Package ‘bivgeom’

July 22, 2025

Type Package

Title Roy's Bivariate Geometric Distribution

Version 1.0

Date 2018-10-17

Author Alessandro Barbiero

Maintainer Alessandro Barbiero <alessandro.barbiero@unimi.it>

Imports methods, stats, utils, bbmle, copula

Description Implements Roy's bivariate geometric model (Roy (1993) <doi:10.1006/jmva.1993.1065>): joint probability mass function, distribution function, survival function, random generation, parameter estimation, and more.

License GPL

NeedsCompilation no

Repository CRAN

Date/Publication 2018-10-26 15:20:06 UTC

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`bivgeom-package` *Roy's Bivariate Geometric Distribution*

Description

Implements Roy's bivariate geometric model (Roy (1993) <doi:10.1006/jmva.1993.1065>): joint probability mass function, distribution function, survival function, random generation, parameter estimation, and more.

Details

The DESCRIPTION file:

Package:	bivgeom
Type:	Package
Title:	Roy's Bivariate Geometric Distribution
Version:	1.0
Date:	2018-10-17
Author:	Alessandro Barbiero
Maintainer:	Alessandro Barbiero <alessandro.barbiero@unimi.it>
Imports:	methods, stats, utils, bbmle, copula
Description:	Implements Roy's bivariate geometric model (Roy (1993) <doi:10.1006/jmva.1993.1065>): joint probal
License:	GPL
NeedsCompilation:	no
Packaged:	2018-10-16 12:34:47 UTC; Barbiero

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Author(s)

Alessandro Barbiero

Maintainer: Alessandro Barbiero (alessandro.barbiero@unimi.it)

References

Roy, D. (1993) Reliability measures in the discrete bivariate set-up and related characterization results for a bivariate geometric distribution, Journal of Multivariate Analysis 46(2), 362-373.

Barbiero, A. (2018) Properties and estimation of a bivariate geometric model with locally constant failure rates, submitted

See Also

dbivgeomRoy, rbivgeomRoy, estbivgeomRoy, FbivgeomRoy

Examples

```
#####################################
#### MONTE CARLO SIMULATION PLAN ####
#####################################
# setting the parameters' values
theta1 <- 0.3
theta2 <- 0.7
theta3 <- 0.6
N <- 20       # number of Monte Carlo runs
n <- 100      # sample size
# arranging the array containig the simulation results
# N runs, 7 methods, 3 estimates
h <- array(0,c(N,7,3))
# setting the seed
set.seed(12345)
# function for handling missing values
# when computing the mean and standard deviation of the estimates:
meanrm <- function(x){mean(x,na.rm=TRUE)}
sdrm <- function(x){sd(x,na.rm=TRUE)}
colnames <- c("ML","MMP","MM1","MM2","MM3","MM4","LS")
dimnames(h)[[2]] <- colnames
# Monte Carlo simulation:
for(i in 1:N)
{
d <- rbivgeomRoy(n,theta1,theta2,theta3)
cat("MC run #",i,"\n")
x<-d[,1]
y<-d[,2]
# implementing all the estimation methods
# and saving the point estimates in the array
h[i,1,] <- estbivgeomRoy(x, y, "ML")
h[i,2,] <- estbivgeomRoy(x, y, "MMP")
h[i,3,] <- estbivgeomRoy(x, y, "MM1")
h[i,4,] <- estbivgeomRoy(x, y, "MM2")
h[i,5,] <- estbivgeomRoy(x, y, "MM3")
```

```
h[i,6,] <- estbivgeomRoy(x, y, "MM4")
h[i,7,] <- estbivgeomRoy(x, y, "LS")
}
# printing MC expected values and standard errors
# for each of the proposed estimation methods
cat("hattheta1:","\n")
cbind(mean=apply(h,c(2,3),meanrm)[,1],se=apply(h,c(2,3),sdrm)[,1])
cat("hattheta2:","\n")
cbind(mean=apply(h,c(2,3),meanrm)[,2],se=apply(h,c(2,3),sdrm)[,2])
cat("hattheta3:","\n")
cbind(mean=apply(h,c(2,3),meanrm)[,3],se=apply(h,c(2,3),sdrm)[,3])
# boxplots of MC distribution of the estimators of theta3
boxplot(h[,,3])
abline(h=theta3, lty=3)
```

`corbivgeomRoy` *Linear correlation*

Description

Linear correlation for Roy's bivariate geometric model

Usage

```
corbivgeomRoy(theta1, theta2, theta3)
```

Arguments

`theta1`	paramater θ_1
`theta2`	paramater θ_2
`theta3`	paramater θ_3

Value

the value of Pearson's linear correlation - see Barbiero (2018). The linear correlation for Roy's bivariate geometric distribution is negative (or null, for $\theta_3 = 1$) for any feasible choice of its parameters

Author(s)

Alessandro Barbiero

References

Roy, D. (1993) Reliability measures in the discrete bivariate set-up and related characterization results for a bivariate geometric distribution, Journal of Multivariate Analysis 46(2), 362-373.

Barbiero, A. (2018) Properties and estimation of a bivariate geometric model with locally constant failure rates, submitted

See Also

dbivgeomRoy

Examples

```
corbivgeomRoy(0.3,0.7,0.5)
```

---

dbivgeomRoy *Joint probability mass function*

Description

Joint probability mass function for Roy's bivariate geometric model

Usage

```
dbivgeomRoy(x, y, theta1, theta2, theta3)
```

Arguments

x	vector of values for the first variable X
y	vector of values for the second variable Y
theta1	paramater θ_1
theta2	paramater θ_2
theta3	paramater θ_3

Value

Value of the probability $p(x, y) := P(X = x, Y = y)$.

Author(s)

Alessandro Barbiero

References

Roy, D. (1993) Reliability measures in the discrete bivariate set-up and related characterization results for a bivariate geometric distribution, Journal of Multivariate Analysis 46(2), 362-373.

See Also

FbivgeomRoy

Examples

```
dbivgeomRoy(x=2, y=0, theta1=0.7, theta2=0.2, theta3=0.8)
dbivgeomRoy(0:5, y=0, theta1=0.7, theta2=0.2, theta3=0.8)
# these are p(0,0), p(1,0), ..., p(5,0)
dbivgeomRoy(0:2, 1:3, theta1=0.7, theta2=0.2, theta3=0.8)
# these are p(0,1), p(1,2), p(2,3)
```

`estbivgeomRoy` *Parameter estimation*

Description

Parameter estimation for Roy's bivariate geometric model

Usage

```
estbivgeomRoy(x, y, method = "LS")
```

Arguments

`x`	vector of observations from the first variable X
`y`	vector of observations from the first variable y, same length as `x`
`method`	One of the possible estimation methods: "ML" (maximum likelihood), "LS" (least squares), "MMP" (method of moment and poroportion), "M1", "M2", "M3", and "M4" (several variants of the method of moments)

Value

a vector of length 3 containing the estimates of $theta_1$, $theta_2$, and $theta_3$

Author(s)

Alessandro Barbiero

References

Barbiero, A. (2018) Properties and estimation of a bivariate geometric model with locally constant failure rates, submitted

Roy, D. (1993) Reliability measures in the discrete bivariate set-up and related characterization results for a bivariate geometric distribution, Journal of Multivariate Analysis 46(2), 362-373.

See Also

`dbivgeomRoy`, `minuslogRoy`

Examples

```
theta1 <- 0.5
theta2 <- 0.7
theta3 <- 0.9
# random sample of size n=1000:
set.seed(12345)
n <- 1000
d <- rbivgeomRoy(n, theta1, theta2, theta3)
# parameter estimation, using the different proposed methods:
hattheta <- estbivgeomRoy(d[,1], d[,2], "ML")
hattheta # MLEs
estbivgeomRoy(d[,1], d[,2], "LS")
estbivgeomRoy(d[,1], d[,2], "MMP")
```

EyxbivgeomRoy *Conditional moment*

Description

Conditional moment of Y given $X = x$ for Roy's bivariate geomtric model

Usage

```
EyxbivgeomRoy(theta1, theta2, theta3, x)
```

Arguments

theta1	paramater θ_1
theta2	paramater θ_2
theta3	paramater θ_3
x	value of the conditioning variable X

Value

Value of the conditional moment of Y given $X = x$

Author(s)

Alessandro Barbiero

References

Roy, D. (1993) Reliability measures in the discrete bivariate set-up and related characterization results for a bivariate geometric distribution, Journal of Multivariate Analysis 46(2), 362-373.

See Also

FyxbivgeomRoy

Examples

```
theta1 <- 0.5
theta2 <- 0.7
theta3 <- 0.9
EyxbivgeomRoy(theta1, theta2, theta3, 2)
```

FbivgeomRoy *Joint distribution function*

Description

Joint cumulative distribution function for Roy's bivariate geometric model

Usage

```
FbivgeomRoy(x, y, theta1, theta2, theta3)
```

Arguments

x	vector of values for the first variable X
y	vector of values for the second variable Y
theta1	paramater θ_1
theta2	paramater θ_2
theta3	paramater θ_3

Value

The probability $F(x, y) := P(X \leq x, Y \leq x)$

Author(s)

Alessandro Barbiero

References

Roy, D. (1993) Reliability measures in the discrete bivariate set-up and related characterization results for a bivariate geometric distribution, Journal of Multivariate Analysis 46(2), 362-373.

See Also

dbivgeomRoy, SbivgeomRoy

Examples

```
theta1 <- 0.5
theta2 <- 0.7
theta3 <- 0.9
# probability that X<=2 and Y<=3:
FbivgeomRoy(2, 3, theta1, theta2, theta3)
```

`FyxbivgeomRoy` *Conditional distribution*

Description

Conditional distribution function of Y given $X = x$

Usage

```
FyxbivgeomRoy(y, theta1, theta2, theta3, x)
```

Arguments

`y`	vector of observations from Y
`theta1`	paramater θ_1
`theta2`	paramater θ_2
`theta3`	paramater θ_3
`x`	value of the conditioning variable X

Value

The value of the conditional cumulative distribution function $F_{Y|x}$ in y. Used in `rbivgeomRoy` for conditional sampling

Author(s)

Alessandro Barbiero

References

Roy, D. (1993) Reliability measures in the discrete bivariate set-up and related characterization results for a bivariate geometric distribution, Journal of Multivariate Analysis 46(2), 362-373.

See Also

`EyxbivgeomRoy`, `rbivgeomRoy`

Examples

```
theta1 <- 0.5
theta2 <- 0.7
theta3 <- 0.9
# probability that Y<=3 given that X=2:
FyxbivgeomRoy(3, theta1, theta2, theta3, 2)
# the unconditional probability would be
pgeom(3, 1-theta2) # i.e. a geometric distribution with parameter 1-theta2
```

lambda1Roy *Bivariate failure rates*

Description

Bivariate failure rate λ_1

Usage

```
lambda1Roy(x, y, theta1, theta2, theta3)
```

Arguments

x	observation from the first variable
y	observation from the second variable
theta1	paramater θ_1
theta2	paramater θ_2
theta3	paramater θ_3

Details

It is defined as $P(X = x, Y \geq y)/P(X \geq x, Y \geq y)$. For this model, $\lambda_1(x, y) = 1 - \theta_1\theta_3^y$

Value

Value of the bivariate failure rate λ_1 for Roy's bivariate geometric model (Roy, 1993)

Author(s)

Alessandro Barbiero

References

Roy, D. (1993) Reliability measures in the discrete bivariate set-up and related characterization results for a bivariate geometric distribution, Journal of Multivariate Analysis 46(2), 362-373.

See Also

lambda2Roy

Examples

```
theta1 <- 0.5
theta2 <- 0.7
theta3 <- 0.9
# bivariate failure rate lambda1
# computed in x=1, y=2
x <- 1
y <- 2
lambda1Roy(x,y,theta1,theta2,theta3)
```

---

lambda2Roy *Bivariate failure rate*

Description

Bivariate failure rate λ_2

Usage

```
lambda2Roy(x, y, theta1, theta2, theta3)
```

Arguments

x	observation from the first variable
y	observation from the second variable
theta1	paramater θ_1
theta2	paramater θ_2
theta3	paramater θ_3

Details

It is defined as $P(X \geq x, Y = y)/P(X \geq x, Y \geq y)$. For this model, $\lambda_2(x, y) = 1 - \theta_2 \theta_3^x$

Value

Value of the bivariate failure rate λ_2 for Roy's bivariate geometric model (Roy, 1993)

Author(s)

Alessandro Barbiero

References

Roy, D. (1993) Reliability measures in the discrete bivariate set-up and related characterization results for a bivariate geometric distribution, Journal of Multivariate Analysis 46(2), 362-373.

See Also

lambda1Roy

Examples

```
theta1 <- 0.5
theta2 <- 0.7
theta3 <- 0.9
# bivariate failure rate lambda 2
# computed in x=1, y=2
x <- 1
y <- 2
lambda2Roy(x,y,theta1,theta2,theta3)
```

---

loglikgeomRoy *Log-likelihood function*

Description

Negative log-likelihood function for Roy's bivariate geometric model

Usage

```
loglikgeomRoy(par, x, y)
```

Arguments

par	a vector containing the values of the three parameters θ_1, θ_2, and θ_3
x	numeric vector of sample x-values (non-negative integers)
y	numeric vector of sample x-values (non-negative integers), same length as x

Value

Value of the negative log-likelihood function

Author(s)

Alessandro Barbiero

References

Roy, D. (1993) Reliability measures in the discrete bivariate set-up and related characterization results for a bivariate geometric distribution, Journal of Multivariate Analysis 46(2), 362-373.

See Also

dbivgeomRoy

Examples

```
theta1 <- 0.5
theta2 <- 0.7
theta3 <- 0.9
# random sample of size n=1000:
set.seed(12345)
n <- 1000
d <- rbivgeomRoy(n, theta1, theta2, theta3)
# parameter estimation, using the different proposed methods:
hattheta <- estbivgeomRoy(d[,1], d[,2], "ML")
loglikgeomRoy(hattheta, x=d[,1], y=d[,2])
# negative value of the (maximized) log-likelihood function
```

---

minuslogRoy *Log-likelihood function*

Description

Log-likelihood function (with minus sign) for Roy's bivariate geometric model

Usage

```
minuslogRoy(x, y, theta1 = 0.5, theta2 = 0.5, theta3 = 1)
```

Arguments

x	a vector of observed values (non-negative integers)
y	a vector of observed values (non-negative integers) of the same length as x
theta1	paramater θ_1
theta2	paramater θ_2
theta3	paramater θ_3

Value

The value of the log-likelihood function, changed in sign

Note

Just to be used inside the `estbivgeomRoy` function

Author(s)

Alessandro Barbiero

References

Roy, D. (1993) Reliability measures in the discrete bivariate set-up and related characterization results for a bivariate geometric distribution, Journal of Multivariate Analysis 46(2), 362-373.

See Also

estbivgeomRoy

---

rbivgeomRoy *Pseudo-random generation*

Description

Generation of pseudo-random values from Roy's bivariate geometric model

Usage

```
rbivgeomRoy(n, theta1, theta2, theta3)
```

Arguments

n	a positive integer, corresponding to the sample size
theta1	paramater θ_1
theta2	paramater θ_2
theta3	paramater θ_3

Value

A $n \times 2$ numeric matrix containing the bivariate sample values

Author(s)

Alessandro Barbiero

References

Roy, D. (1993) Reliability measures in the discrete bivariate set-up and related characterization results for a bivariate geometric distribution, Journal of Multivariate Analysis 46(2), 362-373.

See Also

dbivgeomRoy, FbivgeomRoy

Examples

```
theta1 <- 0.5
theta2 <- 0.7
theta3 <- 0.9
# random sample of size n=1000:
set.seed(12345)
n <- 1000
d <- rbivgeomRoy(n, theta1, theta2, theta3)
# joint frequency distribution:
table(d[,1],d[,2])
```

RelbivgeomRoy *Reliability parameter*

Description

Stress-strength reliability parameter R for Roy's bivariate geometric model

Usage

```
RelbivgeomRoy(theta1, theta2, theta3)
```

Arguments

theta1	paramater θ_1
theta2	paramater θ_2
theta3	paramater θ_3

Value

The probability $R := P(X \leq Y)$ for Roy's bivariate geometric model - see Barbiero (2018) for its computation

Author(s)

Alessandro Barbiero

References

Barbiero, A. (2018) Properties and estimation of a bivariate geometric model with locally constant failure rates, submitted

Roy, D. (1993) Reliability measures in the discrete bivariate set-up and related characterization results for a bivariate geometric distribution, Journal of Multivariate Analysis 46(2), 362-373.

See Also

dbivgeomRoy, FbivgeomRoy

Examples

```
theta1 <- 0.5
theta2 <- 0.7
theta3 <- 0.9
RelbivgeomRoy(theta1, theta2, theta3)
# theoretical stress-strength reliability parameter R=P(X<=Y)
```

S.n — *Empirical joint survival function*

Description

Empirical joint survival function

Usage

```
S.n(x, X)
```

Arguments

`x`	matrix with two columns of non-negative integer values where the empirical joint survival function is computed
`X`	matrix with two columns corresponding to the full observed sample

Value

value of the empirical joint survival function $\hat{S}_X(x)$

Author(s)

Alessandro Barbiero

References

Roy, D. (1993) Reliability measures in the discrete bivariate set-up and related characterization results for a bivariate geometric distribution, Journal of Multivariate Analysis 46(2), 362-373.

See Also

estbivgeomRoy

Examples

```
theta1 <- 0.5
theta2 <- 0.7
theta3 <- 0.9
set.seed(12345)
n <- 1000
d <- rbivgeomRoy(n, theta1, theta2, theta3)
S.n(cbind(1,1),d) # empirical sf
# compare it with the theoretical
SbivgeomRoy(1,1,theta1,theta2,theta3)
```

SbivgeomRoy — *Joint survival function*

Description

Joint survival function for Roy's bivariate geometric model

Usage

```
SbivgeomRoy(x, y, theta1, theta2, theta3)
```

Arguments

x	vector of observations from the first variable X
y	vector of observations from the second variable Y (same length as x)
theta1	paramater θ_1
theta2	paramater θ_2
theta3	paramater θ_3

Value

The probability $P(X \geq x, Y \geq y$. For this model it is equal to $S(x, y) = \theta_1^x \theta_2^y \theta_3^{xy}$

Author(s)

Alessandro Barbiero

References

Roy, D. (1993) Reliability measures in the discrete bivariate set-up and related characterization results for a bivariate geometric distribution, Journal of Multivariate Analysis 46(2), 362-373.

See Also

FbivgeomRoy

Examples

```
theta1 <- 0.5
theta2 <- 0.7
theta3 <- 0.9
# probability that X>=2 and Y>=3:
SbivgeomRoy(2, 3, theta1, theta2, theta3)
```

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