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Description Estimation of latent class models with individual covariates for capture-recapture data. See Bartolucci, F. and Forcina, A. (2022), Estimating the size of a closed population by modeling latent and observed heterogeneity, Biometrics, 80(2), ujae017.

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`LCCR-package` *Latent Class Capture-Recapture Models*

Description

Estimation of latent class models with individual covariates for capture-recapture data. See Bartolucci, F. and Forcina, A. (2022), Estimating the size of a closed population by modeling latent and observed heterogeneity, Biometrics, 80(2), ujae017.

Details

The package provides functions to specify latent class models for capture-recapture data with individual covariates, simulate data from the specified model and estimate it on the basis of observed data, including the possibility to obtain a profile confidence interval for the population size.

The latent class models may be specified by a log-linear or a recursive logit parametrization of the conditional distribution of the capture configurations given the latent class. The log-linear parametrization is based on main effects that may depend on some covariates and may include bivariate interaction terms. The recursive logit parametrization allows us to model the dependence of capture probabilities on previous capture history. Linear constraints on the model parameters may be assumed to make the model more parsimonious. Covariates may also affect the latent class weights by a Multinomial logit parametrization.

Estimation of the specified model is based on the unconditional likelihood method following the approach formalized in Forcina and Bartolucci (2021), which may be seen as a refinement of the one in Liu et al. (2017). The approach uses as additional parameters the weights associated to the different strata that are estimated together with the model parameters and the population size. Functions for constructing a profile confidence interval for the population size are provided; this proceduire is recommended as an alternative to using the normal approximation.

Functions for conditional maximum likelihood estimation as described in Bartolucci and Forcina (2006) are also included in the package.

Author(s)

Francesco Bartolucci [aut, cre], Antonio Forcina [aut]

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References

Bartolucci, F. and Forcina, A. (2006). Estimating the size of a closed population by modeling latent and observed heterogeneity. *Journal of the American Statistical Association*, **101**, 786-794.

Forcina, A. and Bartolucci, F. (2021). Estimating the size of a closed population by modeling latent and observed heterogeneity, *arXiv:2106.03811*.

Liu, Y., Li, P., and Qin, J. (2017). Maximum empirical likelihood estimation for abundance in a closed population from capture-recapture data. *Biometrika*, **104**, 527-543.

Examples

```
data(data_sim2)
# estimate latent class model with 2 classes, same main log-linear effect across lists,
# one covariate affecting the weights, and bivariate interaction between consecutive lists
est = estLCCR(Y=data_sim2$Y,H=2,W=data_sim2$W,biv=matrix(c(1,2,3,4,2,3,4,5),4),main="same")
est
# compute profile confidence interval
conf = confint(est)
conf
plot(conf)
```

---

aggr_data *Aggregate capture-recapture data*

Description

Given a matrix of individual capture configurations, and the corresponding matrix and array of covariates (affecting the class weights and the conditional capture probabilities given the latent class), the function aggregates data, providing a stratified capture-recapture format.

Usage

```
aggr_data(Y, W = NULL, X = NULL)
```

Arguments

Y	matrix of frequencies of capture configurations
W	matrix of covariates affecting the class weights
X	array of covariates affecting the conditional capture probabilities

Value

Ya	matrix of aggregated frequencies of capture configurations
Wa	matrix of aggregated covariates affecting the class weights
Xa	array of aggregated covariates affecting the conditional capture probabilities

Author(s)

Francesco Bartolucci, Antonio Forcina

See Also

freq_data

Examples

```
# case without covariates
Y = rbind(c(0,1,0,0,0,0,0,0),c(0,0,0,1,0,0,0,0),c(0,0,0,0,0,0,1,0))
aggr_data(Y)

# case with covariates
W = c(1,1,2); X = as.matrix(c(0,0,2))
aggr_data(Y,W,X)
```

---

confint.estLCCR *Confidence interval*

Description

Profile confidence interval for a latent class model with covariates.

Usage

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

Arguments

object	output from estLCCR
parm	a list containing control arguments for the step length of the N values(step, default value depending on the estimate of N), range of N values in terms of distance of the log-likelihood from the its maximum (mult, default value 1.5), and maximum value of this grid as a multiple of the estimate of this parameter (max, default value 5)
level	the confidence level required
...	additional argument(s) for methods

Value

conf	confidence interval
Nv	vector of values of N tried
lkv	corresponding vector of log-likelihood values
level	level of confidence
Nh	point estimate of N
lkh	maximum log-likelihood values
lk1	log-likelihood value at the lower bound
lk2	log-likelihood value at the upper bound
step	step used in the grid search
err	error in the grid search

Author(s)

Francesco Bartolucci, Antonio Forcina

References

Forcina, A. and Bartolucci, F. (2021). Estimating the size of a closed population by modeling latent and observed heterogeneity, *arXiv:2106.03811*.

Liu, Y., Li, P., and Qin, J. (2017). Maximum empirical likelihood estimation for abundance in a closed population from capture-recapture data. *Biometrika*, **104**, 527-543.

See Also

estLCCR, plot.confLCCR

Examples

```
data(data_sim2)
est = estLCCR(Y=data_sim2$Y,H=2,W=data_sim2$W,biv=matrix(c(1,2,3,4,2,3,4,5),4),main="same")
conf = confint(est)
plot(conf)
```

---

confint.estLCCRcon *Confidence interval*

Description

Profile confidence interval for a latent class model with covariates based on the CML method.

Usage

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

Arguments

object	output from estLCCR
parm	a list containing control arguments for the step length of the N values(step, default value depending on the estimate of N), range of N values in terms of distance of the log-likelihood from the its maximum (mult, default value 1.5), and maximum value of this grid as a multiple of the estimate of this parameter (max, default value 5)
level	the confidence level required
...	additional argument(s) for methods

Value

conf	confidence interval
Nv	vector of values of N tried
lkv	corresponding vector of log-likelihood values
level	level of confidence
Nh	point estimate of N
devh	minimum deviance
dev1	deviance at the lower bound
dev2	deviance at the upper bound
step	step used in the grid search
err	error in the grid search

Author(s)

Francesco Bartolucci, Antonio Forcina

References

Bartolucci, F. and Forcina, A. (2006). Estimating the size of a closed population by modeling latent and observed heterogeneity. *Journal of the American Statistical Association*, **101**, 786-794.

See Also

estLCCR, plot.confLCCR

Examples

```
data(data_sim2)
est = estLCCRcon(Y=data_sim2$Y,H=2,W=data_sim2$W,biv=matrix(c(1,2,3,4,2,3,4,5),4),main="same")
conf = confint(est)
plot(conf)
```

data_sim1 *Simulated data 1*

Description

Simulated capture-recapture data from a latent class model with 2 classes having the same weight on 5 lists.

Usage

```
data(data_sim1)
```

Format

A matrix containing the capture configurations at individual level.

References

Forcina, A. and Bartolucci, F. (2021). Estimating the size of a closed population by modeling latent and observed heterogeneity, *arXiv:2106.03811*.

Examples

```
data(data_sim1)
est = estLCCR(Y=data_sim1,H=2)
```

data_sim2 *Simulated data 2*

Description

Simulated capture-recapture data from a latent class model with 2 classes, one covariate affecting the class weights, and bivariate loglinear interactions between consecutive lists.

Usage

```
data(data_sim2)
```

Format

A list containing capture configurations at individual level and corresponding covariates.

`Y` capture configurations

`W` values of the covariate affecting the class weights

References

Forcina, A. and Bartolucci, F. (2021). Estimating the size of a closed population by modeling latent and observed heterogeneity, *arXiv:2106.03811*.

Examples

```
data(data_sim2)
est = estLCCR(Y=data_sim2$Y,H=2,W=data_sim2$W,biv=matrix(c(1,2,3,4,2,3,4,5),4),main="same")
```

`data_sim3` *Simulated data 3*

Description

Simulated capture-recapture data from a latent class model with 3 classes, one covariate affecting the logits of each response, and lag dependence.

Usage

```
data(data_sim3)
```

Format

A list containing capture configurations at individual level and corresponding covariates.

`Y` capture configurations

`X` values of the covariate affecting the conditional capture probabilities given the latent class

References

Forcina, A. and Bartolucci, F. (2021). Estimating the size of a closed population by modeling latent and observed heterogeneity, *arXiv:2106.03811*.

Examples

```
data(data_sim3)
est = estLCCR(Y=data_sim3$Y,H=3,model="logit",X=data_sim3$X,flag="atleast")
```

data_sim4 *Simulated data 4*

Description

Simulated stratified capture-recapture data from a latent class model with 2 classes and covariates affecting both the class weights and the conditional capture probabilities given the latent class.

Usage

```
data(data_sim4)
```

Format

A list containing capture configurations at individual level and corresponding covariates.

`Y` capture configurations

`W` values of the covariate affecting the class weights

`X` values of the covariate affecting the conditional capture probabilities given the latent class

References

Forcina, A. and Bartolucci, F. (2021). Estimating the size of a closed population by modeling latent and observed heterogeneity, *arXiv:2106.03811*.

Examples

```
data(data_sim4)
est = estLCCR(Y=data_sim4$Y,H=2,X=data_sim4$X,W=data_sim4$W)
```

design_matrix_logit *Design matrix for recursive logit parametrization*

Description

For a latent class model for capture-recapture data, it provides design matrices for the recursive logit parametrization used to formulate the conditional distribution of capture configurations given the latent class. It is possible to include the effect of covariates and of previous captures.

Usage

```
design_matrix_logit(J, H = 1, main = c("LC", "same", "Rasch"), X = NULL,
                    free_cov = c("no", "class", "resp", "both"),
                    flag = c("no", "prev", "sum", "atleast"),
                    free_flag = c("no", "class", "resp", "both"))
```

Arguments

J	number of capture occasions
H	number of latent classes
main	"LC" for the latent class model in which there is a separate main effect for each capture occasion and latent class; "same" for the constrained model in which the main effect is the same across capture occasions but different across latent classes; "Rasch" for the constrained model in which each main effect is expressed in an additive form with a parameter related to the latent class and another parameter related to the capture occasion
X	array of covariates (n. strata x n. covariates x n. responses)
free_cov	"no" for constant effect of the covariates across capture occasions and latent classes; "class" for effect of covariates varying only with the latent class; "resp" for effect of covariates varying only with the capture occasion; "both" for effect of covariates varying with the capture occasion and the latent class
flag	"no" for no lag effect; "prev" for effect of the previous capture occasion only; "sum" for the effect of the sum of the previous capture occasions; "atleast" for the effect of at least one capture at the previous occasions
free_flag	"no" for constant effect of the previous capture occasions with respect to the occasion and the latent class; "class" for free effect only with respect to the latent class; "int" for free effect only with respect to the occasion; "both" for free effect with respect to capture occasion and latent class

Value

M	design matrices
par_list	list of parameter names
Main	list of capture configurations

Author(s)

Francesco Bartolucci, Antonio Foricna

References

Forcina, A. and Bartolucci, F. (2021). Estimating the size of a closed population by modeling latent and observed heterogeneity, *arXiv:2106.03811*.

See Also

design_matrix_loglin, matrix_logit, estLCCR

`design_matrix_loglin` *Design matrix for loglinear parametrization*

Description

For a latent class model for capture-recapture data, it provides design matrices for the loglinear parametrization used to formulate the conditional distribution of the capture configurations given the latent class. It is possible to include the effect of covariates and bivariate interactions.

Usage

```
design_matrix_loglin(J, H = 1, main = c("LC", "same", "Rasch"), X = NULL,
                     free_cov = c("no", "class", "resp", "both"),
                     biv = NULL, free_biv = c("no", "class", "int", "both"))
```

Arguments

`J`	number of capture occasions
`H`	number of latent classes
`main`	"LC" for the latent class model in which there is a separate main effect for each capture occasion and latent class; "same" for the constrained model in which the main effect is the same across capture occasions but different across latent classes; "Rasch" for the constrained model in which each main effect is expressed in an additive form with a parameter related to the latent class and another parameter related to the capture occasion
`X`	array of covariates (n. strata x n. covariates x n. responses)
`free_cov`	"no" for constant effect of the covariates across capture occasions and latent classes; "class" for effect of covariates varying only with the latent class; "resp" for effect of covariates varying only with the capture occasion; "both" for effect of covariates varying with the capture occasion and the latent class
`biv`	matrix with two columns containing the list of bivariate interactions
`free_biv`	"no" for constant bivariate interation effect with respect to the occasion and the latent class; "class" for free interaction with respect to the latent class; "int" for free effect only with respect to the interation; "both" for free effect with respect to interation and latent class

Value

`M`	design matrices
`par_list`	list of parameter names
`Main`	list of capture configurations

Author(s)

Francesco Bartolucci, Antonio Foricna

References

Forcina, A. and Bartolucci, F. (2021). Estimating the size of a closed population by modeling latent and observed heterogeneity, *arXiv:2106.03811*.

See Also

design_matrix_logit, estLCCR

---

estLCCR — *Estimate latent class models for capture-recapture data with individual covariates*

Description

For a latent class model for stratified capture-recapture data with individual covariates, it estimates the model on the basis of observed data by the unconditional likelihood method, exploiting weights associated to the different strata. Estimation of the model parameters, included the population size, is based on an EM algorithm.

Usage

```
estLCCR(Y, H, model = c("loglin", "logit"), W = NULL, X = NULL, N = NULL, biv = NULL,
        flag = c("no", "prev", "sum", "atleast"),
        main = c("LC", "same", "Rasch"),
        free_cov = c("no", "class", "resp", "both"),
        free_biv = c("no", "class", "int", "both"),
        free_flag = c("no", "class", "resp", "both"),
        N0 = NULL, beta0 = NULL, lambda0 = NULL, control = list(),
        verb = TRUE, init_rand = FALSE, se_out = FALSE)
```

Arguments

Y	matrix of frequencies for each stratum (by row)
H	number of latent classes
model	"loglin" for loglinear parametrization; "logit" for recursive logit parametrization
W	matrix of covariates on the class weights
X	array of covariates (n. strata x n. covariates x n. responses)
N	fixed population size
biv	matrix with two columns containing the list of bivariate interactions (for loglinear parametrization)
flag	"no" for no lag effect; "prev" for effect of the previous capture occasion only; "sum" for the effect of the sum of the previous capture occasions; "atleast" for the effect of at least one capture at the previous occasions (for recursive logit parametrization)

main	"LC" for the latent class model in which there is a separate main effect for each capture occasion and latent class; "same" for the constrained model in which the main effect is the same across capture occasions but different across latent classes; "Rasch" for the constrained model in which each main effect is expressed in an additive form with a parameter related to the latent class and another parameter related to the capture occasion
free_cov	"no" for constant effect of the covariates across capture occasions and latent classes; "class" for effect of covariates varying only with the latent class; "resp" for effect of covariates varying only with the capture occasion; "both" for effect of covariates varying with the capture occasion and the latent class
free_biv	"no" for constant bivariate interation effect with respect to the occasion and the latent class; "class" for free interaction with respect to the latent class; "int" for free effect only with respect to the interation; "both" for free effect with respect to interation and latent class (for loglinear parametrization)
free_flag	"no" for constant effect of the previous capture occasions with respect to the occasion and the latent class; "class" for free effect only with respect to the latent class; "int" for free effect only with respect to the occasion; "both" for free effect with respect to capture occasion and latent class (for recursive logit parametrization)
N0	initial value of the population size
beta0	initial value of the parameters affecting the class weights
lambda0	initial value of the parameters affecting the conditional distribution of capture configurations given the latent class
control	a list containing control arguments for the maximum number of iterations of the EM algorithm (maxit, default value 5000) and relative tollerance (reltol, default value 10^{-10})
verb	to have partial output during the model fitting
init_rand	to use a random initialization of the parameters
se_out	to require computation of the standard errors

Value

beta	estimate of the parameters affecting the class weights
lambda	estimate of the parameters affecting the conditional distribution of capture configurations given the latent class
lk	final log-likelihood value
N	estimate of the population size
np	number of free parameters
AIC	value of AIC for model selection
BIC	value of BIC for model selection
M	design matrices used for the recursive logit or loglinear parametrization of the conditional distribution of capture configurations given the latent class
tauv	estimate of the weights of each stratum

phiv	estimate of the probability of being never captured for each stratum
Piv	matrix of the probabilities of the latent classes for each stratum
Q	array of the conditional probabilities of the capture configurations given each latent class and stratum
seN	standard error for the estimate of N
sebeta	standard error for the estimate of beta
selambda	standard error for the estimate of lambda
lk1	component of the log-likelihood based on the binomial factor in N
lk2	component of the log-likelihood involving N and the overall probability of being never captured
lk3	component of the log-likelihood involving the capture probabilities
lk4	component of the log-likelihood involving the stratum weights

Author(s)

Francesco Bartolucci, Antonio Forcina

References

Forcina, A. and Bartolucci, F. (2021). Estimating the size of a closed population by modeling latent and observed heterogeneity, *arXiv:2106.03811*.

Liu, Y., Li, P., and Qin, J. (2017). Maximum empirical likelihood estimation for abundance in a closed population from capture-recapture data. *Biometrika*, **104**, 527-543.

See Also

design_matrix_logit, design_matrix_loglin, simLCCR

Examples

```
# estimate latent class model with 2 classes having the same weight on 5 lists
data(data_sim1)
est = estLCCR(Y=data_sim1,H=2)
est

# estimate latent class model with 2 classes, one covariate affecting the weights and bivariate
# loglinear interactions between consecutive lists
data(data_sim2)
est = estLCCR(Y=data_sim2$Y,H=2,W=data_sim2$W,biv=matrix(c(1,2,3,4,2,3,4,5),4),main="same")
est

# estimate latent class model with 3 classes, one covariate affecting the logits of each response,
# and lag dependence
data(data_sim3)
est = estLCCR(Y=data_sim3$Y,H=3,model="logit",X=data_sim3$X,flag="atleast")
est

# estimate latent class model with 2 classes and covariates affecting both the class weights and
```

```
# conditional capture probabilities given the latent class
data(data_sim4)
est = estLCCR(Y=data_sim4$Y,H=2,X=data_sim4$X,W=data_sim4$W)
est
```

`estLCCRcon` *CML estimation of latent class models for capture-recapture data with individual covariates*

Description

For a latent class model for stratified capture-recapture data with individual covariates, it estimates the model on the basis of observed data by the conditional likelihood method, exploiting weights associated to the different strata. Estimation of the model parameters, included the population size, is based on an EM algorithm.

Usage

```
estLCCRcon(Y, H, model = c("loglin", "logit"), W = NULL, X = NULL, N = NULL, biv = NULL,
        flag = c("no", "prev", "sum", "atleast"),
        main = c("LC", "same", "Rasch"),
        free_cov = c("no", "class", "resp", "both"),
        free_biv = c("no", "class", "int", "both"),
        free_flag = c("no", "class", "resp", "both"),
        beta0 = NULL, lambda0 = NULL, control = list(),
        verb = TRUE, init_rand = FALSE, se_out = FALSE)
```

Arguments

`Y`	matrix of frequencies for each stratum (by row)
`H`	number of latent classes
`model`	"loglin" for loglinear parametrization; "logit" for recursive logit parametrization
`W`	matrix of covariates on the class weights
`X`	array of covariates (n. strata x n. covariates x n. responses)
`N`	fixed population size
`biv`	matrix with two columns containing the list of bivariate interactions (for loglinear parametrization)
`flag`	"no" for no lag effect; "prev" for effect of the previous capture occasion only; "sum" for the effect of the sum of the previous capture occasions; "atleast" for the effect of at least one capture at the previous occasions (for recursive logit parametrization)

main	"LC" for the latent class model in which there is a separate main effect for each capture occasion and latent class; "same" for the constrained model in which the main effect is the same across capture occasions but different across latent classes; "Rasch" for the constrained model in which each main effect is expressed in an additive form with a parameter related to the latent class and another parameter related to the capture occasion
free_cov	"no" for constant effect of the covariates across capture occasions and latent classes; "class" for effect of covariates varying only with the latent class; "resp" for effect of covariates varying only with the capture occasion; "both" for effect of covariates varying with the capture occasion and the latent class
free_biv	"no" for constant bivariate interation effect with respect to the occasion and the latent class; "class" for free interaction with respect to the latent class; "int" for free effect only with respect to the interation; "both" for free effect with respect to interation and latent class (for loglinear parametrization)
free_flag	"no" for constant effect of the previous capture occasions with respect to the occasion and the latent class; "class" for free effect only with respect to the latent class; "int" for free effect only with respect to the occasion; "both" for free effect with respect to capture occasion and latent class (for recursive logit parametrization)
beta0	initial value of the parameters affecting the class weights
lambda0	initial value of the parameters affecting the conditional distribution of capture configurations given the latent class
control	a list containing control arguments for the maximum number of iterations of the EM algorithm (maxit, default value 5000) and relative tollerance (reltol, default value 10^{-10})
verb	to have partial output during the model fitting
init_rand	to use a random initialization of the parameters
se_out	to require computation of the standard errors

Value

beta	estimate of the parameters affecting the class weights
lambda	estimate of the parameters affecting the conditional distribution of capture configurations given the latent class
lk	final log-likelihood value
dev	final value of the deviance that is used to build confidence intervals
N	estimate of the population size
np	number of free parameters
AIC	value of AIC for model selection
BIC	value of BIC for model selection
M	design matrices used for the recursive logit or loglinear parametrization of the conditional distribution of capture configurations given the latent class
phiv	estimate of the probability of being never captured for each stratum

Piv	matrix of the probabilities of the latent classes for each stratum
Q	array of the conditional probabilities of the capture configurations given each latent class and stratum
seN	standard error for the estimate of N
sebeta	standard error for the estimate of beta
selambda	standard error for the estimate of lambda

Author(s)

Francesco Bartolucci, Antonio Forcina

References

Bartolucci, F. and Forcina, A. (2006). Estimating the size of a closed population by modeling latent and observed heterogeneity. *Journal of the American Statistical Association*, **101**, 786-794.

See Also

design_matrix_logit, design_matrix_loglin, simLCCR

Examples

```
# estimate latent class model with 2 classes having the same weight on 5 lists
data(data_sim1)
est = estLCCRcon(Y=data_sim1,H=2)
est

# estimate latent class model with 2 classes, one covariate affecting the weights and bivariate
# loglinear interactions between consecutive lists
data(data_sim2)
est = estLCCRcon(Y=data_sim2$Y,H=2,W=data_sim2$W,biv=matrix(c(1,2,3,4,2,3,4,5),4),main="same")
est

# estimate latent class model with 3 classes, one covariate affecting the logits of each response,
# and lag dependence
data(data_sim3)
est = estLCCRcon(Y=data_sim3$Y,H=3,model="logit",X=data_sim3$X,flag="atleast")
est

# estimate latent class model with 2 classes and covariates affecting both the class weights and
# conditional capture probabilities given the latent class
data(data_sim4)
est = estLCCRcon(Y=data_sim4$Y,H=2,X=data_sim4$X,W=data_sim4$W)
est
```

freq_data *Convert capture-recapture configurations into frequency data*

Description

Given a matrix of observed capture-recapture configurations, convert the data to a matrix of frequencies having the same number of rows and a number of columns equal to the number of possible configurations.

Usage

```
freq_data(R,count=rep(1,nrow(R)))
```

Arguments

R	Matrix of size n (sample size) x J (number of capture occastions) of observed capture-recapture configurations
count	Vector of counts for each configuration

Value

Y	Matrix of frequency of each capture configuration of size n x (2^J)

Author(s)

Francesco Bartolucci, Antonio Forcina

See Also

aggr_data

Examples

```
R = rbind(c(0,0,0,1),c(0,1,0,0),c(0,0,1,1),c(1,1,1,1),c(1,1,1,1))
Y = freq_data(R)
```

matrix_logit *Design matrices of saturated logit parametrization*

Description

For J binary responses, it provides design matrices A and B used to express the saturated recursive logit parametrization of type log(p) = [A*eta-B*log(1+exp(eta))].

Usage

```
matrix_logit(J)
```

Arguments

J	number of capture occasions

Value

A	first matrix involved in the recursive logit parametrization
B	second matrix involved in the recursive logit parametrization

Author(s)

Francesco Bartolucci, Antonio Foricna

References

Forcina, A. and Bartolucci, F. (2021). Estimating the size of a closed population by modeling latent and observed heterogeneity, *arXiv:2106.03811*.

See Also

matrix_logit, estLCCR

plot *Plot profile confidence interval*

Description

Plot for output from confint.estLCCR.

Usage

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

Arguments

x	an object of class condLCCR
...	further possible arguments

Value

M	matrix of binary configurations

Author(s)

Francesco Bartolucci, Antonio Forcina

Examples

```
data(data_sim2)
est = estLCCR(Y=data_sim2$Y,H=2,W=data_sim2$W,biv=matrix(c(1,2,3,4,2,3,4,5),4),main="same")
conf = confint(est)
plot(conf)
```

---

print *Print the output*

Description

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

Usage

```
## S3 method for class 'estLCCR'
print(x, ...)
## S3 method for class 'estLCCRcon'
print(x, ...)
## S3 method for class 'confLCCR'
print(x, ...)
```

Arguments

x	output from estLCCR, estLCCRcon or confint.estLCCR
...	further arguments passed to or from other methods

Value

No return value

Author(s)

Francesco Bartolucci, Antonio Forcina

simLCCR *Simulate capture-recapture data from a latent class model with individual covariates*

Description

The function simulates capture-recapture data from a latent class model with individual covariates that may affect the class weights and/or the conditional distribution of capture configurations given the latent class. The data may be in disaggregated form (with each stratum having unitary dimension) or aggregated form (with strata having generic dimension).

Usage

```
simLCCR(H, J, beta, lambda, N, model = c("loglin", "logit"), Wc = NULL, Xc = NULL,
        biv = NULL, flag = c("no", "prev", "sum", "atleast"),
        main = c("LC", "same", "Rasch"),
        free_cov = c("no", "class", "resp", "both"),
        free_biv = c("no", "class", "int", "both"),
        free_flag = c("no", "class", "resp", "both"))
```

Arguments

H	number of latent classes
J	number of capture occasions
beta	value of the parameters affecting the class weights
lambda	value of the parameters affecting the conditional distribution of capture configurations given the latent
N	population size (with individual data); vector containing the size of any stratum (with aggregated data)
model	population size (with individual data); vector containing the size of any stratum (with aggregated data)
Wc	matrix of covariates affecting the class weights at population level
Xc	array of covariates at population level (n. strata x n. covariates x n. responses)
biv	matrix with two columns containing the list of bivariate interactions (for loglinear parametrization)
flag	"no" for no lag effect; "prev" for effect of the previous capture occasion only; "sum" for the effect of the sum of the previous capture occasions; "atleast" for the effect of at least one capture at the previous occasions (for recursive logit parametrization)
main	"LC" for the latent class model in which there is a separate main effect for each capture occasion and latent class; "same" for the constrained model in which the main effect is the same across capture occasions but different across latent classes; "Rasch" for the constrained model in which each main effect is expressed in an additive form with a parameter related to the latent class and another parameter related to the capture occasion

free_cov	"no" for constant effect of the covariates across capture occasions and latent classes; "class" for effect of covariates varying only with the latent class; "resp" for effect of covariates varying only with the capture occasion; "both" for effect of covariates varying with the capture occasion and the latent class
free_biv	"no" for constant bivariate interation effect with respect to the occasion and the latent class; "class" for free interaction with respect to the latent class; "int" for free effect only with respect to the interation; "both" for free effect with respect to interation and latent class (for loglinear parametrization)
free_flag	"no" for constant effect of the previous capture occasions with respect to the occasion and the latent class; "class" for free effect only with respect to the latent class; "int" for free effect only with respect to the occasion; "both" for free effect with respect to capture occasion and latent class (for recursive logit parametrization)

Value

Y	matrix of frequencies for each stratum (by row), only for captured indivdiuals
Yc	matrix of frequencies for each stratum (by row), for all indivdiuals
Piv	matrix of class weights for each stratum
Q	matrix of the conditional distribution of capture configurations given the latent class
Pm	matrix of the distribution of the capture configurations (with aggregated data)
R	matrix of single capture occasions (with individual data), only for captured individuals
U	vector of latent classes (with individual data)
Rc	matrix of single capture occasions (with individual data), for all individuals
W	matrix of covariates affecting the class weights, only for captured individuals
X	array of covariates affecting the conditional distribution of capture configurations given the latent class, only for captured individuals

Author(s)

Francesco Bartolucci, Antonio Forcina

References

Forcina, A. and Bartolucci, F. (2021). Estimating the size of a closed population by modeling latent and observed heterogeneity, *arXiv:2106.03811*.

See Also

design_matrix_logit, design_matrix_loglin, estLCCR

Examples

```
# simulate data from latent class model with 2 classes having the same weight on 5 lists
out = simLCCR(2,5,be=0,la=c(rep(-1,5),rep(1,5)),N=200)

# simulate data from a latent class model with 2 classes, one covariate affecting the weights and
# bivariate loglinear interactions between consecutive lists
Wc = rnorm(200)
out = simLCCR(2,6,beta=c(0,1),lambda=c(-1,1,1),N=200,Wc=Wc,biv=matrix(c(1,2,3,4,2,3,4,5),4),
              main="same")

# simulate data from a latent class model with 3 classes, one covariate affecting the logits of
# each response, and lag dependence
Xc = rnorm(200)
out = simLCCR(3,6,model="logit",beta=c(0,0),lambda=c(rep(-1,6),rep(0,6),rep(1,6),1,1),
              N=200,Xc=Xc,flag="atleast")

# simulate data from latent class model with 2 classes and covariates affecting both class weights
# and conditional probabilities of capture configurations given the latent class
Wc = c(-1,0,1); Xc = rnorm(3)
out = simLCCR(2,5,beta=c(0,0),lambda=c(rep(-1,5),rep(1,5),1),N=c(100,100,100),Wc=Wc,Xc=Xc)
```

---

sq *Build matrix of binary vectors of a fixed lenght*

Description

It creates all possible binary (with elements equal to 0 or 1) vectors of a specified length; these vectors are casted in a matrix having a number of columns equal to the vector length. If required, the binary vectors are constrained to have the same total (sum of their elements).

Usage

```
sq(J, t = NULL)
```

Arguments

J	legnth of binary vectors
t	possible fixed total

Value

M	matrix containing all binary vectors

Author(s)

Francesco Bartolucci, Antonio Forcina

Examples

```
# build matrix of all possible binary vectors of legnth 5
  M = sq(5)

# build matrix of all possible binary vectors of legnth 5 with total equal 2
  M = sq(5,2)
```

---

summary *Summary of output*

Description

Summary of output from fitting latent class models for capture-recapture data with covariates.

Usage

```
## S3 method for class 'estLCCR'
summary(object, ...)
## S3 method for class 'estLCCRcon'
summary(object, ...)
## S3 method for class 'confLCCR'
summary(object, ...)
```

Arguments

object	output from estLCCR,estLCCRcon or confint.estLCCR
...	further arguments passed to or from other methods

Value

No return value

Author(s)

Francesco Bartolucci, Antonio Forcina

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