Package 'HMMcopula'

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Type Package

Title Markov Regime Switching Copula Models Estimation and Goodness-of-Fit

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Description Estimation procedures and goodness-of-fit test for several Markov regime switching models and mixtures of bivariate copula models. The goodness-of-fit test is based on a Cramer-von Mises statistic and uses Rosenblatt's transform and parametric bootstrap to estimate the p-value. The proposed methodologies are described in Nasri, Remillard and Thioub (2020) <doi:10.1002/cjs.11534>.

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Depends mvtnorm, foreach, doParallel, copula

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Contents

`CopulaFamiliesCDF` *CopulaFamiliesCDF*

Description

COPULACDF Cumulative probability function for a copula with linear correlation parameters RHO

Usage

```
CopulaFamiliesCDF(family, u, ...)
```

Arguments

`family`	copula familly= "gaussian" , "t" , "clayton" , "frank" , "gumbel"
`u`	is an N-by-P matrix of values in [0,1], representing N points in the P-dimensional unit hypercube
`...`	additionnal parameter like RHO a P-by-P correlation matrix.

Value

Y = COPULACDF('Gaussian',U,RHO) returns the cumulative probability of the Gaussian copula with linear correlation parameters RHO, evaluated at the points in U. U is an N-by-P matrix of values in [0,1], representing N points in the P-dimensional unit hypercube. RHO is a P-by-P correlation matrix. If U is an N-by-2 matrix, RHO may also be a scalar correlation coefficient.

Y = COPULACDF('t',U,RHO,NU) returns the cumulative probability of the t copula with linear correlation parameters RHO and degrees of freedom parameter NU, evaluated at the points in U. U is an N-by-P matrix of values in [0,1]. RHO is a P-by-P correlation matrix. If U is an N-by-2 matrix, RHO may also be a scalar correlation coefficient.

Y = COPULACDF(FAMILY,U,ALPHA) returns the cumulative probability of the bivariate Archimedean copula determined by FAMILY, with scalar parameter ALPHA, evaluated at the points in U. FAMILY is 'Clayton', 'Frank', ort 'Gumbel'. U is an N-by-2 matrix of values in [0,1].

Examples

```
u = seq(0,1,0.1);
   U1=matrix(rep(u,length(u)),nrow=length(u),byrow = TRUE); U2=t(U1)
  F = CopulaFamiliesCDF('clayton',cbind(c(U1), c(U2)),1)
```

`dilog` *Dilogarithm function*

Description

Computation of the dilogarithm function by nemerical integration.

Usage

```
dilog(x)
```

Arguments

`x`	a real number

Value

`out`	dilogarithm

`EstHMMCop` *Estimation of bivariate Markov regime switching bivariate copula model*

Description

Estimation of parameters from a bivariate Markov regime switching bivariate copula model

Usage

```
EstHMMCop(y, reg, family, max_iter, eps)
```

Arguments

`y`	(nx2) data matrix (observations or residuals) that will be transformed to pseudo-observations
`reg`	number of regimes
`family`	'gaussian' , 't' , 'clayton' , 'frank' , 'gumbel'
`max_iter`	maximum number of iterations of the EM algorithm
`eps`	precision (stopping criteria); suggestion 0.0001.

Value

theta	(1 x reg) estimated parameter of the copula according to CRAN copula package (except for Frank copula, where theta = log(theta_R_Package)) for each regime (except for degrees of freedom)
dof	estimated degree of freedom, only for the Student copula
Q	(reg x reg) estimated transition matrix
eta	(n x reg) conditional probabilities of being in regime k at time t given observations up to time t
tau	estimated Kendall tau for each regime
U	(n x 2) matrix of Rosenblatt transforms
cvm	Cramer-von-Mises statistic for goodness-of-fit
W	regime probabilities for the conditional distribution given the past Kendall's tau

Author(s)

Mamadou Yamar Thioub and Bruno Remillard, April 12, 2018

References

<doi::10.1002/cjs.11534>

Examples

```
Q <- matrix(c(0.8, 0.3, 0.2, 0.7),2,2) ; kendallTau <- c(0.3 ,0.7) ;
data <- SimHMMCop(Q, 'clayton', kendallTau, 10)$SimData;
estimations <- EstHMMCop(data,2,'clayton',10000,0.0001)
```

EstKendallTau *Sample Kendall's tau Estimation*

Description

This function estimates the sample Kendall's tau of a bivariate data matrix

Usage

```
EstKendallTau(X)
```

Arguments

X	(n x 2) matrix

Value

KendallTau	estimated sample Kendall's tau of the data

`EstMixtureCop` *Estimation of bivariate mixture bivariate copula model*

Description

Estimation of parameters from a mixture of bivariate copula models

Usage

```
EstMixtureCop(y, reg, family, max_iter, eps)
```

Arguments

`y`	(nx2) data matrix (observations or residuals) that will be transformed to pseudo-observations
`reg`	number of regimes
`family`	'gaussian' , 't' , 'clayton' , 'frank' , 'gumbel'
`max_iter`	maximum number of iterations of the EM algorithm
`eps`	precision (stopping criteria); suggestion 0.0001.

Value

`theta`	(1 x reg) estimated parameter of the copula according to CRAN copula package (except for Frank copula, where theta = log(theta_R_Package)) for each component (except for degrees of freedom)
`dof`	estimated degree of freedom, only for the Student copula
`Q`	(1 x reg) estimated weights vector
`eta`	(n x reg) conditional probabilities of being in regime k at time t given observations up to time t
`tau`	estimated Kendall tau for each regime
`U`	(n x 2) matrix of Rosenblatt transforms
`cvm`	Cramer-von-Mises statistic for goodness-of-fit

Author(s)

Mamadou Yamar Thioub and Bruno Remillard, April 12, 2018

References

<doi::10.1002/cjs.11534>

GofHMMCop *Goodness-of-fit of Markov regime switching bivariate copula model*

Description

Goodness-of-fit test of a Markov regime switching bivariate copula model

Usage

```
GofHMMCop(R, reg, family, max_iter, eps, n_sample, n_cores)
```

Arguments

R	(n x 2) data matrix that will be transformed to pseudo-observations
reg	number of regimes
family	'gaussian' , 't' , 'clayton' , 'frank' , 'gumbel'
max_iter	maxmimum number of iterations of the EM algorithm
eps	precision (stopping criteria); suggestion 0.0001
n_sample	number of bootstrap; suggestion 1000
n_cores	number of cores to use in the parallel computing

Value

pvalue	pvalue (significant when the result is greater than 5)
theta	(1 x reg) estimated parameter of the copula according to CRAN copula package (except for Frank copula, where theta = log(theta_R_Package)) for each regime (except for degrees of freedom)
dof	estimated degree of freedom, only for the Student copula
Q	(reg x reg) estimated transition matrix
eta	(n x reg) conditional probabilities of being in regime k at time t given observations up to time t
tau	estimated Kendall tau for each regime
U	(n x 2) matrix of Rosenblatt transforms
cvm	Cramer-von-Mises statistic for goodness-of-fit
W	regime probabilities for the conditional distribution given the past Kendall's tau

References

<doi::10.1002/cjs.11534>

GofMixtureCop *Goodness-of-fit of mixture bivariate copula model*

Description

Goodness-of-fit test of a mixture bivariate copula model

Usage

```
GofMixtureCop(R, reg, family, max_iter, eps, n_sample, n_cores)
```

Arguments

R	(nx2) data matrix (observations or residuals) that will be transformed to pseudo-observations
reg	number of regimes
family	'gaussian' , 't' , 'clayton' , 'frank' , 'gumbel'
max_iter	maxmimum number of iterations of the EM algorithm
eps	precision (stopping criteria); suggestion 0.0001
n_sample	number of bootstrap; suggestion 1000
n_cores	number of cores to use in the parallel computing

Value

pvalue	pvalue (significant when the result is greater than 5)
theta	(1 x reg) estimated parameter of the copula according to CRAN copula package (except for Frank copula, where theta = log(theta_R_Package)) for each component (except for degrees of freedom)
dof	estimated degree of freedom, only for the Student copula
Q	(1 x reg) estimated weights vector
eta	(n x reg) conditional probabilities of being in regime k at time t given observations up to time t
tau	estimated Kendall tau for each regime
U	(n x 2) matrix of Rosenblatt transforms
cvm	Cramer-von-Mises statistic for goodness-of-fit

Author(s)

By Bruno Remillard, Nov 28, 2010

References

<doi::10.1002/cjs.11534>

KendallTau *Kendall's tau of a copula*

Description

Computation of Kendall's tau of a copula family with an unconstrainted parameter alpha.

Usage

```
KendallTau(family, alpha)
```

Arguments

family	"gaussian" , "t" , "clayton" , "frank" , "gumbel"
alpha	unconstrainted parameters of the copula family

Value

tau	estimated Kendall's tau

ParamCop *Theta estimation*

Description

Parameters of a copula according to CRAN copula package (except for Frank copula, where theta = log(theta_R_Package)), corresponding to the unconstrainted parameters alpha.

Usage

```
ParamCop(family, alpha)
```

Arguments

family	"gaussian" , "t" , "clayton" , "frank" , "gumbel"
alpha	unconstrainted parameters of the copula family

Value

theta	matlab parameters

ParamTau *Alpha estimation*

Description

Unconstrainted parameter for a given Kendall's tau.

Usage

```
ParamTau(family, tau)
```

Arguments

family	'gaussian' , 't' , 'clayton' , 'frank' , 'gumbel'
tau	Kendall's tau of the copula family

Value

alpha	estimated unconstrainted parameter

RosenblattClayton *Rosenblatt transform for Clayton copula*

Description

Computation of the Rosenblatt transform fot Clayton's copula

Usage

```
RosenblattClayton(u, theta)
```

Arguments

u	(n x d) matrix of pseudos-observations (normalized ranks)
theta	parameter of the Clayton copula

Value

R	Rosenblatt transform

RosenblattFrank *Rosenblatt transform for Frank copula*

Description

Computation of the Rosenblatt transform for Frank's copula

Usage

```
RosenblattFrank(U, theta)
```

Arguments

U	(n x d) matrix of pseudos-observations (normalized ranks)
theta	parameter of the Frank copula

Value

R	Rosenblatt transform

RosenblattGaussian *Rosenblatt transform for Gaussian copula*

Description

Computation of the Rosenblatt transform for the Gaussian copula

Usage

```
RosenblattGaussian(u, rho)
```

Arguments

u	(n x d) matrix of pseudos-observations (normalized ranks)
rho	(d x d) correlation matrix, or the correlation coefficient (if, d = 2)

Value

R	Rosenblatt transform

RosenblattGumbel *Rosenblatt transform for Gumbel copula*

Description

Computation of the Rosenblatt transform for Gumbel's copula

Usage

```
RosenblattGumbel(U, theta)
```

Arguments

U	(n x d) matrix of pseudos-observations (normalized ranks)
theta	parameter of the Gumbel copula

Value

R	Rosenblatt transform

RosenblattStudent *Rosenblatt transform for Student copula*

Description

Computation of the Rosenblatt transform for the Student copula

Usage

```
RosenblattStudent(u, rho, nu)
```

Arguments

u	(n x d) matrix of pseudos-observations (normalized ranks)
rho	(d x d) correlation matrix
nu	degrees of freedom

Value

R	Rosenblatt transform

SimHMMCop *Simulation of bivariate Markov regime switching copula model*

Description

Simulaion of values from a bivariate Markov regime switching copula model

Usage

```
SimHMMCop(Q, family, KendallTau, n, DoF)
```

Arguments

Q	Transition probality matrix (d x d);
family	'gaussian' , 't' , 'clayton' , 'frank' , 'gumbel'
KendallTau	Kendall's rank correlation
n	number of simulated vectors
DoF	degree of freedom only for the Student copula

Value

SimData	Simulated Data
MC	Markov chain regimes
alpha	parameters alpha

Examples

```
Q <- matrix(c(0.8, 0.3, 0.2, 0.7),2,2) ; kendallTau <- c(0.3 ,0.7) ;
simulations <- SimHMMCop(Q, 'gumbel', kendallTau, 300)
```

SimMarkovChain *Markov chain simulation*

Description

Simulation of n consecutive values of a Markov chain with transition matrix Q, starting from a state eta0 or the uniform distribution on the set 1,..., r.

Usage

```
SimMarkovChain(Q, n, eta0)
```

Arguments

Q	Transition probability matrix (d x d)
n	number of simulated vectors
eta0	variable eta

Value

x	Simulated Markov chain sequence

SimMixtureCop *Simulation of bivariate mixture copula model*

Description

Simulation of observations from a bivariate mixture copula model

Usage

```
SimMixtureCop(Q, family, KendallTau, n, DoF)
```

Arguments

Q	Weights vector (1 x component);
family	'gaussian' , 't' , 'clayton' , 'frank' , 'gumbel'
KendallTau	Kendall's rank correlation
n	number of simulated vectors
DoF	vector of degree of freedom only for the Student copula

Value

SimData	Simulated Data
MC	Markov chain regimes
alpha	parameters alpha

Examples

```
Q <- matrix(c(0.8, 0.2),1,2) ; kendallTau <- c(0.3 ,0.7) ;
simulations <- SimMixtureCop(Q, 'gaussian', kendallTau, 300)
```

SnB — *Cramer-von Mises statistic SnB for GOF based on the Rosenblatt transform*

Description

Computation of the Cramer-von Mises statistic SnB for GOF based on the Rosenblatt transform

Usage

```
SnB(E)
```

Arguments

E	(n x d) matrix of pseudos-observations (normalized ranks)

Value

Sn	Cramer-von Mises statistic

Tau2Rho — *Spearman's rho*

Description

Value of Spearman's rho corresponding to a constrainted (matlab) parameter theta for a copula family.

Usage

```
Tau2Rho(family, theta)
```

Arguments

family	'gaussian' , 't' , 'clayton' , 'frank' , 'gumbel'
theta	parameter of the copula according to CRAN copula package (except for Frank copula, where theta = log(theta_R_Package))

Value

rho	estimated Spearman's rho

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