dyadic variance
$Y$	square relational matrix with nonnegative entries

**Value**

a square matrix, the new value of  $Z$

**Author(s)**

Peter Hoff

---

 sampsonmonks

*Sampson's monastery data*


---

### Description

Several dyadic variables measured on 18 members of a monastery.

### Format

A socioarray whose dimensions represent nominators, nominatees and relations. Each monk was asked to rank up to three other monks on a variety of positive and negative relations. A rank of three indicates the "highest" ranking for a particular relational variable. The relations like\_m2 and like\_m1 are evaluations of likeing at one and two timepoints previous to when the other relations were measured.

### Source

Linton Freeman

---

 sheep

*Sheep dominance data*


---

### Description

Number of dominance encounters between 28 female bighorn sheep. Cell (i,j) records the number of times sheep i dominated sheep j. From Hass (1991).

### Format

A list consisting of the following:

- dom: a directed socioarray recording the number of dominance encounters.
- age: the age of each sheep in years.

### Source

Linton Freeman

---

simY_bin	<i>Simulate a network, i.e. a binary relational matrix</i>
----------	--

---

**Description**

Simulates a network, i.e. a binary relational matrix

**Usage**

```
simY_bin(EZ, rho)
```

**Arguments**

EZ	square matrix giving the expected value of the latent Z matrix
rho	dyadic correlation

**Value**

a square binary matrix

**Author(s)**

Peter Hoff

---

simY_frn	<i>Simulate an relational matrix based on a fixed rank nomination scheme</i>
----------	--

---

**Description**

Simulate an relational matrix based on a fixed rank nomination scheme

**Usage**

```
simY_frn(EZ, rho, odmax, Y0)
```

**Arguments**

EZ	a square matrix giving the expected value of the latent Z matrix
rho	dyadic correlation
odmax	a scalar or vector giving the maximum number of nominations for each node
Y0	a square matrix identifying where missing values should be maintained

**Value**

a square matrix, where higher values represent stronger relationships

**Author(s)**

Peter Hoff

---

`simY_nrm`*Simulate a normal relational matrix*

---

**Description**

Simulates a normal relational matrix

**Usage**`simY_nrm(EY, rho, s2)`**Arguments**

EY	square matrix giving the expected value of the relational matrix
rho	dyadic correlation
s2	dyadic variance

**Value**

a square matrix

**Author(s)**

Peter Hoff

---

`simY_ord`*Simulate an ordinal relational matrix*

---

**Description**

Simulates an ordinal relational matrix having a particular marginal distribution

**Usage**`simY_ord(EZ, rho, Y)`**Arguments**

EZ	square matrix giving the expected value of the latent Z matrix
rho	scalar giving the within-dyad correlation
Y	ordinal relational data matrix

**Value**

a square matrix

**Author(s)**

Peter Hoff

---

simY_rrl	<i>Simulate an relational matrix based on a relative rank nomination scheme</i>
----------	---

---

**Description**

Simulate an relational matrix based on a relative rank nomination scheme

**Usage**

```
simY_rrl(EZ, rho, odobs, Y0)
```

**Arguments**

EZ	a square matrix giving the expected value of the latent $Z$ matrix
rho	dyadic correlation
odobs	a scalar or vector giving the observed number of nominations for each node
Y0	a square matrix identifying where missing values should be maintained

**Value**

a square matrix, where higher values represent stronger relationships

**Author(s)**

Peter Hoff

---

simY\_tob                      *Simulate a tobit relational matrix*

---

**Description**

Simulates a tobit relational matrix

**Usage**

```
simY_tob(EY, rho, s2)
```

**Arguments**

EY	square matrix giving the expected value of the relational matrix
rho	dyadic correlation
s2	dyadic variance

**Value**

a square matrix

**Author(s)**

Peter Hoff

---

simZ                              *Simulate Z given its expectation and covariance*

---

**Description**

Simulate Z given its expectation and covariance

**Usage**

```
simZ(EZ, rho, s2 = 1)
```

**Arguments**

EZ	expected value of Z
rho	dyadic correlation
s2	dyadic variance

**Value**

a simulated value of Z

**Author(s)**

Peter Hoff

---

sm2el*Sociomatrix to edgelist*

---

**Description**

Construction of an edgelist from a sociomatrix

**Usage**`sm2el(sm,directed=TRUE)`**Arguments**

`sm` a sociomatrix with possibly valued relations  
`directed` if TRUE, only use the upper triangular part of the matrix to enumerate edges

**Value**

an edgelist

**Author(s)**

Peter Hoff

**Examples**

```
Y<-matrix(rpois(10*10,.5),10,10) ; diag(Y)<-NA
E<-sm2el(Y)
e12sm(E) - Y
```

---

summary.ame*Summary of an AME object*

---

**Description**

Summary method for an AME object

**Usage**

```
## S3 method for class 'ame'
summary(object, ...)
```

**Arguments**

object            the result of fitting an AME model  
...                additional parameters (not used)

**Value**

a summary of parameter estimates and confidence intervals for an AME fit

**Author(s)**

Peter Hoff

---

Xbeta

*Linear combinations of submatrices of an array*

---

**Description**

Computes a matrix of expected values based on an array X of predictors and a vector beta of regression coefficients.

**Usage**

Xbeta(X, beta)

**Arguments**

X                 an n by n by p array  
beta              a p by 1 vector

**Value**

An n by n matrix

**Author(s)**

Peter Hoff

---

xnet	<i>Network embedding</i>
------	--------------------------

---

**Description**

Compute an embedding of a sociomatrix into a two-dimensional space.

**Usage**

```
xnet(Y, fm = suppressWarnings(require("network")), seed = 1)
```

**Arguments**

Y	(square matrix) The sociomatrix.
fm	(logical scalar) If TRUE, the Fruchterman-Reingold layout will be used (requires the network package).
seed	(integer) The random seed (the FR layout is random).

**Details**

Coordinates are obtained using the Fruchterman-Reingold layout if the package network is installed, and otherwise uses the first two eigenvectors the sociomatrix.

**Value**

(matrix) A matrix of two-dimensional coordinates.

**Author(s)**

Peter Hoff

**Examples**

```
data(addhealthc3)
Y<-addhealthc3$Y
X<-xnet(Y)
netplot(Y,X)
```

---

YX_bin	<i>binary relational data and covariates</i>
--------	--

---

**Description**

a synthetic dataset that includes binary relational data as well as information on eight covariates

**Usage**

```
data(YX_bin)
```

**Format**

The format is: List of 2 \$ Y: num [1:100, 1:100] NA 0 0 0 0 0 0 0 1 ... \$ X: num [1:100, 1:100, 1:8] 1 1 1 1 1 1 1 1 1 1 ... ..- attr(\*, "dimnames")=List of 3 .. ..\$: NULL .. ..\$: NULL .. ..\$: chr [1:8] "intercept" "rgpa" "rsmoke" "cgpa" ...

**Examples**

```
data(YX_bin)
gofstats(YX_bin$Y)
```

---

YX_bin_long	<i>binary relational data and covariates</i>
-------------	--

---

**Description**

a synthetic dataset that includes longitudinal binary relational data as well as information on covariates

**Usage**

```
data(YX_bin_long)
```

**Format**

a list

**Examples**

```
data(YX_bin_long)
gofstats(YX_bin_long$Y[, , 1])
```

---

YX_cbin	<i>Censored binary nomination data and covariates</i>
---------	---

---

**Description**

a synthetic dataset that includes relational data where the number of nominations per row is censored at 10, along with information on eight covariates

**Usage**

```
data(YX_cbin)
```

**Format**

The format is: List of 2 \$ Y: num [1:100, 1:100] NA 0 0 0 1 0 0 0 0 3 ... \$ X: num [1:100, 1:100, 1:8] 1 1 1 1 1 1 1 1 1 1 ... ..- attr(\*, "dimnames")=List of 3 .. ..\$: NULL .. ..\$: NULL .. ..\$: chr [1:8] "intercept" "rgpa" "rsmoke" "cgpa" ...

**Examples**

```
data(YX_cbin)
gofstats(YX_cbin$Y)
```

---

YX_frn	<i>Fixed rank nomination data and covariates</i>
--------	--

---

**Description**

a synthetic dataset that includes fixed rank nomination data as well as information on eight covariates

**Usage**

```
data(YX_frn)
```

**Format**

The format is: List of 2 \$ Y: num [1:100, 1:100] NA 0 0 0 1 0 0 0 0 3 ... \$ X: num [1:100, 1:100, 1:8] 1 1 1 1 1 1 1 1 1 1 ... ..- attr(\*, "dimnames")=List of 3 .. ..\$: NULL .. ..\$: NULL .. ..\$: chr [1:8] "intercept" "rgpa" "rsmoke" "cgpa" ...

**Examples**

```
data(YX_frn)
gofstats(YX_frn$Y)
```

---

YX_nrm	<i>normal relational data and covariates</i>
--------	--

---

**Description**

a synthetic dataset that includes continuous (normal) relational data as well as information on eight covariates

**Usage**

```
data(YX_nrm)
```

**Format**

The format is: List of 2 \$ Y: num [1:100, 1:100] NA -4.05 -0.181 -3.053 -1.579 ... \$ X: num [1:100, 1:100, 1:8] 1 1 1 1 1 1 1 1 1 ... ..- attr(\*, "dimnames")=List of 3 .. ..\$: NULL .. ..\$: NULL .. ..\$: chr [1:8] "intercept" "rgpa" "rsmoke" "cgpa" ...

**Examples**

```
data(YX_nrm)
gofstats(YX_nrm$Y)
```

---

YX_ord	<i>ordinal relational data and covariates</i>
--------	---

---

**Description**

a synthetic dataset that includes ordinal relational data as well as information on seven covariates

**Usage**

```
data(YX_ord)
```

**Format**

The format is: List of 2 \$ Y: num [1:100, 1:100] NA 0 3 0 3 1 0 1 1 0 ... \$ X: num [1:100, 1:100, 1:7] 1 1 1 1 1 1 1 1 1 ... ..- attr(\*, "dimnames")=List of 3 .. ..\$: NULL .. ..\$: NULL .. ..\$: chr [1:7] "rgpa" "rsmoke" "cgpa" "csmoke" ...

**Examples**

```
data(YX_ord)
gofstats(YX_ord$Y)
```

---

YX_rr1	<i>row-specific ordinal relational data and covariates</i>
--------	--

---

**Description**

a synthetic dataset that includes row-specific ordinal relational data as well as information on five covariates

**Usage**

```
data(YX_rr1)
```

**Format**

The format is: List of 2 \$ Y: num [1:100, 1:100] NA 0 3 0 3 1 0 1 1 0 ... \$ X: num [1:100, 1:100, 1:5] 1 1 1 1 1 1 1 1 1 1 ... ..- attr(\*, "dimnames")=List of 3 .. ..\$: NULL .. ..\$: NULL .. ..\$: chr [1:5] "cgpa" "csmoke" "igrade" "ismoke" ...

**Examples**

```
data(YX_rr1)
gofstats(YX_rr1$Y)
```

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zscores	<i>rank-based z-scores</i>
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**Description**

Computes the normal scores corresponding to the ranks of a data vector

**Usage**

```
zscores(y, ties.method="average")
```

**Arguments**

y	a numeric vector
ties.method	method for dealing with ties

**Value**

a numeric vector

**Author(s)**

Peter Hoff

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