Package ‘TOHM’

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Title Testing One Hypothesis Multiple Times

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Description
Approximations of global p-values when testing hypothesis in presence of non-identifiable nuisance parameters. The method relies on the Euler characteristic heuristic and the expected Euler characteristic is efficiently computed by in Algeri and van Dyk (2018) <arXiv:1803.03858>.

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Contents

TOHM-package *Testing One Hypothesis Multiple Times*

Description

Approximations of global p-values when testing hypothesis in presence of non-identifiable nuisance parameters. The method relies on the Euler characteristic heuristic and the expected Euler characteristic is efficiently computed by in Algeri and van Dyk (2018) <arXiv:1803.03858>.

Details

The functions collected in `TOHM` mainly focus on the implementation of the Likelihood Ratio Tests (see `TOHM_LRT`). However, several functions (e.g.,`EC_T`, `global_p`) can be used to obtain global p-values for other test statistics and to compute the Euler characteristic using the graph algorithm described in Algeri and van Dyk (2018).

Author(s)

Sara Algeri Maintainer: Sara Algeri <salgeri@umn.edu>

References

S. Algeri and D.A. van Dyk. Testing one hypothesis multiple times: The multidimensional case. arXiv:1803.03858, submitted to the Journal of Computational and Graphical Statistics, 2018.

Examples

```
#generating data of interest
N<-100
x<-as.matrix(cbind(runif(N*2,172.5,217.5),runif(N*2,-2,58)))
x2<-x[(x[,1]<=217.5)&(x[,1]>=172.5),]
x_sel<-x2[(x2[,2]<=(28+sqrt(30^2-(x2[,1]-195)^2)))&(x2[,2]>=(28-
sqrt(30^2-(x2[,1]-195)^2))),]
data<-x_sel[sample(seq(1:(dim(x_sel)[1])),N),]

#Specifying minus-log-likelihood
kg<-function(theta){integrate(Vectorize(function(x) {
exp(-0.5*((x-theta[1])/0.5)^2)*integrate(function(y) {
exp(-0.5*((y-theta[2])/0.5)^2) }, 28-sqrt(30^2-(x-195)^2),
28+sqrt(30^2-(x-195)^2))$value}) , 172.5, 217.5)$value}
mll<-function(eta,x,theta){
  -sum(log((1-eta)/(pi*(30)^2)+eta*exp(-0.5*((x[,1]-
  theta[1])/0.5)^2-
  0.5*((x[,2]-theta[2])/0.5)^2)/kg(theta)))}

#Specifying search region
theta1<-seq(172.5,217.5,by=15)
theta2<-seq(-2,58,by=10)
THETA<-as.matrix(expand.grid(theta1,theta2))
```

```
originalR<-dim(THETA)[1]
rownames(THETA)<-1:(dim(THETA)[1])
THETA2<-THETA[(THETA[,1]<=217.5)&(THETA[,1]>=172.5),]
THETA_sel<-THETA2[(THETA2[,2]<=(28+sqrt(30^2-(THETA2[,1]-
195)^2)))&(THETA2[,2]>=(28-sqrt(30^2-(THETA2[,1]-195)^2))),]

#Generating toy EC
ECs<-cbind(rpois(100,1.5),rpois(100,1))

TOHM_LRT(data,mll,null0=0,init=c(0.1),lowlim=c(0),uplim=c(1),
THETA=THETA_sel,ck=c(1,8),type=c(”Chi-bar^2”),
k=NULL,k_vec=c(0,1),weights=c(0.5,0.5),
ECdensities=NULL,ECs=ECs)
```

chi2_ECden *Compute Euler characteristic density for Chi-square random fields*

Description

Computes the Euler characteristic (EC) density of a given order for Chi-squared random fields.

Usage

```
chi2_ECden(c, k, j)
```

Arguments

c	Value on which the EC density is evaluated.
k	Degrees of freedom of the Chi-square random field.
j	Order of the EC density to be implemented.

Value

Returns the value of the EC density of order j evaluated at c for a Chi-square random field with k degrees of freedom.

Author(s)

Sara Algeri

References

R.J. Adler and J.E. Taylor. Random fields and geometry. Springer Science and Business Media, 2009.

See Also

Gauss_ECden, ECden_vec

Examples

```
c<-1
k<-1
j<-2
chi2_ECden(c,k,j)
```

`ECden_vec` *Compute the Euler characteristic densities*

Description

Compute the Euler characteristic (EC) densities for Gaussian, Chi-square and Chi-bar-square random fields up to a given order.

Usage

```
ECden_vec(c, D, type = c("Gaussian", "Chi^2", "Chi-bar^2"),
k = NULL, k_vec = NULL, weights = NULL)
```

Arguments

`c` Value on which the EC densities are evaluated.

`D` Maximum order of the EC density to be computed.

`type` Type of random field. The possible options are `"Gaussian"`, `"Chi^2"`, and `"Chi-bar^2"`. See details.

`k` If `type="Chi^2"`, degrees of freedom of the Chi-square random field.

`k_vec` If `type="Chi-bar^2"` the degrees of freedom of the Chi-square random fields in the mixture.

`weights` If `type="Chi-bar^2"` the weights of the mixure of Chi-square random fields in the mixture. The ordering should be the same as in `k_vec`.

Details

If `type="Chi-bar^2"` the degrees of freedom of the Chi-square random fields involved in the mixture, as well as the respective weights, have to be spefcified in the arguments `k_vec` and `weights`.

Value

Returns the values of the EC densities of order zero up to the dimension of the search area considered and evaluated at `c`.

Author(s)

Sara Algeri

References

R.J. Adler and J.E. Taylor. Random fields and geometry. Springer Science and Business Media, 2009.

J.E. Taylor and K.J.Worsley. Detecting sparse cone alternatives for gaussian random fields, with an application to fmri. Statistica Sinica, 2013.

See Also

chi2_ECden, Gauss_ECden

Examples

```
ECden_vec(12,2,"Chi-bar^2",k_vec=c(0,1),weights=c(0.5,0.5))
```

EC_LRT *Compute the Euler characteristic for the generalized Likelihood Ratio Test field*

Description

It computes the Euler characteristic (EC) of the generalized Likelihood Ratio test (LRT) field above specified thresholds over a given search area.

Usage

```
EC_LRT(ck, x, mll, null0, init, lowlim, uplim, THETA)
```

Arguments

`ck` Vector of thresholds defining the excursions sets with respect to which the ECs are computed.

`x` A vector or matrix collecting the data on which the LRT is computed.

`mll` A function specifying the negative (profile) log-likelihood. See details.

`null0` A scalar or vector collecting the values of the free parameters under the null hypothesis. See details.

`init` Vector of initial values for the MLE.

`lowlim` Vector of lower bounds for the MLE.

`uplim` Vector of upper bounds for the MLE.

`THETA` A vector or matrix of grid values for the nuisance parameter with respect to which the search is performed.

Details

mll takes as first argument the vector of the parameters for which the MLE is generated. Other arguments of mll are the data vector or matrix (x) and a scalar or vector corresponding to the fixed value for the nuisance parameter with respect to which the profiling is computed (theta, see gLRT). If the latter is a vector it must be of same length of the rows in THETA. If the null model has nuisance parameters, null0 takes as arguments the values of the parameters being tested under the null hypothesis, followed by the estimates of the nuisance parameters obtained assuming that the null hypothesis is true.

Value

Returns a vector of EC values with respect to the thresholds specified in ck.

Author(s)

Sara Algeri

References

S. Algeri and D.A. van Dyk. Testing one hypothesis multiple times: The multidimensional case. arXiv:1803.03858, submitted to the Journal of Computational and Graphical Statistics, 2018.

See Also

EC_T

Examples

```
#generating data of interest
N<-100
x<-as.matrix(cbind(runif(N*2,172.5,217.5),runif(N*2,-2,58)))
x2<-x[(x[,1]<=217.5)&(x[,1]>=172.5),]
x_sel<-x2[(x2[,2]<=(28+sqrt(30^2-(x2[,1]-195)^2)))&(x2[,2]>=(28-
sqrt(30^2-(x2[,1]-195)^2))),]
data<-x_sel[sample(seq(1:(dim(x_sel)[1])),N),]

#Specifying minus-log-likelihood
kg<-function(theta){integrate(Vectorize(function(x) {
exp(-0.5*((x-theta[1])/0.5)^2)*integrate(function(y) {
exp(-0.5*((y-theta[2])/0.5)^2) }, 28-sqrt(30^2-(x-195)^2),
28+sqrt(30^2-(x-195)^2))$value}) , 172.5, 217.5)$value}
mll<-function(eta,x,theta){
  -sum(log((1-eta)/(pi*(30)^2)+eta*exp(-0.5*((x[,1]-
  theta[1])/0.5)^2-
  0.5*((x[,2]-theta[2])/0.5)^2)/kg(theta)))}

#Specifying search region
theta1<-seq(172.5,217.5,by=15)
theta2<-seq(-2,58,by=10)
THETA<-as.matrix(expand.grid(theta1,theta2))
originalR<-dim(THETA)[1]
```

```
rownames(THETA)<-1:(dim(THETA)[1])
THETA2<-THETA[(THETA[,1]<=217.5)&(THETA[,1]>=172.5),]
THETA_sel<-THETA2[(THETA2[,2]<=(28+sqrt(30^2-(THETA2[,1]-
195)^2)))&(THETA2[,2]>=(28-sqrt(30^2-(THETA2[,1]-195)^2))),]

EC_LRT(ck=c(1,8),x=data,mll=mll,null0=0,init=c(0.1),
lowlim=c(0),uplim=c(1), THETA_sel)
```

EC_T *Compute the Euler characteristic for a given field*

Description

It computes the Euler characteristic (EC) of a given field above specified thresholds over a specified search area.

Usage

```
EC_T(ck, Ts, THETA)
```

Arguments

ck	Vector of thresholds defining the excursions sets with respect to which the ECs are computed.
Ts	Vector of values of the field for each grid point in THETA.
THETA	A vector or matrix of grid values for the nuisance parameter with respect to which the search is performed.

Value

Returns a vector of EC values with respect to the thresholds specified in ck.

Author(s)

Sara Algeri

References

S. Algeri and D.A. van Dyk. Testing one hypothesis multiple times: The multidimensional case. arXiv:1803.03858, submitted to the Journal of Computational and Graphical Statistics, 2018.

See Also

EC_LRT

Examples

```
EC_T(ck=c(3,4),Ts=rnorm(10), THETA=cbind(1:10,21:30))
```

find_max *Maximum of Likelihood Ratio Test field*

Description

It computes the maximum of the generalized Likelihood Ratio Test (LRT) evaluated over a grid of values.

Usage

```
find_max(x, mll, null0, init, lowlim, uplim, THETA)
```

Arguments

`x`	A vector or matrix collecting the data on which the LRT field is computed.
`mll`	A function specifying the negative (profile) log-likelihood. See details.
`null0`	A vector or scalar of the free parameters under the null hypothesis. See details.
`init`	A vector or scalar of initial values for the MLE.
`lowlim`	A vector or scalar of lower bounds for the MLE.
`uplim`	A vector or scalar of upper bounds for the MLE.
`THETA`	A vector or matrix of grid values of the nuisance parameter with respect to which the search is performed.

Details

`mll` takes as first argument the vector of the parameters for which the MLE is generated. Other arguments of `mll` are the data vector or matrix (`x`) and a scalar or vector corresponding to the fixed value for the nuisance parameter with respect to which the profilying is computed (`theta`, see `gLRT`). If the latter is a vector it must be of same length of the rows in `THETA`. If the null model has nuisance parameters, `null0` takes as arguments the values of the parameters being tested under the null hypothesis, followed by the estimates of the nuisance parameters obtained assuming that the null hypothesis is true.

Value

`max_gLRT`	Maximum observed of the LRT field.
`theta_max`	Value of `THETA` at which the maximum is observed.

Author(s)

Sara Algeri

References

S. Algeri and D.A. van Dyk. Testing one hypothesis multiple times: The multidimensional case. arXiv:1803.03858, submitted to the Journal of Computational and Graphical Statistics, 2018.

See Also

gLRT, global_p

Examples

```
#generating data of interest
N<-100
x<-as.matrix(cbind(runif(N*2,172.5,217.5),runif(N*2,-2,58)))
x2<-x[(x[,1]<=217.5)&(x[,1]>=172.5),]
x_sel<-x2[(x2[,2]<=(28+sqrt(30^2-(x2[,1]-195)^2)))&(x2[,2]>=(28-
sqrt(30^2-(x2[,1]-195)^2))),]
data<-x_sel[sample(seq(1:(dim(x_sel)[1])),N),]

#Specifying minus-log-likelihood
kg<-function(theta){integrate(Vectorize(function(x) {
exp(-0.5*((x-theta[1])/0.5)^2)*integrate(function(y) {
exp(-0.5*((y-theta[2])/0.5)^2) }, 28-sqrt(30^2-(x-195)^2),
28+sqrt(30^2-(x-195)^2))$value}) , 172.5, 217.5)$value}
mll<-function(eta,x,theta){
  -sum(log((1-eta)/(pi*(30)^2)+eta*exp(-0.5*((x[,1]-
  theta[1])/0.5)^2-
  0.5*((x[,2]-theta[2])/0.5)^2)/kg(theta)))}

#Specifying search region
theta1<-seq(172.5,217.5,by=15)
theta2<-seq(-2,58,by=10)
THETA<-as.matrix(expand.grid(theta1,theta2))
originalR<-dim(THETA)[1]
rownames(THETA)<-1:(dim(THETA)[1])
THETA2<-THETA[(THETA[,1]<=217.5)&(THETA[,1]>=172.5),]
THETA_sel<-THETA2[(THETA2[,2]<=(28+sqrt(30^2-(THETA2[,1]-
195)^2)))&(THETA2[,2]>=(28-sqrt(30^2-(THETA2[,1]-195)^2))),]

find_max(x=data,mll=mll,null0=0,init=c(0.1),
lowlim=c(0),uplim=c(1), THETA=THETA_sel)
```

Gauss_ECden *Compute Euler characteristic density for Gaussian random fields*

Description

Computes the Euler characteristic (EC) density of a given order for Gaussian random fields.

Usage

```
Gauss_ECden(c, j)
```

Arguments

c Value on which the EC density is evaluated.

j Order of the EC density to be implemented.

Value

Returns the value of the EC density of order j evaluated at c for a Gaussian random field.

Author(s)

Sara Algeri

References

R.J. Adler and J.E. Taylor. Random fields and geometry. Springer Science and Business Media, 2009.

See Also

chi2_ECden, ECden_vec

Examples

```
c<-1
j<-2
Gauss_ECden(c,4)
```

global_p *Compute global p-values*

Description

It computes the global p-value for a given value of the test statistic.

Usage

```
global_p(c, ck, type = c("Gaussian", "Chi^2", "Chi-bar^2"),
k = NULL, k_vec = NULL, weights = NULL, ECdensities = NULL, ECs)
```

Arguments

c Observed value of the test statistic.

ck Vector of thresholds defining the excursions sets with respect to which the ECs are computed.

type Type of random field. The possible options are "Gaussian", "Chi^2", and "Chi-bar^2". See details.

k If type="Chi^2", degrees of freedom of the Chi-square random field.

k_vec If type="Chi-bar^2" the degrees of freedom of the Chi-square random fields in the mixture.

weights If type="Chi-bar^2" the weights of the mixure of Chi-square random fields in the mixture. The ordering should be the same as in k_vec.

ECdensities See datails.

ECs A vector or matrix containing the Euler characteristics (ECs) computed over a Monte Carlo simulation of the random field under the null model. Each colum correspond to the ECs obtained for each of the thresholds in ck.

Details

If type="Chi-bar^2" the degrees of freedom of the Chi-square random fields involved in the mixture, as well as the respective weights, have to be spefcified in the arguments k_vec and weights. If the distribution of the random field is not available in type, the user can specify in ECdensities a function taking c as argument and returning the vector of the desired EC densities to be evaluated at c. Notice that the length of the vector returned by the function specified in ECdensities must corresponds to one plus the dimension of the search area (since the first value should correspond to the EC density of order zero (see ECden_vec)).

Value

global_p Global p-value.

MCerror Monte Carlo error associated to the global p-vaue.

Author(s)

Sara Algeri

References

S. Algeri and D.A. van Dyk. Testing one hypothesis multiple times: The multidimensional case. arXiv:1803.03858, submitted to the Journal of Computational and Graphical Statistics, 2018.

See Also

find_max,TOHM_LRT,ECden_vec

Examples

```
ck<-c(1,2)
ECs<-cbind(rpois(100,1.5),rpois(100,1))
global_p(c=12,ck=ck,type="Gaussian",ECs=ECs)
```

gLRT *Compute the generalized Likelihood Ratio Test*

Description

Compute the generalized Likelihood Ratio Test (LRT) for a specified value of the nuisance parameter.

Usage

```
gLRT(theta, mll, x, init, lowlim, uplim, null0)
```

Arguments

`theta`	A vector or scalar of the value of the nuisance parameter with respect to which the LRT is computed.
`mll`	A function specifying the negative (profile) log-likelihood. See details.
`x`	A vector or matrix collecting the data.
`init`	A vector or scalar of initial values for the MLE.
`lowlim`	A vector or scalar of lower bounds for the MLE.
`uplim`	A vector or scalar of upper bounds for the MLE.
`null0`	A vector or scalar of the free parameters under the null hypothesis. See details.

Details

`mll` takes as first argument the vector of the parameters for which the MLE is generated. Other arguments of `mll` are the data vector or matrix (`x`) and a scalar or vector corresponding to the fixed value for the nuisance parameter with respect to which the profilying is computed (`theta`, see `gLRT`). If the latter is a vector it must be of same length of the rows in `THETA`. If the null model has nuisance parameters, `null0` takes as arguments the values of the parameters being tested under the null hypothesis, followed by the estimates of the nuisance parameters obtained assuming that the null hypothesis is true.

Value

The value of the generalized LRT for a specified value of `theta`.

Author(s)

Sara Algeri

References

S. Algeri and D.A. van Dyk. Testing one hypothesis multiple times: The multidimensional case. arXiv:1803.03858, submitted to the Journal of Computational and Graphical Statistics, 2018.

A.C. Davison. Statistical models, volume 11. Cambridge University Press, 2003.

See Also

find_max, TOHM_LRT

Examples

```
#generating data of interest
N<-100
x<-as.matrix(cbind(runif(N*2,172.5,217.5),runif(N*2,-2,58)))
x2<-x[(x[,1]<=217.5)&(x[,1]>=172.5),]
x_sel<-x2[(x2[,2]<=(28+sqrt(30^2-(x2[,1]-195)^2)))&(x2[,2]>=(28-
sqrt(30^2-(x2[,1]-195)^2))),]
data<-x_sel[sample(seq(1:(dim(x_sel)[1])),N),]

#Specifying minus-log-likelihood
kg<-function(theta){integrate(Vectorize(function(x) {
exp(-0.5*((x-theta[1])/0.5)^2)*integrate(function(y) {
exp(-0.5*((y-theta[2])/0.5)^2) }, 28-sqrt(30^2-(x-195)^2),
28+sqrt(30^2-(x-195)^2))$value}) , 172.5, 217.5)$value}
mll<-function(eta,x,theta){
  -sum(log((1-eta)/(pi*(30)^2)+eta*exp(-0.5*((x[,1]-
  theta[1])/0.5)^2-
  0.5*((x[,2]-theta[2])/0.5)^2)/kg(theta)))}

gLRT(theta=c(200,30),mll=mll,init=0.1,lowlim=0,uplim=1,null0=0,x=data)
```

TOHM_LRT *Compute the Likelihood Ratio Test under non-standard conditions.*

Description

It implements the procedure described in Algeri and van Dyk (2018) to perform tests of hypothesis under non-regular conditions, and which can be formulated as test of hypothesis where a nuisance parameter is present only under the alternative.

Usage

```
TOHM_LRT(x, mll, null0, init, lowlim, uplim, THETA, ck,
type = c("Chi^2", "Chi-bar^2"), k = NULL, k_vec = NULL,
weights = NULL, ECdensities = NULL, ECs = NULL)
```

Arguments

x	A vector or matrix collecting the data.
mll	A function specifying the negative (profile) log-likelihood. See details.
null0	A vector or scalar of the free parameters under the null hypothesis. See details.
init	A vector or scalar of initial values for the MLE.
lowlim	A vector or scalar of lower bounds for the MLE.

`uplim` A vector or scalar of upper bounds for the MLE.

`THETA` A vector or matrix of grid values of the nuisance parameter with respect to which the search is performed.

`ck` Vector of thresholds defining the excursions sets with respect to which the ECs are computed.

`type` Type of random field. The possible options are `"Gaussian"`, `"Chi^2"`, and `"Chi-bar^2"`. See details.

`k` If `type="Chi^2"`, degrees of freedom of the Chi-square random field.

`k_vec` If `type="Chi-bar^2"` the degrees of freedom of the Chi-square random fields in the mixture.

`weights` If `type="Chi-bar^2"` the weights of the mixure of Chi-square random fields in the mixture. The ordering should be the same as in `k_vec`.

`ECdensities` See datails.

`ECs` A vector or matrix containing the Euler characteristics (ECs) computed over a Monte Carlo simulation of the random field under the null model. Each colum correspond to the ECs obtained for each of the thresholds in `ck`.

Details

`mll` takes as first argument the vector of the parameters for which the MLE is generated. Other arguments of `mll` are the data vector or matrix (`x`) and a scalar or vector corresponding to the fixed value for the nuisance parameter with respect to which the profilying is computed (`theta`, see `gLRT`). If the latter is a vector it must be of same length of the rows in `THETA`. If the null model has nuisance parameters, `null0` takes as arguments the values of the parameters being tested under the null hypothesis, followed by the estimates of the nuisance parameters obtained assuming that the null hypothesis is true. If `type="Chi-bar^2"` the degrees of freedom of the Chi-square random fields involved in the mixture, as well as the respective weights, have to be spefcified in the arguments `k_vec` and `weights`. If the distribution of the random field is not available in `type`, the user can specify in `ECdensities` a function taking `c` as argument and returning the vector of the desired EC densities to be evaluated at `c`. Notice that the length of the vector returned by the function specified in `ECdensities` must corresponds to one plus the dimension of the search area (since the first value should correspond to the EC density of order zero (see `ECden_vec`)).

Value

`max_gLRT` Maximum observed of the LRT field.

`theta_max` Value of `THETA` at which the maximum is observed.

`global_p` Global p-value.

`MCerror` Monte Carlo error associated to the global p-vaue.

Author(s)

Sara Algeri

References

S. Algeri and D.A. van Dyk. Testing one hypothesis multiple times: The multidimensional case. arXiv:1803.03858, submitted to the Journal of Computational and Graphical Statistics, 2018.

See Also

find_max, global_p,EC_T.

Examples

```
#generating data of interest
N<-100
x<-as.matrix(cbind(runif(N*2,172.5,217.5),runif(N*2,-2,58)))
x2<-x[(x[,1]<=217.5)&(x[,1]>=172.5),]
x_sel<-x2[(x2[,2]<=(28+sqrt(30^2-(x2[,1]-195)^2)))&(x2[,2]>=(28-
sqrt(30^2-(x2[,1]-195)^2))),]
data<-x_sel[sample(seq(1:(dim(x_sel)[1])),N),]

#Specifying minus-log-likelihood
kg<-function(theta){integrate(Vectorize(function(x) {
exp(-0.5*((x-theta[1])/0.5)^2)*integrate(function(y) {
exp(-0.5*((y-theta[2])/0.5)^2) }, 28-sqrt(30^2-(x-195)^2),
28+sqrt(30^2-(x-195)^2))$value}) , 172.5, 217.5)$value}
mll<-function(eta,x,theta){
  -sum(log((1-eta)/(pi*(30)^2)+eta*exp(-0.5*((x[,1]-
  theta[1])/0.5)^2-
  0.5*((x[,2]-theta[2])/0.5)^2)/kg(theta)))}

#Specifying search region
theta1<-seq(172.5,217.5,by=15)
theta2<-seq(-2,58,by=10)
THETA<-as.matrix(expand.grid(theta1,theta2))
originalR<-dim(THETA)[1]
rownames(THETA)<-1:(dim(THETA)[1])
THETA2<-THETA[(THETA[,1]<=217.5)&(THETA[,1]>=172.5),]
THETA_sel<-THETA2[(THETA2[,2]<=(28+sqrt(30^2-(THETA2[,1]-
195)^2)))&(THETA2[,2]>=(28-sqrt(30^2-(THETA2[,1]-195)^2))),]

#Generating toy EC
ECs<-cbind(rpois(100,1.5),rpois(100,1))

TOHM_LRT(data,mll,null0=0,init=c(0.1),lowlim=c(0),uplim=c(1),
THETA=THETA_sel,ck=c(1,8),type=c("Chi-bar^2"),
k=NULL,k_vec=c(0,1),weights=c(0.5,0.5),
ECdensities=NULL,ECs=ECs)
```

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