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Title Generalized Exponentiated Composite Distributions

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Description Contains the framework of the estimation, sampling, and hypotheses testing for two special distributions (Exponentiated Exponential-Pareto and Exponentiated Inverse Gamma-Pareto) within the family of Generalized Exponentiated Composite distributions. The detailed explanation and the applications of these two distributions were introduced in Bowen Liu, Malwane M.A. Ananda (2022) <doi:10.1080/03610926.2022.2050399>, Bowen Liu, Malwane M.A. Ananda (2022) <doi:10.3390/math10111895>, and Bowen Liu, Malwane M.A. Ananda (2022) <doi:10.3390/app13010645>.

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Contents

`asymptotic_eep` *Asymptotic Wald's test for testing the exponent in a EEP model.*

Description

This function computes the test statistic and the p-value of Wald's test for the exponent parameter in EEP model.

Usage

```
asymptotic_eep(data, eta0, theta1, eta1)
```

Arguments

`data`	Observations.
`eta0`	To test if the exponent equals 1, the default for eta0 is et to be 1.
`theta1`	The unrestricted MLE of theta.
`eta1`	The unrestricted MLE of eta.

Details

asymptotic_eep

Value

This function returns the test statistic and the p-value of the Wald's test.

Examples

```
sample1 = eep_sampling(200,eta = 1.1,theta = 3)
theta1 = mle_search_eep(data = sample1)$theta
eta1 = mle_search_eep(data = sample1)$eta
asymptotic_eep(sample1,eta0 = 1,theta1,eta1)
```

---

asymptotic_eigp *Asymptotic Wald's test for testing the exponent in a EIGP model.*

Description

This function computes the test statistic and the p-value of Wald's test for the exponent parameter in EIGP model.

Usage

```
asymptotic_eigp(data, eta0 = 1, theta1, eta1)
```

Arguments

data	Observations.
eta0	To test if the exponent equals 1, the default for eta0 is et to be 1.
theta1	The unrestricted MLE of theta.
eta1	The unrestricted MLE of eta.

Details

asymptotic_eigp

Value

This function returns the test statistic and the p-value of the Wald's test.

Examples

```
sample1 = eigp_sampling(200,eta = 1.1,theta = 3)
theta1 = mle_search_eigp(data = sample1)$theta
eta1 = mle_search_eigp(data = sample1)$eta
asymptotic_eigp(sample1,eta0 = 1,theta1,eta1)
```

cdf_eep *The cumulative distribution function of EEP.*

Description

cdf_eep

Usage

```
cdf_eep(theta, eta, data)
```

Arguments

theta	The location parameter for the base distribution (eta = 1). The value needs to be positive.
eta	The exponent parameter. The value provided needs to be positive.
data	Observations.

Value

Return the cumulative probability of EEP at the specific location.

Examples

```
cdf_eep(1,2,5)
```

cdf_eigp *The cumulative distribution function of EIGP.*

Description

cdf_eigp

Usage

```
cdf_eigp(theta, eta, data)
```

Arguments

theta	The location parameter for the base distribution (eta = 1). The value needs to be positive.
eta	The exponent parameter. The value provided needs to be positive.
data	Observations.

Value

Return the cumulative probability of EIGP at the specific location.

Examples

```
cdf_eigp(1,2,5)
```

`eep_nll` *The EEP Negative Log-likelihood Function.*

Description

This function serves as the objective function for the Maximum Likelihood Estimation procedure for EEP.

Usage

```
eep_nll(x, m, data)
```

Arguments

`x`	Vector of parameters.
`m`	The number of data items less than the density change point.
`data`	Observations.

Details

eep_nll

Value

A scalar that represents the negative loglikelihood of a EEP sample given the model parameter and the data.

Examples

```
eep_nll(c(2,2),50,seq(1:100))
```

`eep_optim` *The Wrapper Function that Returns the Final Estimates from Maximum Likelihood Estimation for EEP.*

Description

This function serves as a wrapper that returns the final estimates of theta, eta, and the corresponding density change point

Usage

```
eep_optim(data, init = c(1, 1), lower_bound = c(0.01, 0.01))
```

Arguments

`data`	Observations.
`init`	The vector of initial values of the model parameters. The default is c(1,1).
`lower_bound`	The vector of the lower bound for the parameters. The default is c(0.01,0.01).

Details

eep_optim

Value

A data frame with 1 row and 3 columns that contains the MLE of theta, eta, and the predicted density change point.

Examples

```
eep_optim(seq(1:100))
```

`eep_sampling` *The Random Number Generation Function for EIGP*

Description

Create a EEP random sample.

Usage

```
eep_sampling(n, theta, eta)
```

Arguments

n	Number of observations. (n>=1)
theta	The location parameter for the parent EP distribution (eta = 1). The value needs to be positive.
eta	The exponent parameter. The parameter should be positive.

Details

eep_sampling

Value

returns a numerical vector of size n.

Examples

```
eep_sampling(100,1,1)
```

---

eigp_nll *The EIGP Negative Log-likelihood Function.*

Description

This function serves as the objective function for the Maximum Likelihood Estimation procedure for EIGP.

Usage

```
eigp_nll(x, m, data)
```

Arguments

x	Vector of parameters.
m	The number of data items less than the density change point.
data	Observations.

Details

eigp_nll

Value

A scalar that represents the negative loglikelihood of a EIGP sample given the model parameter and the data.

Examples

```
eigp_nll(c(2,2),50,seq(1:100))
```

eigp_optim — *The Wrapper Function that Returns the Final Estimates from Maximum Likelihood Estimation for EIGP.*

Description

This function serves as a wrapper that returns the final estimates of theta, eta, and the corresponding density change point

Usage

```
eigp_optim(data, init = c(1, 1), lower_bound = c(0.01, 0.01))
```

Arguments

data	Observations.
init	The vector of initial values of the model parameters. The default is c(1,1).
lower_bound	The vector of the lower bound for the parameters. The default is c(0.01,0.01).

Details

eigp_optim

Value

A data frame with 1 row and 3 columns that contains the MLE of theta, eta, and the predicted density change point.

Examples

```
eigp_optim(seq(1:100))
```

eigp_sampling — *The Random Number Generation Function for EIGP*

Description

Create a EIGP random sample.

Usage

```
eigp_sampling(n, theta, eta)
```

Arguments

n	Number of observations. (n>=1)
theta	The location parameter for the parent IGP distribution (eta = 1). The value needs to be positive.
eta	The exponent parameter. The parameter should be positive.

Details

eigp_sampling

Value

This function returns a numerical vector of size n.

Examples

```
eigp_sampling(100,1,1)
```

---

exp_eep *The negative log density of a sample item if it follows exponential in a EEP model*

Description

This function return the negative log density of a sample item if if it follows exponential in a EEP model.

Usage

```
exp_eep(x, theta, eta)
```

Arguments

x	The value of a sample item.
theta	The location parameter for the base distribution (eta = 1). The value needs to be positive.
eta	The exponent parameter. The value provided needs to be positive.

Details

exp_exp

Value

This function return the negative log density of a sample item if if it follows exponential in a EEP model.

Examples

```
exp_eep(1,5,2)
```

`hazard_eep` *The hazard function of EEP.*

Description

hazard_eep

Usage

```
hazard_eep(theta, eta, data)
```

Arguments

`theta`	The location parameter for the base distribution (eta = 1). The value needs to be positive.
`eta`	The exponent parameter. The value provided needs to be positive.
`data`	Observations.

Value

Return the hazard of EEP at the specific location.

Examples

```
hazard_eep(2,1,5)
plot(hazard_eep(2,1,seq(0.01,100,by=0.01)))
```

`hazard_eigp` *The hazard function of EIGP.*

Description

hazard_eigp

Usage

```
hazard_eigp(theta, eta, data)
```

Arguments

`theta`	The location parameter for the base distribution (eta = 1). The value needs to be positive.
`eta`	The exponent parameter. The value provided needs to be positive.
`data`	Observations.

Value

Return the hazard of EIGP at the specific location.

Examples

```
hazard_eigp(1,2,5)
plot(hazard_eep(2,1,seq(0.01,100,by=0.01)))
```

`inv_gamma_eigp` *The negative log density of a sample item if it follows inverse gamma in a EIGP model*

Description

This function return the negative log density of a sample item if if it follows inverse gamma in a EIGP model.

Usage

```
inv_gamma_eigp(x, theta, eta)
```

Arguments

`x`	The value of a sample item.
`theta`	The location parameter for the base distribution (eta = 1). The value needs to be positive.
`eta`	The exponent parameter. The value provided needs to be positive.

Details

inv_gamma_eigp

Value

This function return the negative log density of a sample item if if it follows inverse gamma in a EIGP model.

Examples

```
inv_gamma_eigp(1,5,2)
```

LRT_eep *Likelihood Ratio Test (LRT) for the exponent parameter in EEP model.*

Description

This function computes the test statistic and the p-value of LRT for the exponent parameter in EEP model.

Usage

```
LRT_eep(data, theta0, theta1, eta1)
```

Arguments

data	Observations.
theta0	The MLE of theta when eta = 1.
theta1	The unrestricted MLE of theta.
eta1	The unrestricted MLE of eta.

Details

LRT_eep

Value

This function returns the test statistic and the p-value of the LRT test

Examples

```
sample1 = eep_sampling(200,eta = 1.1,theta = 6)
eta1 = mle_search_eep(data = sample1)$eta
theta1 = mle_search_eep(data = sample1)$theta
theta0 = mle_iter_eep(data = sample1,eta = 1)
LRT_eep(sample1,theta0,theta1,eta1)
```

LRT_eigp *Likelihood Ratio Test (LRT) for the exponent parameter in EIGP model.*

Description

This function computes the test statistic and the p-value for LRT for the exponent parameter in EIGP model.

Usage

```
LRT_eigp(data, theta0, theta1, eta1)
```

Arguments

data	Observations.
theta0	The MLE of theta when eta = 1.
theta1	The unrestricted MLE of theta.
eta1	The unrestricted MLE of eta.

Details

LRT_eigp

Value

This function returns the test statistic and the p-value from the LRT test

Examples

```
sample1 = eigp_sampling(200,eta = 1.1,theta = 3)
eta1 = mle_search_eigp(data = sample1)$eta
theta1 = mle_search_eigp(data = sample1)$theta
theta0 = mle_iter_eigp(data = sample1,eta = 1)
LRT_eigp(sample1,theta0,theta1,eta1)
```

---

mle_eep *Analytical solution of theta given eta in EEP model.*

Description

This function provides the analytical solution of theta for given eta EEP model.

Usage

```
mle_eep(s, m, n)
```

Arguments

s	A numeric value the sum of log(1/x_i^eta), where i is from 1 to m.
m	m is the number of data items less than the density change point.
n	n is the sample size, n has to be greater than m.

Details

mle_eep

Value

This function returns the Maximum Likelihood Estimate of theta for a given eta

Examples

```
mle_eep(5,2,5)
```

`mle_eigp` *Analytical solution of theta given eta in EIGP model.*

Description

This function provides the analytical solution of theta for given eta EIGP model.

Usage

```
mle_eigp(s, m, n)
```

Arguments

`s`	a numeric value the sum of log(1/x_i^eta), where i is from 1 to m.
`m`	m is the number of data items less than the density change point.
`n`	n is the sample size, n has to be greater than m.

Details

mle_eigp

Value

This function returns the Maximum Likelihood Estimate of theta for a given eta.

Examples

```
mle_eigp(5,2,5)
```

`mle_iter_eep` *Iteration function to find the analytical solution of theta given eta and data in EEP model.*

Description

This function finds the analytical solution of theta given eta and data in EEP model.

Usage

```
mle_iter_eep(data, eta)
```

Arguments

`data`	Observations.
`eta`	The exponent parameter. This value is greater than 0.

Details

mle_iter_eep

Value

This function returns the Maximum Likelihood Estimate of theta for a given eta with data.

Examples

```
mle_iter_eep(seq(1:100),2)
```

`mle_iter_eigp` *Iteration function to find the analytical solution of theta given eta and data in EIGP model.*

Description

This function finds the analytical solution of theta given eta and data in EIGP model.

Usage

```
mle_iter_eigp(data, eta)
```

Arguments

`data`	Observations.
`eta`	The exponent parameter. This value is greater than 0.

Details

mle_iter_eigp

Value

This function returns the Maximum Likelihood Estimate of theta for a given eta with data.

Examples

```
mle_iter_eigp(seq(1:100),2)
```

`mle_search_eep` *The grid search procedure for parameter estimation of EEP.*

Description

This function find the parameter estimates of EEP throgh a grid search procedure.

Usage

```
mle_search_eep(eta_seq = seq(0.5, 10, by = 0.01), data)
```

Arguments

`eta_seq`	A predefined range for eta values. The default is c(0.5,10,by = 0.01)
`data`	Observations.

Details

mle_search_eep

Value

This function returns a data frame as the parameter estimates for EEP from grid search methods.

Examples

```
sample1 = eep_sampling(200,eta = 2,theta = 3)
mle_search_eep(data = sample1)
```

mle_search_eigp *The grid search procedure for parameter estimation of EIGP.*

Description

This function find the parameter estimates of EIGP through a grid search procedure.

Usage

```
mle_search_eigp(eta_seq = seq(0.5, 10, by = 0.01), data)
```

Arguments

eta_seq	A predefined range for eta values. The default is c(0.5,10,by = 0.01)
data	n by 1 vector with all positive entries.

Details

mle_search_eigp

Value

This function returns data frame as the parameter estimates for EIGP from grid search methods.

Examples

```
sample1 = eigp_sampling(200,eta = 2,theta = 3)
mle_search_eigp(data = sample1)
```

neg_log_eep *The negative log likelihood function for EEP distribution.*

Description

This function computes the negative log-likelihood for EEP distribution.

Usage

```
neg_log_eep(y, theta, eta)
```

Arguments

y	n by 1 vector with all positive entries.
theta	The location parameter for the base distribution (eta = 1). The value needs to be positive.
eta	The exponent parameter. The value provided needs to be positive.

Details

neg_log_eigp

Value

This function return the negative log density of a sample item if if it follows Pareto in a EEP model.

Examples

```
neg_log_eep(seq(1:100),2,2)
```

`neg_log_eigp` *The negative log likelihood function for EIGP distribution.*

Description

This function computes the negative log-likelihood for EIGP distribution.

Usage

```
neg_log_eigp(y, theta, eta)
```

Arguments

`y`	n by 1 vector with all positive entries.
`theta`	The location parameter for the base distribution (eta = 1). The value needs to be positive.
`eta`	The exponent parameter. The value provided needs to be positive.

Details

neg_log_eigp

Value

This function return the negative log density of a sample item if if it follows Pareto in a EIGP model.

Examples

```
neg_log_eigp(seq(1:100),2,2)
```

`pareto_eep` *The negative log density of a sample item if it follows Pareto in a EEP model*

Description

This function return the negative log density of a sample item if if it follows Pareto in a EEP model.

Usage

```
pareto_eep(x, theta, eta)
```

Arguments

`x`	The value of a sample item.
`theta`	The location parameter for the base distribution (eta = 1). The value needs to be positive.
`eta`	The exponent parameter. The value provided needs to be positive.

Details

pareto_eep

Value

This function return the negative log density of a sample item if if it follows Pareto in a EEP model.

Examples

```
pareto_eep(10,5,2)
```

`pareto_eigp` *The negative log density of a sample item if it follows Pareto in a EIGP model*

Description

This function return the negative log density of a sample item if if it follows Pareto in a EIGP model.

Usage

```
pareto_eigp(x, theta, eta)
```

Arguments

x	The value of a sample item.
theta	The location parameter for the base distribution (eta = 1). The value needs to be positive.
eta	The exponent parameter. The value provided needs to be positive.

Details

pareto_eigp

Value

This function return the negative log density of a sample item if if it follows Pareto in a EIGP model.

Examples

```
pareto_eigp(10,5,2)
```

---

pdf_eep *The probability function of EEP.*

Description

pdf_eep

Usage

```
pdf_eep(theta, eta, data)
```

Arguments

theta	The location parameter for the base distribution (eta = 1). The value needs to be positive.
eta	The exponent parameter. The value provided needs to be positive.
data	Observations.

Value

Return the density of EEP

Examples

```
pdf_eep(1,2,5)
```

pdf_eigp *The probability density function of EIGP.*

Description

pdf_eigp

Usage

```
pdf_eigp(theta, eta, data)
```

Arguments

theta	The location parameter for the base distribution (eta = 1). The value needs to be positive.
eta	The exponent parameter. The value provided needs to be positive.
data	Observations.

Value

Return the density of EIGP

Examples

```
pdf_eigp(1,2,5)
```

q_eep *The quantile function of EEP.*

Description

q_eep

Usage

```
q_eep(theta, eta, p)
```

Arguments

theta	The location parameter for the base distribution (eta = 1). The value needs to be positive.
eta	The exponent parameter. The value provided needs to be positive.
p	This indicates the p-th percentile. p is greater than 0 and less than 100.

Value

Return the p-th percentile of EEP.

Examples

```
q_eigp(1,2,5)
```

`q_eigp` *The quantile function of EIGP.*

Description

q_eigp

Usage

```
q_eigp(theta, eta, p)
```

Arguments

`theta`	The location parameter for the base distribution (eta = 1). The value needs to be positive.
`eta`	The exponent parameter. The value provided needs to be positive.
`p`	This indicates the p-th percentile. p is greater than 0 and less than 100.

Value

Return the p-th percentile of EIGP.

Examples

```
q_eigp(1,2,5)
```

`raw_est_eep` *The Optimization Function for EEP Maximum Likelihood Estimation.*

Description

This function serves as the optimization function for EEP at different locations of density change points.

Usage

```
raw_est_eep(data, init = c(1, 1), lower_bound = c(0.01, 0.01))
```

Arguments

data	Observations.
init	The vector of initial values of the model parameters. The default is c(1,1).
lower_bound	The vector of the lower bound for the parameters. The default is c(0.01,0.01).

Details

raw_est_eep

Value

The matrix with estimates of theta and eta for n-1 different locations of density change points (1st column for theta, 2nd column for eta).

Examples

```
raw_est_eep(seq(1:100))
```

---

raw_est_eigp *The Optimization Function for EIGP Maximum Likelihood Estimation.*

Description

This function serves as the optimization function for EIGP at different locations of density change points.

Usage

```
raw_est_eigp(data, init = c(1, 1), lower_bound = c(0.01, 0.01))
```

Arguments

data	Observations.
init	The vector of initial values of the model parameters. The default is c(1,1).
lower_bound	The vector of the lower bound for the parameters. The default is c(0.01,0.01).

Details

raw_est_eigp

Value

The matrix with estimates of theta and eta for n-1 different locations of density change points (1st column for theta, 2nd column for eta).

Examples

```
raw_est_eigp(seq(1:100))
```

se_eep *The function for calculating the standard errors of the parameters of EEP model.*

Description

This function find the parameter estimates of EEP through a grid search procedure.

Usage

```
se_eep(data, theta, eta)
```

Arguments

data	Observations.
theta	The MLE of theta
eta	The MLE of eta

Details

se_eep

Value

The estimate of SE for theta and eta

Examples

```
sample1 = eep_sampling(200,eta = 2,theta = 3)
theta = mle_search_eep(data = sample1)$theta
eta = mle_search_eep(data = sample1)$eta
se_eep(sample1,theta,eta)
```

se_eigp *The function for calculating the standard errors of the parameters of EIGP model.*

Description

This function find the parameter estimates of EIGP through a grid search procedure.

Usage

```
se_eigp(data, theta, eta)
```

Arguments

data	Observations.
theta	The MLE of theta
eta	The MLE of eta

Details

se_eigp

Value

The estimate of SE for theta and eta

Examples

```
sample1 = eigp_sampling(200,eta = 2,theta = 3)
theta = mle_search_eigp(data = sample1)$theta
eta = mle_search_eigp(data = sample1)$eta
se_eigp(sample1,theta,eta)
```

---

validation *The validation Function for Model Parameters.*

Description

This function checks if the estimates from raw_est_eigp or raw_est_eep satisfy the pre-defined conditions for the parameters.

Usage

```
validation(data, estimate)
```

Arguments

data	Observations.
estimate	The data frame with 2 columns named 'theta' and 'eta'.

Details

validation

Value

A Boolean vector.

Examples

```
estimate = raw_est_eigp(seq(1:100),init = c(1,1),lower_bound = c(0.01,0.01))
estimate = data.frame(estimate)
colnames(estimate) = c('theta','eta')
validation(seq(1:100),estimate)
```

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