Package ‘RMediation’

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**Description**

We provide functions to compute confidence intervals (CIs) for a well-defined nonlinear function of the model parameters (e.g., product of k coefficients) in single-level and multilevel structural equation models.

**Details**

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`medci` produces a CI for the product of two normal random variables using three methods: the distribution of the product of coefficients, Monte Carlo, and asymptotic normal theory with the multivariate-delta standard error (Asymptotic-Delta) method. `pprodnormal` produces percentiles for the distribution of product of two normal random variables. `qprodnormal` generates quantiles for the distribution of product of two normal random variables. `ci` produces a CI for a well-defined nonlinear function of the model parameters in single-level and multilevel structural equation models using the Monte Carlo and Asymptotic-Delta method.

**Note**

Two web applications of the RMediation program are available from [http://amp.gatech.edu/RMediation](http://amp.gatech.edu/RMediation) and [http://amp.gatech.edu/MonteCarlo](http://amp.gatech.edu/MonteCarlo).

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**References**


See Also

qprodnormal pprodnormal medci ci

Examples

```r
medci(mu.x=.2,mu.y=.4,se.x=.1,se.y=.05,rho=0,alpha=.05)
pprodnormal(q=.4, mu.x=.5, mu.y=.3, se.x=.03, se.y=.08, rho=0)
pprodnormal(p=.1, mu.x=.5, mu.y=.3, se.x=.03, se.y=-.8, rho=0)
ci(mu=c(b1=0,b2=0),Sigma=c(1,2,10), quant=-b1*b2)
ci(mu=c(b1=1,b2=.7,b3=6,b4=.45),Sigma=c(.05,.0,0,.05,0,0,.03,0,.03), quant=-b1*b2*b3*b4, type="all", plot=TRUE, plotCI=TRUE)
```

---

### ci

**CI for a nonlinear function of coefficients estimates**

**Description**

This function returns a \((1 - \alpha)\%\) confidence interval (CI) for a well-defined nonlinear function of the coefficients in single-level and multilevel structural equation models. The `ci` function uses the Monte Carlo (`type"mc"`) and the asymptotic normal theory (`type"asymp"`) with the multivariate delta standard error (Asymptotic-Delta) method (Sobel, 1982) to compute a CI. In addition, for each of the methods, when a user specifies `plot=TRUE` and `plotCI=TRUE`, a plot of the sampling distribution of the quantity of interest in the `quant` argument and an overlaid plot of the CI will be produced. When `type="all"` and `plot=TRUE`, two overlaid plots of the sampling distributions corresponding to each method will be produced; when `plotCI=TRUE`, then the overlaid plots of the CIs for both methods will be displayed as well.

**Usage**

```r
ci(mu, Sigma, quant, alpha = 0.05, type = "MC", plot = FALSE, plotCI = FALSE, n.mc = 1e+06, H0 = FALSE, mu0 = NULL, Sigma0 = NULL, ...)
```

**Arguments**

- `mu` (1) a vector of means (e.g., coefficient estimates) for the normal random variables. A user can assign a name to each mean value, e.g., `mu=c(b1=.1,b2=3)`. Otherwise, the coefficient names are assigned automatically as follows: `b1, b2, ...` Or, a `lavaan` object.

- `Sigma` either a covariance matrix or a vector that stacks all the columns of the lower triangle variance-covariance matrix one underneath the other.
quant

quantity of interest, which is a nonlinear/linear function of the model parameters. Argument quant is a **formula** that **must** start with the symbol "tilde" (~): e.g., ~b1*b2*b3*b4. The names of coefficients must conform to the names provided in the argument `mu` or to the default names, i.e., b1, b2, . . .

alpha

significance level for the CI. The default value is .05.

type

method used to compute a CI. It takes on the values "mc" (default) for Monte Carlo, "asym" for Asymptotic–Delta, or "all" that produces CIs using both methods.

plot

when TRUE, plot the approximate sampling distribution of the quantity of interest using the specified method(s) in the argument type. The default value is FALSE. When type="all", superimposed density plots generated by both methods are displayed.

plotCI

when TRUE, overlays a CI plot with error bars on the density plot of the sampling distribution of quant. When type="all", the superimposed CI plots generated by both methods are added to the density plots. Note that to obtain a CI plot, one must also specify plot="TRUE". The default value is FALSE.

n.mc

Monte Carlo sample size. The default sample size is 1e+6.

H0

False. If TRUE, it will estimate the sampling distribution of \( H_0 : f(b) = 0 \). See the arguments `mu0` and `Sigma0`.

mu0

a vector of means (e.g., coefficient estimates) for the normal random variables that satisfy the null hypothesis \( H_0 : f(b) = 0 \). If it is not provided, smallest z value of `mu` is set to zero.

Sigma0

either a covariance matrix or a vector that stacks all the columns of the lower triangle variance–covariance matrix one underneath the other. If it is not provided, then `Sigma` is used instead.

... additional arguments.

**Value**

When type is "mc" or "asym", ci returns a list that contains:

(1 − α)% CI a vector of lower and upper confidence limits,

Estimate a point estimate of the quantity of interest,

SE standard error of the quantity of interest,

MC Error When type="mc", error of the Monte Carlo estimate.

When type="all", ci returns a list of two objects, each of which a list that contains the results produced by each method as described above.

**Note**

The web applications for this function is available at [http://amp.gatech.edu/MonteCarlo](http://amp.gatech.edu/MonteCarlo).

**Author(s)**

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Confidence Interval for the Mediated Effect

Description

Produces confidence intervals for the mediated effect and the product of two normal random variables.

Usage

medci(mu.x, mu.y, se.x, se.y, rho = 0, alpha = 0.05, type = "dop", plot = FALSE, plotCI = FALSE, n.mc = 1e+05, ...)

Arguments

mu.x mean of x
mu.y mean of y
se.x standard error (deviation) of x
se.y standard error (deviation) of y
rho correlation between x and y, where -1 < rho < 1. The default value is 0.
alpha significance level for the confidence interval. The default value is 0.05.
type method used to compute confidence interval. It takes on the values "dop" (default), "MC", "asymp" or "all".

plot when TRUE, plots the distribution of n.mc data points from the distribution of product of two normal random variables using the density estimates provided by the function density. The default value is FALSE.

plotCI when TRUE, overlays a confidence interval with error bars on the plot for the mediated effect. Note that to obtain the CI plot, one must also specify plot="TRUE". The default value is FALSE.

n.mc when type="MC", n.mc determines the sample size for the Monte Carlo method. The default sample size is 1E5.

... additional arguments to be passed on to the function.

Details

This function returns a \((1 - \alpha)\%\) confidence interval for the mediated effect (product of two normal random variables). To obtain a confidence interval using a specific method, the argument type should be specified. The default is type="dop", which uses the code we wrote in R to implement the distribution of product of the coefficients method described by Meeker and Escobar (1994) to evaluate the CDF of the distribution of product. type="MC" uses the Monte Carlo approach to compute the confidence interval (Tofighi & MacKinnon, 2011). type="asymp" produces the asymptotic normal confidence interval. Note that except for the Monte Carlo method, the standard error for the indirect effect is based on the analytical results by Craig (1936):

\[
\sqrt{(se.y^2 \mu_x^2 + se.x^2 \mu_y^2 + 2 \mu_x \mu_y \rho se.x se.y + se.x^2 se.y^2 + se.x^2 se.y^2 \rho^2)}
\]

In addition, the estimate of indirect effect is \(\mu_x \mu_y + \sigma_{xy}\). type="all" prints confidence intervals using all four options.

Value

A vector of lower confidence limit and upper confidence limit. When type is "prodclin" (default), "DOP", "MC" or "asymp", medci returns a list that contains:

(1 - \alpha)\% CI a vector of lower and upper confidence limits,

Estimate a point estimate of the quantity of interest,

SE standard error of the quantity of interest,

MC Error When type="MC", error of the Monte Carlo estimate.

Note that when type="all", medci returns a list of four objects, each of which a list that contains the results produced by each method as described above.

Note

The PRODCLIN programs may be downloaded from http://www.public.asu.edu/~davidpm/ripl/Prodclin/. A web application of the RMediation program is available from http://amp.gatech.edu/RMediation.
**pmC**

Probability (percentile) for the Monte Carlo Sampling Distribution of a nonlinear function of coefficients estimates

**Description**

This function returns a probability corresponding to the quantile q.

**Usage**

`pmC(q, mu, Sigma, quant, lower.tail = TRUE, n.mc = 1e+06, ...)`
Arguments

q  quantile
mu a vector of means (e.g., coefficient estimates) for the normal random variables. A user can assign a name to each mean value, e.g., \(\mu = (b1 = 1, b2 = 3)\); otherwise, the coefficient names are assigned automatically as follows: \(b1, b2, \ldots\).

Sigma either a covariance matrix or a vector that stacks all the columns of the lower triangle variance–covariance matrix one underneath the other.

quant quantity of interest, which is a nonlinear/linear function of the model parameters. Argument quant is a formula that must start with the symbol "tilde" (~): e.g., \(-b1*b2*b3*b4\). The names of coefficients must conform to the names provided in the argument mu or to the default names, i.e., \(b1, b2, \ldots\).

lower.tail logical; if \(\text{TRUE} \) (default), the probability is \(P[\text{quant} < q]\); otherwise, \(P[\text{quant} > q]\).

n.mc Monte Carlo sample size. The default sample size is 1e+6.

Value

scalar probability value.

Author(s)

Davood Tofighi <dtofighi@unm.edu> and David P. MacKinnon <davidpm@asu.edu>

References


See Also

medci Rmediation-package

Examples

```r
pMC(.2, mu=c(b1=1, b2=.7, b3=.6, b4=.45), Sigma=c(.05,0,0,0,.05,0,0,.03,0,.03), quant=-b1*b2*b3*b4)
```
pprodnormal

Percentile for the Distribution of Product of Two Normal Variables

Description

Generates percentiles (100 based quantiles) for the distribution of product of two normal random variables and the mediated effect

Usage

pprodnormal(q, mu.x, mu.y, se.x=1, se.y=1, rho = 0, lower.tail=TRUE, type="dop", n.mc=1e5)

Arguments

- **q**: quantile or value of the product
- **mu.x**: mean of x
- **mu.y**: mean of y
- **se.x**: standard error (deviation) of x
- **se.y**: standard error (deviation) of y
- **rho**: correlation between x and y, where -1 < rho < 1. The default value is 0.
- **lower.tail**: logical; if TRUE (default), the probability is \(P[X \times Y < q]\); otherwise, \(P[X \times Y > q]\)
- **type**: method used to compute \(P[X \times Y < q]\). It takes on the values "dop" (default), "MC", or "all".
- **n.mc**: when type="MC", n.mc determines the sample size for the Monte Carlo method. The default sample size is 1E5.

Details

This function returns the percentile (probability) and the associated error for the distribution of product of mediated effect (two normal random variables). To obtain a percentile using a specific method, the argument type should be specified. The default method is type="dop", which is based on the method described by Meeker and Escobar (1994) to evaluate the CDF of the distribution of product of two normal random variables. type="MC" uses the Monte Carlo approach (Tofighi & MacKinnon, 2011). type="all" prints percentiles using all three options. For the method type="dop", the error is the modulus of absolute error for the numerical integration (for more information see Meeker and Escobar, 1994). For type="MC", the error refers to the Monte Carlo error.

Value

An object of the type `list` that contains the following values:

- **p**: probability (percentile) corresponding to quantile q
- **error**: estimate of the absolute error
Author(s)

Davood Tofighi <dtofighi@unm.edu> and David P. MacKinnon <davidpm@asu.edu>

References


See Also

medci qprodnormal RMediation-package

Examples

pprodnormallq=q, mu.x=.5, mu.y=.3, se.x=1, se.y=1, rho= 0, type="all")

| qMC | Quantile for the Monte Carlo Sampling Distribution of a nonlinear function of coefficients estimates |

Description

This function returns a quantile corresponding to the probability p.

Usage

qMC(p, mu, Sigma, quant, n.mc = 1e+06, ...)

Arguments

- **p** probability.
- **mu** a vector of means (e.g., coefficient estimates) for the normal random variables. A user can assign a name to each mean value, e.g., mu=c(b1=.1,b2=3); otherwise, the coefficient names are assigned automatically as follows: b1,b2,....
- **Sigma** either a covariance matrix or a vector that stacks all the columns of the lower triangle variance–covariance matrix one underneath the other.
- **quant** quantity of interest, which is a nonlinear/linear function of the model parameters. Argument quant is a formula that must start with the symbol “tilde” (~): e.g., ~b1*b2*b3*b4. The names of coefficients must conform to the names provided in the argument mu or to the default names, i.e., b1,b2,....
- **n.mc** Monte Carlo sample size. The default sample size is 1e+6.
- **...** additional arguments.
qprodnormal

Value

scalar quantile value.

Author(s)

Davood Tofighi <dtofighi@psych.gatech.edu> and David P. MacKinnon <davidpm@asu.edu>

References


See Also

medci RMediation-package

Examples

```r
qMC(.05, mu=c(b1=1, b2=-.7, b3=.6, b4=.45), Sigma=c(.05, 0, 0, .05, 0, 0, .03, 0, .03), quant=-b1*b2*b3*b4)
```

---

### qprodnormal

**Quantile for the Distribution of Product of Two Normal Variables**

#### Description

Generates quantiles for the distribution of product of two normal random variables

#### Usage

`qprodnormal(p, mu.x, mu.y, se.x, se.y, rho=0, lower.tail=TRUE, type="dop", n.mc=1e5)`

#### Arguments

- `p` probability
- `mu.x` mean of `x`
- `mu.y` mean of `y`
- `se.x` standard error (deviation) of `x`
- `se.y` standard error (deviation) of `y`
- `rho` correlation between `x` and `y`, where `-1 < rho < 1`. The default value is 0.
- `lower.tail` logical; if TRUE (default), the probability is `P[X*Y < q]`; otherwise, `P[X*Y > q]`
- `type` method used to compute `P[X*Y < q]`. It takes on the values "dop" (default), "MC", or "all".
- `n.mc` when `type= "MC"`, `n.mc` determines the sample size of Monte Carlo method. The default sample size is 1E5.
Details

This function returns a quantile and the associated error (accuracy) corresponding the requested percentile (probability) \( p \) of the distribution of product of mediated effect (product of two normal random variables). To obtain a quantile using a specific method, the argument type should be specified. The default method is type="dop", which uses the method described by Meeker and Escobar (1994) to evaluate the CDF of the distribution of product of two normal variables. type="MC" uses the Monte Carlo approach (Tofighi & MacKinnon, 2011). type="all" prints quantiles using all three options. For the method type="dop", the error is the modulus of absolute error for the numerical integration (for more information see Meeker and Escobar, 1994). For type="MC", the error refers to the Monte Carlo error.

Value

An object of the type list that contains the following values:

- \( q \): quantile corresponding to probability \( p \)
- error: estimate of the absolute error

Author(s)

Davood Tofighi <dtofighi@unm.edu> and David P. MacKinnon <davidpm@asu.edu>

References


See Also

medci pprodnormal RMediation-package

Examples

```r
# lower tail
qprodnormal(p=.1, mu.x=.5, mu.y=.3, se.x=1, se.y=1, rho=0, lower.tail = TRUE, type="all")
```

```r
# upper tail
qprodnormal(p=.1, mu.x=.5, mu.y=.3, se.x=1, se.y=1, rho=0, lower.tail = FALSE, type="all")
```
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