Package ‘MLCIRTwithin’

Type Package

Title Latent Class Item Response Theory (LC-IRT) Models under Within-Item Multidimensionality

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Description Framework for the Item Response Theory analysis of dichotomous and ordinal polytomous outcomes under the assumption of within-item multidimensionality and discreteness of the latent traits. The fitting algorithms allow for missing responses and for different item parametrizations and are based on the Expectation-Maximization paradigm. Individual covariates affecting the class weights may be included in the new version together with possibility of constraints on all model parameters.

License GPL (>= 2)

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MLCIRTwwithin-package

Description

This package provides a flexible framework for the estimation of discrete two-tier Item Response Theory (IRT) models for the analysis of dichotomous and ordinal polytomous item responses. The class of models at issue is based on the assumption that one or more items are shared by (at most) two latent traits (i.e., within-item multidimensionality) and on the discreteness of latent traits (abilities). Every level of the abilities identify a latent class of subjects. The fitting algorithms are based on the Expectation-Maximization (EM) paradigm and allow for missing responses and for different item parametrizations. The package also allows for the inclusion of individual covariates affecting the class weights together with possibility of constraints on all model parameters.

Details

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<td>performs the parameter estimation of the same model considered in the R package MultiLCIRT when one or more items are shared by two latent traits (within-item multidimensionality); in addition, fixed values and constraints on support points and item parameters are allowed.</td>
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Package: MultiLCIRT
Type: Package
Version: 2.1.1
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License: GPL (>= 2)
Author(s)
Francesco Bartolucci, Silvia Bacci - University of Perugia (IT)
Maintainer: Francesco Bartolucci <bart@stat.unipg.it>

References

Examples
```r
## Not run:
# Estimation of a two-tier LC-IRT model
data(SF12_nomiss)
S = SF12_nomiss[,1:12]
X = SF12_nomiss[,13]
# Define matrices to allocate each item on the latent variables
multi1=rbind(1:6, 7:12)
multi2=rbind(4:8, c(2:3, 10:12))
# Graded response model with two primary latent variables, each of them
# having two dimensions (free discrimination and difficulty parameters;
# two latent classes for both the latent variables; one covariate):
tol = 10^-6 # decrease the tolerance to obtain more reliable results
out1 = est_multi_poly_within(S=S,k1=2,k2=2,X=X,link="global",disc=TRUE,
    multi1=multi1, multi2=multi2, tol=tol,
    disp=TRUE, out_se=FALSE)

# Display output
summary(out1)

## End(Not run)

---

**blkdiag**  
*Build block diagonal matrices*

**Description**

Function that given two matrices builds the corresponding block diagonal matrix.

**Usage**

`blkdiag(A, B)`

**Arguments**

- `A`  
  first matrix to be included

- `B`  
  second matrix to be included

**Value**

- `C`  
  resulting block diagonal matrix

**Author(s)**

Francesco Bartolucci - University of Perugia (IT)

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**coef.est_multi_poly_between**  
*Display the estimated model parameters of est_multi_poly_between object*

**Description**

Given the output from `est_multi_poly_between`, estimated abilities, item parameters, and regression coefficients are displayed
Usage

```r
## S3 method for class 'est_multi_poly_between'
coef(object, ...)
```

Arguments

- `object`: output from `est_multi_poly_between`
- `...`: further arguments passed to or from other methods

Author(s)

Francesco Bartolucci - University of Perugia (IT)

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**Description**

Given the output from `est_multi_poly_within`, estimated abilities, item parameters, and regression coefficients are displayed for the 1st and the 2nd latent variable.

Usage

```r
## S3 method for class 'est_multi_poly_within'
coef(object, ...)
```

Arguments

- `object`: output from `est_multi_poly_within`
- `...`: further arguments passed to or from other methods

Author(s)

Francesco Bartolucci - University of Perugia (IT)
confint.est_multi_poly_between

Display the estimated confidence intervals of the model parameters of est_multi_poly_between object

Description

Given the output from est_multi_poly_between, the inferior and superior limits of confidence intervals at a given level are displayed for abilities, item parameters, and regression coefficients

Usage

```r
## S3 method for class 'est_multi_poly_between'
confint(object, parm, level=0.95, ...)
```

Arguments

- `object`: output from est_multi_poly_between
- `parm`: empty object
- `level`: confidence level
- `...`: further arguments passed to or from other methods

Author(s)

Francesco Bartolucci - University of Perugia (IT)

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confint.est_multi_poly_within

Display the estimated confidence intervals of the model parameters of est_multi_poly_within object

Description

Given the output from est_multi_poly_within, the inferior and superior limits of confidence intervals at a given level are displayed for abilities, item parameters, and regression coefficients for the 1st and the 2nd latent variable

Usage

```r
## S3 method for class 'est_multi_poly_within'
confint(object, parm, level=0.95, ...)
```
est_multi_glob_genZ

Arguments

object        output from est_multi_poly_within
parm          empty object
level         confidence level
...           further arguments passed to or from other methods

Author(s)

Francesco Bartolucci - University of Perugia (IT)

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**est_multi_glob_genZ**  
*Fit marginal regression models for categorical responses*

Description

It estimates marginal regression models to datasets consisting of a categorical response and one or more covariates by a Fisher-scoring algorithm; this is an internal function that also works with response variables having a different number of response categories.

Usage

```r
est_multi_glob_genZ(Y, X, model = c("m","l","g"), ind = 1:nrow(Y), de = NULL,
                      Z = NULL, z = NULL, Dis = NULL, dis = NULL, disp=FALSE,
                      only_sc = FALSE, Int = NULL, der_single = FALSE, maxit = 10)
```

Arguments

Y          matrix of response configurations
X          array of all distinct covariate configurations
model      type of logit (m = multinomial, l = local, g = global)
ind        vector to link responses to covariates
de        initial vector of regression coefficients
Z          design matrix
z          intercept associated with the design matrix
Dis        matrix for inequality constraints on de
dis        vector for inequality constraints on de
disp       to display partial output
only_sc     to exit giving only the score
Int         matrix of the fixed intercepts
der_single  to require single derivatives
maxit       maximum number of iterations
Value

- **be**: estimated vector of regression coefficients
- **lk**: log-likelihood at convergence
- **Pdis**: matrix of the probabilities for each distinct covariate configuration
- **P**: matrix of the probabilities for each covariate configuration
- **sc**: score for the vector of regression coefficients
- **FI**: Fisher information matrix
- **de**: estimated vector of (free) regression coefficients
- **scde**: score for the vector of (free) regression coefficients
- **FIde**: Fisher information matrix for the vector of (free) regression coefficients
- **Sc**: matrix of individual scores for the vector of regression coefficients (if der_single=TRUE)
- **Scde**: matrix of individual scores for the vector of (free) regression coefficients (if der_single=TRUE)

Author(s)

Francesco Bartolucci - University of Perugia (IT)

References


**Description**

The function performs maximum likelihood estimation of the parameters of the IRT models assuming a discrete distribution for the ability and between-item multidimensionality. Every ability level corresponds to a latent class of subjects in the reference population. The class of models is based on a between-item multidimensional formulation with each item loading on a dimension of a given latent variable. Maximum likelihood estimation is based on Expectation- Maximization algorithm.
est_multi_poly_between

Usage

```r
est_multi_poly_between(S, yv = rep(1, ns), k, X = NULL, start = c("deterministic", 
"random","external"), link = c("global","local"), disc = FALSE, 
difl = FALSE, multi = 1:I, Phi = NULL, gat = NULL, De = NULL, 
fort = FALSE, tol = 10^-10, maxitc = 10^4, disp = FALSE, 
output = FALSE, out_se = FALSE, glob = FALSE, Zth=NULL,zth=NULL, 
Zbe=NULL, zbe=NULL,Zga=NULL,zga=NULL)
```

Arguments

- **S**: matrix of all response sequences observed at least once in the sample and listed row-by-row (use NA for missing responses)
- **yv**: vector of the frequencies of every response configuration in S
- **k**: number of ability levels (or latent classes) for the latent variable
- **X**: matrix of covariates that affects the weights
- **start**: method of initialization of the algorithm
- **link**: type of link function ("global" for global logits, "local" for local logits); with global logits a graded response model results; with local logits a partial credit model results (with dichotomous responses, global logits is the same as using local logits resulting in the Rasch or the 2PL model depending on the value assigned to disc)
- **disc**: indicator of constraints on the discriminating indices (FALSE = all equal to one, TRUE = free)
- **difl**: indicator of constraints on the difficulty levels (FALSE = free, TRUE = rating scale parametrization); difl = TRUE is only admitted in the presence of items with the same number of categories
- **multi**: matrix with a number of rows equal to the number of dimensions and elements in each row equal to the indices of the items measuring the dimension corresponding to that row for the latent variable
- **Phi**: initial value of the matrix of the conditional response probabilities (if start="external")
- **gat**: initial value of the vector of free discriminating indices (if start="external")
- **De**: initial value of regression coefficients for the covariates (if start="external")
- **fort**: to use Fortran routines when possible
- **tol**: tolerance level for checking convergence of the algorithm as relative difference between consecutive log-likelihoods
- **maxitc**: maximum number of iterations of the algorithm
- **disp**: to display the likelihood evolution step by step
- **output**: to return additional outputs (Piv,Pp,lkv, Xlabel, XXdis)
- **out_se**: to return standard errors
- **glob**: to use global logits in the covariates
- **Zth**: matrix for the specification of constraints on the support points
- **zth**: vector for the specification of constraints on the support points
matrix for the specification of constraints on the item difficulty parameters
vector for the specification of constraints on the item difficulty parameters
matrix for the specification of constraints on the item discriminating indices
vector for the specification of constraints on the item discriminating indices

Value

estimated vector of weights of the latent classes (average of the weights in case of model with covariates)
vector indicating the reference item chosen for each latent dimension of the latent variable
estimated matrix of free ability levels for each dimension
complete matrix of free and constrained ability levels for each dimension and latent class of the latent variable
estimated vector of free difficulty levels for every item (split in two vectors if difl=TRUE)
complete vector of free and constrained difficulty levels for every item (split in two vectors if difl=TRUE)
estimated vector of free discriminating indices for every item (with all elements equal to 1 if disc=FALSE)
complete vector of free and constrained discriminating indices for every item (with all elements equal to 1 if disc=FALSE)
matrix of regression coefficients for the multinomial (or global if glob=TRUE) logit model on the class weights
array of the conditional response probabilities for every item and each of the k latent classes
log-likelihood at convergence of the EM algorithm
number of free parameters
Akaike Information Criterion index
Bayesian Information Criterion index
entropy index to measure the separation of classes
estimated vector of (ordered) weights of the latent classes (average of the weights in case of model with covariates)
standardized ability levels
standardized values of item difficulty parameters
standardized values of item discriminating indices
call of function
matrix of the posterior probabilities for each response configuration and latent class (if output=TRUE)
vector to trace the log-likelihood evolution across iterations (if output=TRUE)
structure of the design matrix, for internal use (if output=TRUE)
est_multi_poly_between

XXdis  design matrix for the covariates affecting the latent variable (if output=TRUE)
Piv    matrix of the weights for every response configuration (if output=TRUE)
setht  standard errors for vector tht (if out_se=TRUE)
seTh   standard errors for vector Th (if out_se=TRUE)
sebet  standard errors for vector bet (if out_se=TRUE)
seBec  standard errors for vector Bec (if out_se=TRUE)
segat  standard errors for vector gat (if out_se=TRUE)
segac  standard errors for vector gac (if out_se=TRUE)
seDe   standard errors for vector De (if out_se=TRUE)
Vnt    estimated variance-covariance matrix for free parameter estimates (if out_se=TRUE)
Vn     estimated variance-covariance matrix for all parameter estimates (if out_se=TRUE)

Author(s)
Francesco Bartolucci, Silvia Bacci - University of Perugia (IT)

References
Bartolucci, F. (2007), A class of multidimensional IRT models for testing unidimensionality and clustering items, Psychometrika, 72, 141-157.

Examples

## Not run:
# Fit a Graded response model with two dimensions (free discrimination and difficulty parameters; three latent classes):
data(SF12_nomiss)
S = SF12_nomiss[,1:12]
X = SF12_nomiss[,13]
multi0 = rbind(c(1:5, 8), c(6:7,9:12))
k=3
out1 = est_multi_poly_between(S=S,k=k,X=X,link="global",disc=TRUE, multi=multi0,fort=TRUE,disp=TRUE,out_se=TRUE)

# Display output:
summary(out1)
out1$lk
out1$Th
out1$piv
out1$De

## End(Not run)
## Not run:
## Fit the model under different external constraints on abilities and/or item parameters
# Fixed ability levels; all item parameters can be free
S1 = pmin(as.matrix(S),2) # all items have the same number of categories
Zth = matrix(0,nrow(multi0)*k,0)
zth = c(rep(-1, times=nrow(multi0)), rep(0, times=nrow(multi0)), rep(1, times=nrow(multi0)))
Zbe = diag(ncol(S1)*2) # free item difficulties: 12*2 = 24 (12 items with 3 categories)
Zga = diag(ncol(S1)); # free item discriminating parameters = 12 items loading on U
outc1 = est_multi_poly_between(S=S1,k=k,X=X,link="global",disc=TRUE, multi=multi0,disp=TRUE,
                              out_se=TRUE,Zth=Zth,zth=zth,Zbe=Zbe,Zga=Zga)
outc1$Th
outc1$tht
outc1$Bec

# Add equality constraints on item parameters
# Same difficulties for pairs of items 1-7, 2-8, 3-9, 4-10, 5-11, 6-12;
# same discriminating indices for items 2 and 3;
# free ability levels
Zbe = (matrix(1,2,1)%x%diag(12))[-1]
Zga = as.matrix(rep(0, times=12)); Zga[2,1] = 1; Zga[3,1] = 1;
Zga1p1 = matrix(0, nrow=3, ncol=9); Zga1p2 = diag(9); Zga1p = rbind(Zga1p1, Zga1p2)
Zga = cbind(Zga, Zga1p)
# discriminating index of item 1 constrained to 1 for the model identifiability
zga = rep(0,nrow(Zga)); zga[1] = 1
outc2 = est_multi_poly_between(S=S1,k=k,X=X,link="global",disc=TRUE,
                              multi=multi0,disp=TRUE,tol=10^-4,
                              out_se=TRUE,Zbe=Zbe, Zga=Zga, zga=zga)
outc2$tht
outc2$Th
outc2$Ths
outc2$Bec
outc2$Becs
outc2$gac
outc2$gacs

## End(Not run)

est_multi_poly_within  
*Estimate latent class item response theory (LC-IRT) models for dichotomous and polytomous responses under within-item multidimensionality*

### Description

The function performs maximum likelihood estimation of the parameters of the two-tier IRT models assuming a discrete distribution for the ability and within-item multidimensionality. Every ability level corresponds to a latent class of subjects in the reference population. The class of models is based on a particular within-item multidimensional formulation with each item loading on at most two uncorrelated latent variables. Maximum likelihood estimation is based on the Expectation-Maximization algorithm.
est_multi_poly_within

Usage

est_multi_poly_within(S, yv = rep(1, ns), k1, k2, X = NULL,
start = c("deterministic","random","external"), link = c("global",
"local"), disc = FALSE, difl = FALSE, multi1, multi2, Phi = NULL,
galt = NULL, ga2t = NULL, De1 = NULL, De2 = NULL, fort = FALSE,
tol = 10^-10, maxitc = 10^4, disp = FALSE, output = FALSE,
out_se = FALSE, glob = FALSE, Zth1 = NULL, zth1 = NULL, Zth2=NULL,
zth2=NULL, Zbe=NULL, zbe=NULL, Zga1=NULL, zga1=NULL, Zga2=NULL,
zga2=NULL)

Arguments

S matrix of all response sequences observed at least once in the sample and listed
row-by-row (use NA for missing responses)
yv vector of the frequencies of every response configuration in S
k1 number of ability levels (or latent classes) for the 1st latent variable
k2 number of ability levels (or latent classes) for the 2nd latent variable
X matrix of covariates that affects the weights
start method of initialization of the algorithm
link type of link function ("global" for global logits, "local" for local logits); with
global logits a graded response model results; with local logits a partial credit
model results (with dichotomous responses, global logits is the same as using
local logits resulting in the Rasch or the 2PL model depending on the value
assigned to disc)
disc indicator of constraints on the discriminating indices (FALSE = all equal to one,
TRUE = free)
difl indicator of constraints on the difficulty levels (FALSE = free, TRUE = rating
scale parametrization); difl = TRUE is only admitted in the presence of items
with the same number of categories
multi1 matrix with a number of rows equal to the number of dimensions and elements
in each row equal to the indices of the items measuring the dimension corre-
spanding to that row for the 1st latent variable
multi2 matrix with a number of rows equal to the number of dimensions and elements
in each row equal to the indices of the items measuring the dimension corre-
spanding to that row for the 2nd latent variable
Phi initial value of the matrix of the conditional response probabilities (if start="external")
galt initial value of the vector of free discriminating indices (if start="external") for
the 1st latent variable
ga2t initial value of the vector of free discriminating indices (if start="external") for
the 2nd latent variable
De1 initial value of regression coefficients for the covariates (if start="external") af-
feciating the 1st latent variable
De2 initial value of regression coefficients for the covariates (if start="external") af-
feciating the 2nd latent variable
fort to use Fortran routines when possible
tol tolerance level for checking convergence of the algorithm as relative difference between consecutive log-likelihoods
maxitc maximum number of iterations of the algorithm
disp to display the likelihood evolution step by step
output to return additional outputs (Piv1, Piv2, Pp1, Pp2, lkv, Xlabel, XX1dis, XX2dis)
out_se to return standard errors
glob to use global logits in the covariates
Zth1 matrix for the specification of constraints on the support points for the 1st latent variable
zth1 vector for the specification of constraints on the support points for the 1st latent variable
Zth2 matrix for the specification of constraints on the support points for the 2nd latent variable
zth2 vector for the specification of constraints on the support points for the 2nd latent variable
Zbe matrix for the specification of constraints on the item difficulty parameters
zbe vector for the specification of constraints on the item difficulty parameters
Zga1 matrix for the specification of constraints on the item discriminating indices for the 1st latent variable
zga1 vector for the specification of constraints on the item discriminating indices for the 1st latent variable
Zga2 matrix for the specification of constraints on the item discriminating indices for the 2nd latent variable
zga2 vector for the specification of constraints on the item discriminating indices for the 2nd latent variable

Details
In order to ensure the model identifiability, the following conditions must hold. First, suitable constraints on the item parameters are required: one discriminanting index must be equal to 1 and one difficulty parameter must be equal to 0 for each dimension. The constrained items may be chosen in an arbitrary way: by default the algorithm selects the first element of each row of multi1 and multi2. As a consequence, the user must pay attention to specify matrices multi1 and multi2 so that different items are constrained for each dimension. Second, the maximum number of items shared by the two latent variables is equal to the total number of items minus one, that is, the union of rows of multi1 must differ from the union of rows of multi2. These conditions may be skipped specifying in a suitable way the entries of Zth1, zth1, Zth2, zth2, Zbe, zbe, Zga1, zga1, Zga2, and zga2, according to the following equations:

\[
\begin{align*}
Th1 &= Zth1 \times th1t + zth1 \\
Th2 &= Zth2 \times th2t + zth2 \\
Bec &= Zbe \times bet + zbe \\
galc &= Zga1 \times gal1t + zga1
\end{align*}
\]
\[ ga2c = Zga2 \%*\% ga2t + zga2, \]

where \( Th1, Th2, Bec, ga1c, ga2c \) denote the complete matrices/vectors of support points (\( Th1, Th2 \)), item difficulties (\( Bec \)), and item discriminating indices (\( ga1c, ga2c \)), whereas \( th1t, th2t, bet, ga1t, ga2t \) are the corresponding matrices/vectors of free (i.e., unconstrained) parameters.

**Value**

- **piv1**: estimated vector of weights of the latent classes (average of the weights in case of model with covariates) for the 1st latent variable
- **piv2**: estimated vector of weights of the latent classes (average of the weights in case of model with covariates) for the 2nd latent variable
- **fv1**: vector indicating the reference item chosen for each latent dimension for the 1st latent variable
- **fv2**: vector indicating the reference item chosen for each latent dimension for the 2nd latent variable
- **th1t**: estimated matrix of free ability levels for each dimension and for the 1st latent variable
- **th2t**: estimated matrix of free ability levels for each dimension and for the 2nd latent variable
- **Th1**: complete matrix of free and constrained ability levels for each dimension and latent class for the 1st latent variable
- **Th2**: complete matrix of free and constrained ability levels for each dimension and latent class for the 2nd latent variable
- **bet**: estimated vector of free difficulty levels for every item (split in two vectors if \( \text{difl}=\text{TRUE} \))
- **Bec**: complete vector of free and constrained difficulty levels for every item (split in two vectors if \( \text{difl}=\text{TRUE} \))
- **ga1t**: estimated vector of free discriminating indices for every item (with all elements equal to 1 if \( \text{disc}=\text{FALSE} \)) for the 1st latent variable
- **ga2t**: estimated vector of free discriminating indices for every item (with all elements equal to 1 if \( \text{disc}=\text{FALSE} \)) for the 2nd latent variable
- **ga1c**: complete vector of free and constrained discriminating indices for every item for the 1st latent variable (with all elements equal to 1 if \( \text{disc}=\text{FALSE} \) and NA for items that do not load on the 1st latent variable)
- **ga2c**: complete vector of free and constrained discriminating indices for every item for the 2nd latent variable (with all elements equal to 1 if \( \text{disc}=\text{FALSE} \) and NA for items that do not load on the 2nd latent variable)
- **De1**: matrix of regression coefficients for the multinomial (or global if \( \text{glob}=\text{TRUE} \)) logit model on the class weights for the 1st latent variable
- **De2**: matrix of regression coefficients for the multinomial (or global if \( \text{glob}=\text{TRUE} \)) logit model on the class weights for the 2nd latent variable
- **Phi**: array of the conditional response probabilities for every item and each of the \( k1*k2 \) latent classes
**1k** log-likelihood at convergence of the EM algorithm

**np** number of free parameters

**aic** Akaike Information Criterion index

**bic** Bayesian Information Criterion index

**ent** entropy index to measure the separation of classes

**piv1s** estimated vector of (ordered) weights of the latent classes (average of the weights in case of model with covariates) for the 1st standardized latent variable

**piv2s** estimated vector of (ordered) weights of the latent classes (average of the weights in case of model with covariates) for the 2nd standardized latent variable

**Th1s** standardized ability levels for the 1st latent variable, ordered according to the first dimension

**Th2s** standardized ability levels for the 2nd latent variable, ordered according to the first dimension

**Becs** standardized values of item difficulty parameters

**ga1cs** standardized values of item discriminating indices for the 1st latent variable

**ga2cs** standardized values of item discriminating indices for the 2nd latent variable

**call** call of function

**Pp1** matrix of the posterior probabilities for each response configuration and latent class for the 1st latent variable (if output=TRUE)

**Pp2** matrix of the posterior probabilities for each response configuration and latent class for the 2nd latent variable (if output=TRUE)

**lkv** vector to trace the log-likelihood evolution across iterations (if output=TRUE)

**Xlabel** structure of the design matrix, for internal use (if output=TRUE)

**XX1dis** design matrix for the covariates affecting the 1st latent variable (if output=TRUE)

**XX2dis** design matrix for the covariates affecting the 2nd latent variable (if output=TRUE)

**Piv1** matrix of the weights for every covariate pattern configuration for the 1st latent variable (if output=TRUE)

**Piv2** matrix of the weights for every covariate pattern configuration for the 2nd latent variable (if output=TRUE)

**seth1t** standard errors for vector th1t (if out_se=TRUE)

**seth2t** standard errors for vector th2t (if out_se=TRUE)

**seTh1** standard errors for vector Th1 (if out_se=TRUE)

**seTh2** standard errors for vector Th2 (if out_se=TRUE)

**sebet** standard errors for vector bet (if out_se=TRUE)

**seBec** standard errors for vector Bec (if out_se=TRUE)

**sega1t** standard errors for vector ga1t (if out_se=TRUE)

**sega2t** standard errors for vector ga2t (if out_se=TRUE)

**sega1c** standard errors for vector ga1c (if out_se=TRUE)

**sega2c** standard errors for vector ga2c (if out_se=TRUE)

**seDe1** standard errors for vector De1 (if out_se=TRUE)

**seDe2** standard errors for vector De2 (if out_se=TRUE)

**Vnt** estimated variance-covariance matrix for free parameters (if out_se=TRUE)

**Vn** complete variance-covariance matrix for all parameters (if out_se=TRUE)
Author(s)
Francesco Bartolucci, Silvia Bacci - University of Perugia (IT)

References


Examples
```r
## Not run:
# Fit the model under different within-item multidimensional structures
# for SF12_nomiss data
data(SF12_nomiss)
S = SF12_nomiss[,1:12]
X = SF12_nomiss[,13]

# Graded response model with two latent variables sharing six items (free
discrimination and difficulty parameters; two latent classes for each
# latent variable; one covariate):
multi1 = c(1:5, 8:12)
multi2 = c(6:12, 1)
tol = 10^-6 # decrease tolerance to obtain more reliable results
out1 = est_multi_poly_within(S=S,k1=2,k2=2,X=X,link="global",disc=TRUE,
multi1=multi1,multi2=multi2,disp=TRUE,
out_se=TRUE,tol=tol)

# Partial credit model with two latent variables sharing eleven items
# (free discrimination and difficulty parameters; two latent classes for
# the 1st latent variable and three latent classes for the 2nd latent
# variable; one covariate):
multi1 = 1:12
multi2 = 2:12
out2 = est_multi_poly_within(S=S,k1=2,k2=3,X=X,link="local",disc=TRUE,
multi1=multi1,multi2=multi2,disp=TRUE,tol=tol)

# Display output:
```

summary(out2)
out2$lk
out2$Th1
out2$Th1s
out2$piv1
out2$Th2
out2$Th2s
out2$piv2
out2$De1
out2$De2

## End(Not run)

## Not run:
## Fit the model under different situations for RLMS data
# Example of use of the function to account for non-ignorable missing
# item responses
data(RLMS)
X = RLMS[,1:4]
Y = RLMS[,6:9]
YR = cbind(Y,1*(!is.na(Y)))
multi1 = 1:4
multi2 = 5:8
tol = 10^-6 # decrease tolerance to obtain more reliable results

# MAR model
out0 = est_multi_poly_within(YR,k1=3,k2=2,X=X,link="global",
        disc=TRUE,multi1=multi1,multi2=multi2,disp=TRUE,
        out_se=TRUE,glob=TRUE,tol=tol)

# NMAR model
multi1 = 1:8
out1 = est_multi_poly_within(YR,k1=3,k2=2,X=X,link="global",
        disc=TRUE,multi1=multi1,multi2=multi2,disp=TRUE,
        out_se=TRUE,glob=TRUE,tol=tol)

# testing effect of the latent trait on missingness
c(out0$bic,out1$bic)
(test1 = out1$ga1c[-1]/out1$sega1c[-1])

## End(Not run)

## Not run:
## Fit the model under different external constraints on abilities and/or item parameters
data(SF12_nomiss)
S = SF12_nomiss[,1:12]
X = SF12_nomiss[,13]
multi1m = rbind(1:5, 8:12) # two dimensions for the 1st latent variable
multi2m = rbind(6:9, c(10:12, 1)) # two dimensions for the 2nd latent variable
k1 = 2
k2 = 2

# Fixed ability levels; all item parameters can be free
Zth1 = matrix(0, nrow(multi1m)*k1, 0)
zth1 = c(rep(-1, times=nrow(multi1m)), rep(1, times=nrow(multi1m)))
Zth2 = matrix(0, nrow(multi2m)*k2, 0)
zth2 = c(rep(-1, times=nrow(multi2m)), rep(1, times=nrow(multi2m)))

# item difficulties: 10*4 + 2*2 = 44 (10 items with 5 categories plus 2 items with 3 categories)
Zbe = diag(44)

# item discriminating parameters = 10 items loading on the 1st latent variable plus 8 items loading
# on the 2nd latent variable
Zga1 = diag(10); Zga2 = diag(8)
zga1 = rep(0, nrow(Zga1)); zga1[1] = 1
zga2 = rep(0, nrow(Zga2)); zga2[1] = 1

out1c = est_multi_poly_within(S=S, k1=k1, k2=k2, X=X, link="global", disc=TRUE, multi1=multi1m, multi2=multi2m, disp=TRUE, out_se=TRUE, Zth1=Zth1, zth1=zth1, Zth2=Zth2, zth2=zth2, Zbe=Zbe, Zga1=Zga1, zga1=zga1, Zga2=Zga2, zga2=zga2)

summary(out1c)

out1c$Bec

# Constraint difficulties of the first threshold to be equal for all items
# and difficulties of the second threshold to be equal for all items;
# free ability levels
multi1u = c(1:3, 6:10) # one dimension for the 1st latent variable
multi2u = c(4:10, 1) # one dimension for the 2nd latent variable
S1 = pmin(as.matrix(S[, -c(2,3)]), 2) # all items have the same number of categories
Zbe = as.matrix((matrix(1, 2, 1) %x% diag(10))[, -1])

out2c = est_multi_poly_within(S=S1, k1=2, k2=2, X=X, link="global", disc=TRUE, multi1=multi1u, multi2=multi2u, disp=TRUE, out_se=TRUE, Zbe=Zbe)

out2c$Bec

# Same difficulties for pairs of items 1-6, 2-7, 3-8, 4-9, 5-10;
# free ability levels
Zbe = (matrix(1, 2, 1) %x% diag(10))[, -1]

out3c = est_multi_poly_within(S=S1, k1=2, k2=2, X=X, link="global", disc=TRUE, multi1=multi1u, multi2=multi2u, disp=TRUE, out_se=TRUE, Zbe=Zbe)

out3c$Bec

# Add equality constraints on some discriminating indices for the 1st latent variable
Zbe = (matrix(1, 2, 1) %x% diag(10))[, -1]

out4c = est_multi_poly_within(S=S1, k1=2, k2=2, X=X, link="global", disc=TRUE, multi1=multi1u, multi2=multi2u, disp=TRUE, tol=10^-4, out_se=TRUE, Zbe=Zbe, Zga1=Zga1, zga1=zga1)

out4c$Bec
out4c$ga1c
out4c$ga1t

## End(Not run)
lk_obs_score_between  Compute observed log-likelihood and score

Description

Function used within est_multi_poly_between to compute observed log-likelihood and score.

Usage

lk_obs_score_between(part_comp, lde, lpart, lgat, S, R, yv, k, rm, lv,
J, fv, disc, glob, refitem, miss,
ltype, XXdis, Xlabel, ZZ0, fort, Zpar, zpar, Zga, zga, items)

Arguments

part_comp  complete vector of parameters
lde  length of de
lpart  length of part
lgat  length of gat
S  matrix of responses
R  matrix of observed responses indicator
yv  vector of frequencies
k  number of latent classes for the latent variable
rm  number of dimensions for the latent variable
lv  number of response categories for each item
J  number of items
fv  indicator of constrained parameters
disc  presence of discrimination parameters
glob  indicator of global parametrization for the covariates
refitem  vector of reference items
miss  indicator of presence of missing responses
ltype  type of logit
XXdis  array of covariates for the latent variable
Xlabel  indicator for covariate configuration
ZZ0  design matrix
fort  to use Fortran
Zpar  array for the specification of constraints on the support points of the latent variable and for the item difficulty parameters
zpar  vector for the specification of constraints on the support points of the latent variable and for the item difficulty parameters
Zga  matrix for the specification of constraints on the item discriminating indices
zga  vector for the specification of constraints on the item discriminating indices
items  items affected by the latent variable
**lk_obs_score_within**

**Value**
- **lk**: log-likelihood function
- **sc**: score vector

**Author(s)**
Francesco Bartolucci - University of Perugia (IT)

---

**lk_obs_score_within**  *Compute observed log-likelihood and score*

**Description**
Function used within est_multi_poly_within to compute observed log-likelihood and score.

**Usage**
```
lk_obs_score_within(part_comp, lde1, lde2, lpart, lgalt, lgat2, S, R, yv, k1, k2, 
rm1, rm2, lv, J, fv, disc, glob, refitem, miss, ltype, XX1dis, XX2dis, 
Xlabel, ZZ0, fort, Zpar, zpar, Zga1, zga1, Zga2, zga2, items1, items2)
```

**Arguments**
- **part_comp**: complete vector of parameters
- **lde1**: length of de1
- **lde2**: length of de2
- **lpart**: length of part
- **lgalt**: length of ga1t
- **lgat2**: length of ga2t
- **S**: matrix of responses
- **R**: matrix of observed responses indicator
- **yv**: vector of frequencies
- **k1**: number of latent classes for the 1st latent variable
- **k2**: number of latent classes for the 2nd latent variable
- **rm1**: number of dimensions for the 1st latent variable
- **rm2**: number of dimensions for the 2nd latent variable
- **lv**: number of response categories for each item
- **J**: number of items
- **fv**: indicator of constrained parameters
- **disc**: presence of discrimination parameters
- **glob**: indicator of global parametrization for the covariates
refitem  vector of reference items
miss   indicator of presence of missing responses
ltype  type of logit
XX1dis array of covariates for the 1st latent variable
XX2dis array of covariates for the 2nd latent variable
Xlabel indicator for covariate configuration
ZZ0    design matrix
fort   to use Fortran
Zpar   array for the specification of constraints on the support points of the 1st and the 2nd latent variable and for the item difficulty parameters
zpar   vector for the specification of constraints on the support points of the 1st and the 2nd latent variable and for the item difficulty parameters
Zga1   matrix for the specification of constraints on the item discriminating indices for the 1st latent variable
zga1   vector for the specification of constraints on the item discriminating indices for the 1st latent variable
Zga2   matrix for the specification of constraints on the item discriminating indices for the 2nd latent variable
zga2   vector for the specification of constraints on the item discriminating indices for the 2nd latent variable
items1 items affected by the 1st latent variable
items2 items affected by the 2nd latent variable

Value

lk      log-likelihood function
sc      score vector

Author(s)

Francesco Bartolucci - University of Perugia (IT)

---

**logLik.est_multi_poly_between**

Display the log-likelihood at convergence of est_multi_poly_between object

---

**Description**

Given the output from est_multi_poly_between, the log-likelihood at convergence is displayed
Usage

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

Arguments

- `object`: output from `est_multi_poly_between`
- `...`: further arguments passed to or from other methods

Author(s)

Francesco Bartolucci - University of Perugia (IT)

---

**Description**

Given the output from `est_multi_poly_within`, the log-likelihood at convergence is displayed

Usage

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

Arguments

- `object`: output from `est_multi_poly_within`
- `...`: further arguments passed to or from other methods

Author(s)

Francesco Bartolucci - University of Perugia (IT)
print.est_multi_poly_between

*Print the output of est_multi_poly_between object*

Description

Given the output from est_multi_poly_between, the call of it is written

Usage

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

Arguments

- **x**
  - output from est_multi_poly_between
- **...**
  - further arguments passed to or from other methods

Author(s)

Francesco Bartolucci - University of Perugia (IT)

print.est_multi_poly_within

*Print the call of est_multi_poly_within object*

Description

Given the output from est_multi_poly_within, the call of it is written

Usage

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

Arguments

- **x**
  - output from est_multi_poly_within
- **...**
  - further arguments passed to or from other methods

Author(s)

Francesco Bartolucci - University of Perugia (IT)
**prob_multi_glob_gen**  
*Global probabilities*

**Description**

It provides matrix of probabilities under different parametrizations and for the case of response variables having a different number of categories.

**Usage**

\[\text{prob_multi_glob_gen}(X, \text{model}, \text{be}, \text{ind}=(1:\text{dim}(X)[3]))\]

**Arguments**

- **X**
  array of all distinct covariate configurations
- **model**
  type of logit (g = global, l = local, m = multinomial)
- **be**
  initial vector of regression coefficients
- **ind**
  vector to link responses to covariates

**Value**

- **Pdis**
  matrix of distinct probability vectors
- **P**
  matrix of the probabilities for each covariate configuration

**Author(s)**

Francesco Bartolucci - University of Perugia (IT)

**References**


Description
This dataset contains the data about job satisfaction described in: Bartolucci, F., Bacci, S., and Gnaldi, M. (2015), Statistical Analysis of Questionnaires: A Unified Approach Based on R and Stata, Chapman and Hall/CRC press

Usage
data(RLMS)

Format
A data frame with 1485 observations about four polytomous items with covariates:

marital  marital status of the respondent
education  educational level of the respondent
gender  gender of the respondent
age  age of the respondent
work  work status of the respondent
Y1  1st item response
Y2  2nd item response
Y3  3rd item response
Y4  4th item response

References

Examples
data(RLMS)
## maybe str(RLMS)
str(RLMS)
**search.model_between**

Search for the global maximum of the log-likelihood of between-item multidimensional models

**Description**

It searches for the global maximum of the log-likelihood of between-item multidimensional models given a vector of possible number of classes to try for.

**Usage**

```r
search.model_between(S, yv = rep(1, ns), kv, X = NULL, 
  link = c("global","local"), disc = FALSE, dif1 = FALSE, 
  multi = 1:J, fort = FALSE, tol1 = 10^-6, tol2 = 10^-10, 
  glob = FALSE, disp = FALSE, output = FALSE, 
  out_se = FALSE, nrep = 2, Zth=NULL,zth=NULL, 
  Zbe=NULL, zbe=NULL,Zga=NULL,zga=NULL)
```

**Arguments**

- **S** matrix of all response sequences observed at least once in the sample and listed row-by-row (use NA for missing responses)
- **yv** vector of the frequencies of every response configuration in S
- **kv** vector of the possible numbers of latent classes
- **X** matrix of covariates affecting the weights
- **link** type of link function ("global" for global logits, "local" for local logits); with global logits a graded response model results; with local logits a partial credit model results (with dichotomous responses, global logits is the same as using local logits resulting in the Rasch or the 2PL model depending on the value assigned to disc)
- **disc** indicator of constraints on the discriminating indices (FALSE = all equal to one, TRUE = free)
- **dif1** indicator of constraints on the difficulty levels (FALSE = free, TRUE = rating scale parametrization)
- **multi** matrix with a number of rows equal to the number of dimensions and elements in each row equal to the indices of the items measuring the dimension corresponding to that row for the latent variable
- **fort** to use Fortran routines when possible
- **tol1** tolerance level for checking convergence of the algorithm as relative difference between consecutive log-likelihoods (initial check based on random starting values)
- **tol2** tolerance level for checking convergence of the algorithm as relative difference between consecutive log-likelihoods (final convergence)
- **glob** to use global logits in the covariates
disp to display the likelihood evolution step by step
output to return additional outputs (Piv,Pp,lkv)
out_se to return standard errors
nrep number of repetitions of each random initialization
Zth matrix for the specification of constraints on the support points
zth vector for the specification of constraints on the support points
Zbe matrix for the specification of constraints on the item difficulty parameters
zbe vector for the specification of constraints on the item difficulty parameters
Zga matrix for the specification of constraints on the item discriminating indices
zga vector for the specification of constraints on the item discriminating indices

Value
out.single output of each single model for each k in kv; it is similar to output from est_multi_poly_between, with the addition of values of number of latent classes (k) and the sequence of log-likelihoods (lktrace) for the deterministic start, for each random start, and for the final estimation obtained with a tolerance level equal to tol2
aicv Akaike Information Criterion index for each k in kv
bicv Bayesian Information Criterion index for each k in kv
entv Entropy index for each k in kv
necv NEC index for each k in kv
lkv log-likelihood at convergence of the EM algorithm for each k in kv
errv trace of any errors occurred during the estimation process for each k in kv

Author(s)
Francesco Bartolucci, Silvia Bacci - University of Perugia (IT)

References

Examples
## Not run:
# Fit a Graded response model with two latent variables (free discrimination and difficulty parameters; two latent classes):
data(SF12_nomiss)
S = SF12_nomiss[,1:12]
X = SF12_nomiss[,13]
multi0 = rbind(c(1:5, 8), c(6:7,9:12))
out1 = search.model_between(S=S,kv=1:3,X=X,link="global",disc=TRUE,
multi=multi0,fort=TRUE,disp=TRUE,out_se=TRUE)
search.model_within

# Display output
out1$lkv
out1$bicv

# Display output with 2 classes:
out1$out.single[[2]]$lktrace
out1$out.single[[2]]$Th
out1$out.single[[2]]$piv
out1$out.single[[2]]$gac
out1$out.single[[2]]$Bec

## End(Not run)

search.model_within

Search for the global maximum of the log-likelihood of within-item multidimensional models

Description

It searches for the global maximum of the log-likelihood of within-item multidimensional models given a vector of possible number of classes to try for.

Usage

search.model_within(S, yv = rep(1, ns), kv1, kv2, X = NULL,
        link = c("global","local"), disc = FALSE, difl = FALSE,
        multi1, multi2, fort = FALSE, tol1 = 10^-6, tol2 = 10^-10,
        glob = FALSE, disp = FALSE, output = FALSE, out_se = FALSE,
        nrep = 2, Zth1 = NULL, zth1 = NULL, Zth2=NULL, zth2=NULL,
        Zbe=NULL, zbe=NULL, Zga1=NULL, zga1=NULL, Zga2=NULL,
        zga2=NULL)

Arguments

S matrix of all response sequences observed at least once in the sample and listed row-by-row (use NA for missing responses)

yv vector of the frequencies of every response configuration in S

kv1 vector of the possible numbers of ability levels (or latent classes) for the 1st latent variable

kv2 vector of the possible numbers of ability levels (or latent classes) for the 2nd latent variable

X matrix of covariates affecting the weights
link: type of link function ("global" for global logits, "local" for local logits); with global logits a graded response model results; with local logits a partial credit model results (with dichotomous responses, global logits is the same as using local logits resulting in the Rasch or the 2PL model depending on the value assigned to disc)

disc: indicator of constraints on the discriminating indices (FALSE = all equal to one, TRUE = free)

dif1: indicator of constraints on the difficulty levels (FALSE = free, TRUE = rating scale parametrization)

multi1: matrix with a number of rows equal to the number of dimensions and elements in each row equal to the indices of the items measuring the dimension corresponding to that row for the 1st latent variable

multi2: matrix with a number of rows equal to the number of dimensions and elements in each row equal to the indices of the items measuring the dimension corresponding to that row for the 2nd latent variable

fort: to use Fortran routines when possible

tol1: tolerance level for checking convergence of the algorithm as relative difference between consecutive log-likelihoods (initial check based on random starting values)

tol2: tolerance level for checking convergence of the algorithm as relative difference between consecutive log-likelihoods (final convergence)

glob: to use global logits in the covariates

disp: to display the likelihood evolution step by step

output: to return additional outputs (Piv,Pp,lkv)

out_se: to return standard errors

nrep: number of repetitions of each random initialization

Zth1: matrix for the specification of constraints on the support points for the 1st latent variable

zth1: vector for the specification of constraints on the support points for the 1st latent variable

Zth2: matrix for the specification of constraints on the support points for the 2nd latent variable

zth2: vector for the specification of constraints on the support points for the 2nd latent variable

Zbe: matrix for the specification of constraints on the item difficulty parameters

zbe: vector for the specification of constraints on the item difficulty parameters

Zga1: matrix for the specification of constraints on the item discriminating indices for the 1st latent variable

zga1: vector for the specification of constraints on the item discriminating indices for the 1st latent variable

Zga2: matrix for the specification of constraints on the item discriminating indices for the 2nd latent variable

zga2: vector for the specification of constraints on the item discriminating indices for the 2nd latent variable
search.model_within

Value

**out.single**
output of each single model for each k in kv1 and kv2; it is similar to output from est_multi_poly_within, with the addition of values of number of latent classes for the 1st latent variable (k1) and the 2nd latent variable (k2) and the sequence of log-likelihoods (lktrace) for the deterministic start, for each random start, and for the final estimation obtained with a tolerance level equal to tol2

**aicv**
Akaike Information Criterion index for each k in kv1 and kv2

**bicv**
Bayesian Information Criterion index for each k in kv1 and kv2

**entv**
Entropy index for each k in kv1 and kv2

**necv**
NEC index for each k in kv1 and kv2

**lkv**
log-likelihood at convergence of the EM algorithm for each k in kv1 and kv2

**errv**
trace of any errors occurred during the estimation process for each k in kv1 and kv2

Author(s)

Francesco Bartolucci, Silvia Bacci - University of Perugia (IT)

References


Examples

```r
## Not run:
# Fit the model under different within-item multidimensional structures
# for SF12_nomiss data
data(SF12_nomiss)
S = SF12_nomiss[,1:12]
X = SF12_nomiss[,13]

# Partial credit model with two latent variables sharing six items
# (free difficulty parameters and constrained discriminating parameters;
# 1 to 3 latent classes for the 1st latent variable and 1 to 2 classes for the 2nd latent variable;
# one covariate):
multi1 = c(1:5, 8:12)
multi2 = c(6:12, 1)
out1 = search.model_within(S=S,kv1=1:3,kv2=1:2,X=X,link="global",disc=FALSE,
multi1=multi1,multi2=multi2,disp=TRUE,
out_se=TRUE,tol1=10^-4, tol2=10^-7, nrep=1)

# Main output
out1$lkv
out1$aicv
out1$bicv

# Model with 2 latent classes for each latent variable
out1$out.single[[4]]$k1
```
This data set contains the responses of 620 oncological patients to 12 ordinal polytomous items that measure the health-related quality of life, according to the Italian release of Short-Form 12 version 2 (SF-12v2); patient’s age is also provided.

Usage

data(SF12)

Format

A dataframe with 620 observations on 12 items and one covariate:

Y1  general health
Y2  limits in moderate activities
Y3  limits in climbing several flights of stairs
Y4  accomplished less than he/she would like, as a result of his/her physical health
Y5  limited in the kind of work or daily activities, as a result of his/her physical health
Y6  accomplished less than he/she would like, as a result of his/her emotional health
Y7  did work less carefully than usual, as a result of his/her emotional health
Y8  how much did pain interfere with normal work
Y9  how much of the time have he/she felt calm and peaceful
Y10 how much of the time did he/she have a lot of energy
Y11 how much of the time have he/she felt downhearted and depressed
Y12 how much of the time physical health or emotional health interfered with social activities

age  age of the respondent
Details

All items have 5 response categories, with the exception of items Y2 and Y3 having 3 response categories: the minimum value 0 correspond to a low level of quality of life, whereas the maximum value corresponds to a high level of quality of life. A proportion of 0.205 patients (127 out of 620) has missing responses (NA) on one or more items.

References


Examples

data(SF12)
dim(SF12)
## maybe str(SF12)
str(SF12)

SF12_nomiss

*SF12 dataset without missing responses*

Description

This data set contains the responses of 493 oncological patients to 12 ordinal polytomous items that measure the health-related quality of life, according to the Italian release of Short-Form 12 version 2 (SF-12v2); patient’s age is also provided.

Usage

data(SF12)

Format

A dataframe with 493 observations on 12 items and one covariate:

Y1  general health
Y2  limits in moderate activities
Y3  limits in climbing several flights of stairs
Y4  accomplished less than he/she would like, as a result of his/her physical health
Y5  limited in the kind of work or daily activities, as a result of his/her physical health
Y6  accomplished less than he/she would like, as a result of his/her emotional health
Y7  did work less carefully than usual, as a result of his/her emotional health
Y8  how much did pain interfere with normal work
Y9  how much of the time have he/she felt calm and peaceful
Y10 how much of the time did he/she have a lot of energy
Y11 how much of the time have he/she felt downhearted and depressed
Y12 how much of the time physical health or emotional health interfered with social activities
age age of the respondent

Details

All items have 5 response categories, with the exception of items Y2 and Y3 having 3 response
categories: the minimum value 0 correspond to a low level of quality of life, whereas the maximum
value corresponds to a high level of quality of life. All records are complete.

References

Ware, J., Kosinski, M., Turner-Bowker, D. and Gandek, B. (2002), SF-12v2. How to score version
2 of the SF-12 health survey, QualityMetric Incorporated: Lincoln.

Examples

data(SF12_nomiss)
dim(SF12_nomiss)
## maybe str(SF12_nomiss)
str(SF12_nomiss)

summary.est_multi_poly_between

Print the output of est_multi_poly_between object

Description

Given the output from est_multi_poly_between, it is written in a readable form

Usage

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

Arguments

object output from est_multi_poly_between
...

further arguments passed to or from other methods

Author(s)

Francesco Bartolucci - University of Perugia (IT)
**summary.est_multi_poly_within**

*Print the output of est_multi_poly_within object*

**Description**

Given the output from est_multi_poly_within, it is written in a readable form.

**Usage**

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

**Arguments**

- `object` : output from est_multi_poly_within
- `...` : further arguments passed to or from other methods

**Author(s)**

Francesco Bartolucci - University of Perugia (IT)

---

**vcov.est_multi_poly_between**

*Display the estimated variance-and-covariance matrix of est_multi_poly_between object*

**Description**

Given the output from est_multi_poly_between, the estimated variance-and-covariance matrix is displayed.

**Usage**

```r
## S3 method for class 'est_multi_poly_between'
vcov(object, ...)
```

**Arguments**

- `object` : output from est_multi_poly_between
- `...` : further arguments passed to or from other methods

**Author(s)**

Francesco Bartolucci - University of Perugia (IT)
Display the estimated variance-and-covariance matrix of `est_multi_poly_within` object

### Description

Given the output from `est_multi_poly_within`, the estimated variance-and-covariance matrix is displayed.

### Usage

```r
## S3 method for class 'est_multi_poly_within'
vcov(object, ..., )
```

### Arguments

- **object**: output from `est_multi_poly_within`
- **...**: further arguments passed to or from other methods

### Author(s)

Francesco Bartolucci - University of Perugia (IT)
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