Package: ui (via r-universe)

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Title Uncertainty Intervals and Sensitivity Analysis for Missing Data

Version 1.0.1

Description Implements functions to derive uncertainty intervals for (i) regression (linear and probit) parameters under missing not at random (non-ignorable missingness) as introduced in Genbäck, M., Stanghellini, E., and de Luna, X. (2015) <doi:10.1007/s00362-014-0610-x> and Genbäck, M., Ng, N., Stanghellini, E., and de Luna, X. (2018) <doi:10.1007/s10433-017-0448-x>. Also includes methods for doubly robust and outcome regression estimators of average causal effects under unobserved confounding as in Genbäck, M. and de Luna, X. (2018) <doi:10.1111/biom.13001>, and for partial correlation analysis following Gorbach, T. and de Luna, X. (2018) <doi:10.1016/j.spl.2018.05.027>.

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`gridrho_f` *Support function for* `ui_causal`

Description

Divides the `rho` interval into a grid

Usage

```
gridrho_f(rho, gridn, rho_plotrange, plot)
```

Arguments

rho	interval that should be divided
gridn	number of gridpoints
rho_plotrange	a larger interval of grids to be used in a plot
plot	whether or not the larger interval of grids should be created

---

grr *Gradient for the loglikelihood used by ui_probit*

Description

This function derives the gradient in order for ui_probit to run faster.

Usage

```
grr(par, rho, Xz = Xz, Xy = Xy, y = y, z = z)
```

Arguments

par	Coefficients.
rho	Rho.
Xz	Covariate matrix for missingness.
Xy	Covariate matrix for outcome.
y	Outcome.
z	Missing or not.

---

hess *Hessian for the loglikelihood used by ui_probit*

Description

This function derives the hessian in order for ui_probit to run faster.

Usage

```
hess(par, rho, Xz = Xz, Xy = Xy, y = y, z = z)
```

Arguments

par	Coefficients.
rho	Rho.
Xz	Covariate matrix for missingness.
Xy	Covariate matrix for outcome.
y	Outcome.
z	Missing or not.

interv_p *Print interval in parantesis*

Description

This function allows you to print an interval (vector of two elements) in a parantesis single element.

Usage

```
interv_p(v, digits = 3)
```

Arguments

v	Lower and upper bounds.
digits	Number of decimals.

lambda0 *Inverse Mills rato*

Description

This function allows you to calculate the inverse Mills ratio.

Usage

```
lambda0(x)
```

Arguments

x	Vector

lambda1 *Inverse Mills rato*

Description

This function allows you to calculate the inverse Mills ratio.

Usage

```
lambda1(x)
```

Arguments

x	Vector

logl_probit *Loglikelihood used by ui_probit*

Description

This function derives the Loglikelihood for ui_probit.

Usage

```
logl_probit(par, rho, Xz = Xz, Xy = Xy, y = y, z = z)
```

Arguments

par	Coeficient values the logliklihood should be drived at.
rho	The value of the sensitivity parameter.
Xz	covariate matrix for missingness mechanism
Xy	covariate matrix for the outcome regression
y	outcome vector
z	indicator of wether y is missing or not

logl_sand_act *Loglikelohood used in sandwich estimator of average causal effect on the treated for DR*

Description

Loglikelohood used in sandwich estimator of average causal effect on the treated for DR, support function for ui_causal

Usage

```
logl_sand_act(x, X, z)
```

Arguments

x	coefficents.
X	Covariate matrix.
z	Missing or not.

ml_probit *Fit maximum likelihood for fixed values of rho*

Description

This is a support function for ui_probit

Usage

```
ml_probit(out_formula, mis_formula, data, rho, progress = TRUE, method = "NR")
```

Arguments

out_formula	Formula for outcome regression.
mis_formula	Formula for regression model for the missingness mechanism.
data	Data frame containing the variables in the formulas
rho	Vector containing the values of rho for which we want to fit the likelihood.
progress	If TRUE prints out process time for each maximazation of the likelihood.
method	Maximazation method to be passed through maxLik

plot.uiols *Plot of UI and CI*

Description

Plot function for objects returned from ui_ols. Plots confidence intervals, coefficients and significance assuming ignorability and the uncertainty interval under non-ignorability.

Usage

```
## S3 method for class 'uiols'
plot(
  x,
  plot.all = TRUE,
  which = NA,
  intercept = FALSE,
  ylab = NULL,
  col = c("black", "royalblue", "lightpink2"),
  ...
)
```

Arguments

x	An object of class uiols
plot.all	If TRUE, plots all covariates.
which	Specify which variables should be plotted by either sending in their names in a vector or a vector with their numbers (1 intercept, 2 for the first covariate etc.).
intercept	If TRUE, also plots the intercept.
ylab	Vector of names for the y-axis, default is the variable names.
col	Vector containing the color of estimates under MAR and bounds of estimate under MNAR (default black), confidence intervals (default royalblue) and uncertainty intervals (default lightpink2).
...	Additional arguments, use is discouraged.

---

plot.uipcor *Plot of UI and CI for partial correlation*

Description

Plot function for objects returned from ui_pcor. Plots confidence intervals, coefficients and significans assuming ignorability and the uncertainty interval under non-ignorability.

Usage

```
## S3 method for class 'uipcor'
plot(x, col = c("black", "red"), ...)
```

Arguments

x	An object of class uiols
col	Vector containing the color of confidence intervals (default black) and uncertainty intervals (default red).
...	Additional arguments, use is discouraged.

plot.uiprobit *Plot of UI and CI*

Description

Plot function for objects returned from ui_probit.Plots confidence intervals, coefficients and significance assuming ignorability and the uncertainty interval under non-ignorability.

Usage

```
## S3 method for class 'uiprobit'
plot(
  x,
  plot.all = TRUE,
  which = NA,
  intercept = FALSE,
  ylab = NULL,
  col = c("black", "royalblue", "lightpink2"),
  ...
)
```

Arguments

x	An object of class uiprobit
plot.all	If TRUE, plots all covariates.
which	Specify which variables should be plotted by either sending in their names in a vector or a vector with their numbers (1 for the first covariate, 2 for the second etc.).To plot the intercept, set intercept as TRUE.
intercept	If TRUE, also plots the intercept.
ylab	Vector of names for the y-axis, default is the variable names.
col	Vector containing the color of estimates under MAR and bounds of estimate under MNAR (default black), confidence intervals (default royalblue) and uncertainty intervals (default lightpink2).
...	Additional arguments, use is discouraged.

print.uicausal *Print function for object of class uicausal*

Description

Print function for object of class uicausal

Usage

```
## S3 method for class 'uicausal'
print(x, digits = 3, digitsci = digits, digitsui = digits, ...)
```

Arguments

x	An object of returned from ui_causal
digits	number of digits to be printed.
digitsci	number of digits to be printed in the confidence interval.
digitsui	number of digits to be printed in the uncertainty interval.
...	Additional arguments, use is discouraged.

---

print.uiols *Prints objects of class uiols*

Description

Prints objects of class uiols

Usage

```
## S3 method for class 'uiols'
print(x, digits = 3, digitsci = digits, digitsui = digits, ...)
```

Arguments

x	an objects returned from ui_ols
digits	number of digits to be printed.
digitsci	number of digits to be printed in the confidence interval.
digitsui	number of digits to be printed in the uncertainty interval.
...	Additional arguments, use is discouraged.

print.uipcor *Prints objects of class uipcor*

Description

Prints objects of class uipcor

Usage

```
## S3 method for class 'uipcor'
print(x, digits = 3, digitsci = digits, digitsui = digits, ...)
```

Arguments

x	an objects returned from ui_pcor
digits	number of digits to be printed.
digitsci	number of digits to be printed in the confidence interval.
digitsui	number of digits to be printed in the uncertainty interval.
...	Additional arguments, use is discouraged.

print.uiprobit *Prints objects of class uiprobit*

Description

Prints objects of class uiprobit

Usage

```
## S3 method for class 'uiprobit'
print(x, digits = 3, digitsci = digits, digitsui = digits, ...)
```

Arguments

x	an objects returned from ui_probit
digits	number of digits to be printed.
digitsci	number of digits to be printed in the confidence interval.
digitsui	number of digits to be printed in the uncertainty interval.
...	Additional arguments, use is discouraged.

profile *Profile method for ui objects*

Description

Profile method for ui objects

Usage

```
profile(x, ...)
```

Arguments

x	Object
...	Additional arguments

profile.uicausal *Plot of UI and CI*

Description

Plot function for objects returned from ui_causal. Plots confidence intervals for different values of rho and the uncertainty interval.

Usage

```
## S3 method for class 'uicausal'
profile(
  x,
  dr = TRUE,
  profile = "all",
  title = NULL,
  xlab = NULL,
  ylab = NULL,
  ...
)
```

Arguments

x	An object of class uicausal
dr	If TRUE the doubly robust estimator is plotted, otherwise the outcome regression estimator is plotted.
profile	Character specifying profile type ("ui.only" or "all"). If ui.only, only the UI range is plotted; if all, the full profile is shown.

title	Main title
xlab	Title for xaxis, default is expression(rho).
ylab	Title for y axis, default is no title.
...	discouraged from use

---

profile.uiols *Plot of UI and CI*

Description

Plot function for objects returned from ui_ols. Plots confidence intervals for different values of rho and the uncertainty interval.

Usage

```
## S3 method for class 'uiols'
profile(
  x,
  plot.all = TRUE,
  which = NA,
  intercept = FALSE,
  xlab = NULL,
  ylab = NULL,
  scales = "fixed",
  expand = 0.1,
  ...
)
```

Arguments

x	An object of class uiols
plot.all	If TRUE, plots all covariates.
which	Specify which variables should be plotted by either sending in their names in a vector or a vector with their numbers (1 intercept, 2 for the first covariate etc.).
intercept	If TRUE, also plots the intercept.
xlab	Title for x-axis, default is expression(rho).
ylab	Title for y-axis, default is the variable names.
scales	Fixed or different scales of the y axis between panels. Default is "fixed", the other choice is "free_y".
expand	Add space by expanding y-axis range. Default is 0.1 which is 10% extra on above and below.
...	Additional arguments, use is discouraged.

profile.uipcor — *Plot of confidence intervals for partial correlation by values of the sensitivity parameter (s).*

Description

Plots confidence intervals by values of sensitivity parameter (s) for objects returned from `ui_pcor`.

Usage

```
## S3 method for class 'uipcor'
profile(x, ...)
```

Arguments

`x`	An object of class uipcor
`...`	Additional arguments, for instance margins.

Details

Plots estimated partial correlation, lower and upper bounds of confidence intervals for different values of rho (based on on values of the sensitivity parameter(s) in `x$gridrho`). Plots a 2D plot when missing data only in the outcome or the same missing in the outcome and the predictor of interest (missing data mechanisms A and B). Plots a 3D plot when different missing data in the outcome and the predictor of interest (missing data mechanism C).

profile.uiprobit — *Plot of UI and CI*

Description

Plot function for objects returned from `ui_probit`. Plots confidence intervals for different values of rho and the uncertainty interval.

Usage

```
## S3 method for class 'uiprobit'
profile(
  x,
  plot.all = TRUE,
  which = NA,
  intercept = FALSE,
  xlab = NULL,
  ylab = NULL,
  title = NULL,
```

```
  scales = "fixed",
  expand = 0.1,
  ...
)
```

Arguments

x	An object of class uiprobit
plot.all	If TRUE, plots all covariates.
which	Specify which variables should be plotted by either sending in their names in a vector or a vector with their numbers (1 intercept, 2 for the first covariate etc.).
intercept	If TRUE, also plots the intercept.
xlab	Title for x-axis, default is `expression(rho)`.
ylab	Title for y-axis, default is the variable names.
title	Main title
scales	Fixed or different scales of the y axis between panels. Default is "fixed", the other choice is "free_y".
expand	Add space by expanding y-axis range. Default is 0.1 which is 10% extra on above and below.
...	Additional arguments, use is discouraged.

---

sand_dr_act *Calculates standard error of Average causal effect on the treated*

Description

This is a support function for `ui_causal` and calculates standard error of Average causal effect on the treated for the doubly robust estimator.

Usage

```
sand_dr_act(
  deltasigma1,
  X,
  Xz,
  y,
  z,
  u,
  BetaOLSy0,
  phat,
  NaivEst,
  n1,
  n0,
  N,
  p,
  pz
)
```

Arguments

deltasigma1	Coefficients.
X	Covariate matrix outcome.
Xz	Covariate matrix treatment.
y	Outcome vector.
z	Missingness indicator.
u	Fitted values from propensity score regression.
BetaOLSy0	Coefficients from non-treated regression
phat	Fitted propensity scores.
NaivEst	Naiv estimates.
n1	Number of treated.
n0	Number of non-treated.
N	Total number.
p	Number of covariates outcome regression.
pz	Number of covariates treatment regression.

---

sand_or_ace *Calculates standard error of Average causal effect*

Description

This is a support function for ui_causal and calculates standard error of Average causal effect for the outcome regression estimator.

Usage

```
sand_or_ace(X, y, z, BetaOLSy0, BetaOLSy1, NaivEst, N, p)
```

Arguments

X	Covariate matrix.
y	Outcome vector.
z	missingness indicator.
BetaOLSy0	Coefficients from non-treated regression.
BetaOLSy1	Coefficients from treated regression.
NaivEst	Naiv estimates.
N	Total number.
p	Number of covariates outcome regression.

sand_or_act *Calculates standard error of Average causal effect on the treated*

Description

This is a support function for ui_causal and calculates standard error of Average causal effect on the treated for the outcome regression estimator.

Usage

```
sand_or_act(X, y, z, BetaOLSy0, NaivEst, n1, N, p)
```

Arguments

X	Covariate matrix.
y	Outcome vector.
z	missingness indicator
BetaOLSy0	Coefficients from non-treated regression
NaivEst	Naiv estimates.
n1	Number of treated.
N	Total number.
p	Number of covariates outcome regression.

se_ols *Calculation of se for OLS*

Description

This function calculates the se for UI based on OLS when we have MNAR data, for ui_ols.

Usage

```
se_ols(X, sigma_ols_cor, u, gridrho)
```

Arguments

X	Covariate matrix.
sigma_ols_cor	Output from sigma_ols_cor1
u	Fitted values from mis_model.
gridrho	Values of rho.

sigma_ols_cor0 *Correction of OLS sigma for causal effects*

Description

This function is a bias correction of the residual standard deviation under MNAR, for ui_causal.

Usage

```
sigma_ols_cor0(X, sigma_ols, n, p, u, gridrho)
```

Arguments

X	Covariate matrix outcome.
sigma_ols	Residual sd from outcome regression.
n	Number of complete cases.
p	Number of covariates outcome regression.
u	Fitted values from propensity score regression.
gridrho	Values of rho.

sigma_ols_cor1 *Correction of OLS sigma*

Description

This function is a bias correction of the residual standard deviation under MNAR, used by ui_causal and ui_ols.

Usage

```
sigma_ols_cor1(X, sigma_ols, n, p, u, gridrho)
```

Arguments

X	Covariate matrix outcome.
sigma_ols	Residual sd from outcome regression.
n	Number of complete cases.
p	Number of covariates outcome regression.
u	Fitted values from propensity score regression.
gridrho	Values of rho.

ui_causal *Uncertainty intervals for Average Causal Effects*

Description

This function allows you to derive uncertainty intervals for the average causal effect (ACE) or the average causal effect on the treated (ACT). The function uses a regression imputation estimator and a doubly robust estimator. The uncertainty intervals can be used as a sensitivity analysis to unconfoundedness. Note that rho=0 render the same results as assuming no unobserved confounding.

Usage

```
ui_causal(
  out_formula,
  treat_formula,
  data,
  rho = c(-0.3, 0.3),
  rho0 = NULL,
  rho1 = NULL,
  ACT = FALSE,
  sand = TRUE,
  gridn = 21,
  plot = TRUE,
  rho_plotrange = c(-0.5, 0.5),
  alpha = 0.05
)
```

Arguments

out_formula	Formula for the outcome regression models
treat_formula	Formula for the propensity score model (regression model for treatment assignment).
data	data.frame containing the variables in the formula.
rho	Pre-specified interval for rho0 and rho1.
rho0	Pre-specified value of rho0, if an interval it has to be the same as rho1.
rho1	Pre-specified value of rho1, if an interval it has to be the same as rho0.
ACT	If TRUE Average Causal effect of the Treated is calculated, if FALSE Average Causal effect is calculated. Default is FALSE.
sand	Specifies which estimator of the standard errors should be used for OR, see details.
gridn	Number of fixed points within the rho interval for which sigma0 and sigma1 should be estimated.
plot	If TRUE the function runs slightly slower but you will be able to plot your results using profile.uicausal.
rho_plotrange	an interval larger than rho for the plot using profile.uicausal.
alpha	Default 0.05 corresponding to a confidence level of 0.95 for CI and UI.

Details

In order to visualize the results, you can use `profile.uicausal`. Details about estimators can be found in Genbäck and de Luna (2018)

The standard errors are calculated with the following estimators:

DR ACE - simplified sandwich estimator

DR ACT - sandwich estimator

OR ACE - if sand=TRUE sandwich estimator (default and recommended), if sand=FALSE large sample variance

OR ACT - if sand=TRUE sandwich estimator (default and recommended), if sand=FALSE large sample variance

Value

A list containing:

`call`	The matched call
`rho0`	The rage of `rho0` from which the ui is calculated
`rho1`	If ACT==FALSE,range of `rho1` from which the ui is calculated
`out_model0`	Outcome regression model for non-treated.
`out_model1`	Outcome regression model for treated.
`treat_model`	Regression model for treatment mechanism (propensity score).
`sigma0`	Consistent estimate of sigma0 for different values of rho0
`sigma1`	Consistent estimate of sigma1 for different values of rho1
`dr`	DR inference, confidence intervals for different pre-specified values of `rho` for the OR estimator, uncertainty interval, coefficient estimates, confounding bias, indentification bounds, standard error etc.
`or`	OR inference, confidence intervals for different pre-specified values of `rho` for the OR estimator, uncertainty interval, coefficient estimates, confounding bias, indentification bounds, standard error etc.

Author(s)

Minna Genbäck

References

Genbäck, M., de Luna, X. (2018). Causal Inference Accounting for Unobserved Confounding after Outcome Regression and Doubly Robust Estimation. *Biometrics*. DOI: 10.1111/biom.13001

Examples

```
library(MASS)
n<-500
delta<-c(-0.3,0.65)
rho<-0.3
X<-cbind(rep(1,n),rnorm(n))
x<-X[,-1]
s0<-2
s1<-3
error<-mvrnorm(n, c(0,0,0), matrix(c(1,0.6,0.9,0.6,4,0.54,0.9,0.54,9), ncol=3))
zstar<-X%*%delta+error[,1]
z<- zstar>0
y1<-ifelse(x< (-1),0.2*x-0.1*x^2, ifelse(x< 1,0.3*x, ifelse(x<3,0.4-0.1*x^2,-0.2-0.1*x)))+error[,3]
y0<-ifelse(x<1.5, x-0.4*x^2, ifelse(x<2, -0.15-0.25*x+0.5*x^2, 1.85-0.25*x))+error[,2]
y<-y0
y[z==1]<-y1[z==1]
data<-data.frame(y,z,x)


ui<-ui_causal(y~x, z~x, data=data, rho=c(0,0.3), ACT=FALSE)
ui
profile(ui)
mean(y1-y0)

ui<-ui_causal(y~x, z~x, data=data, rho=c(0,0.3), ACT=TRUE)
ui
profile(ui)
profile(ui,profile="ui")
mean(y1[z==1]-y0[z==1])
```

`ui_ols` *Uncertainty intervals for OLS regression*

Description

This function allows you to derive uncertainty intervals for OLS regression when there is missing data in the continuous outcome. The uncertainty intervals can be used as a sensitivity analysis to ignorability (missing at random). Note that rho=0 render the same results as a complete case analysis.

Usage

```
ui_ols(
  out_formula,
  mis_formula = NULL,
  data,
  rho = c(-0.3, 0.3),
  alpha = 0.05,
```

```
  gridn = 101
)
```

Arguments

out_formula	Formula for outcome regression.
mis_formula	Formula for missingness mechanism. If NULL the same covariates as in the outcome regression will be used.
data	data.frame containing the variables in the formula.
rho	The limits of rho for which the uncertainty interval should be constructed.
alpha	Default 0.05 corresponding to a confidence level of 95 for CI and UI.
gridn	The number of distinct points within the interval rho at which confidence intervals should be constructed. Default is 101.

Details

In order to visualize the results, you can use plot.uiols, or profile.uiols.

Value

A list containing:

call	The matched call
ci	Confidence intervals for different values of rho
ui	Uncertainty intervals
coef	Estimated coefficients (outcome regression) for different values of rho
out_model	Outcome regression model when rho=0.
mis_model	Regression model for missingness mechanism (selection).
rho	The range of rho for which we want to construct an uncertainty interval
gridrho	The values of rho for which bias and standard errors are derived
sigma	Consistant estimate of sigma
se	Standard error for different values of rho
ciols	Confidence intervals from a complete case analysis
ident_bound	Bounds for the coefficient estimates.

Author(s)

Minna Genbäck

References

Genbäck, M., Stanghellini, E., de Luna, X. (2015). Uncertainty Intervals for Regression Parameters with Non-ignorable Missingness in the Outcome. *Statistical Papers*, 56(3), 829-847.

Examples

```
library(MASS)
n<-500
delta<-c(0.5,0.3,0.1)
beta<-c(0.8,-0.2,0.3)
X<-cbind(rep(1,n),rnorm(n),rbinom(n,1,0.5))
x<-X[,-1]
rho=0.4
error<-mvrnorm(n,c(0,0),matrix(c(1,rho*2,rho*2,4),2))
zstar<-X%*%delta+error[,1]
z<-as.numeric(zstar>0)
y<-X%*%beta+error[,2]
y[z==0]<-NA
data<-data.frame(y,x,z)
ui<-ui_ols(y~X1+X2,data=data,rho=c(-0.5,0.5))
ui
plot(ui)
```

`ui_pcor` *Uncertainty intervals for partial correlation*

Description

This function is used to calculate uncertainty intervals for partial correlation between two variables adjusting for a set of other variables. The two variables of interest might have missing data according to the three missing data mechanisms (see reference). Data for the variables in the adjustment set should be completely observed.

Usage

```
ui_pcor(
  out_formula,
  data,
  rho = c(-0.3, 0.3),
  rho2 = rho,
  alpha = 0.05,
  gridn = 101,
  gridn2 = 11
)
```

Arguments

`out_formula`	Regression formula where one variable of interest is the outcome and another variable of interest is the first predictor. Other predictors are variables in the adjustment set.
`data`	data.frame containing the variables in the formula.

rho	The min and the max of the sensitivity parameter.
rho2	The min and the max of the sensitivity parameter rho2 in the model for missing in the predictor of interest within missing data mechanism C. The same as rho by default.
alpha	Significance level. Default 0.05 corresponding to a confidence level of 0.95 for CI and UI.
gridn	The number of distinct points for rho at which confidence intervals should be constructed. Default is 101.
gridn2	The number of distinct points for rho2 at which confidence intervals should be constructed for missing data mechanism C. Default is 11.

Details

In order to visualize the results, you can use plot.uipcor. In the initial publication (see reference), the sensitivity parameter is called gamma, while the function denote the sensitivity paramter as rho for the corespondence with other functions in the package.

Value

A list containing:

call	The matched call
out_formula	Regression formula where one variable of interest is the outcome and another variable of interest is the first predictor. Other predictors are variables in the adjustment set.
out_model	A result of a call to lm for the specified regression.
mis_formula	Regression formula for missingness mechanism(s).
mis_model	A result of a call to glm for probit model (s) for the missingness mechanism(s).
rho	The range of values for the sensitivity parameter, rho, for which an uncertainty interval is constructed. Default is (-0.3; 0.3).
gridrho	The values of the sensitivity parameter rho (parameters rho1 and rho2 for missing data mechanisms C) for which confidence intervals are constructed.
pcor, rho0	Estimated partial correlation assuming that the sensitivity parameter(s) is 0.
pcor	Estimated partial correlation for different values of the sensitivity parameter(s) in gridrho.
ident.bound	Bounds for the estimated identification region for partial correlation. An interval from the lowest to the largest estimated partial correlation.
pcor.se	Standard error for different values of the sensitivity parameter(s) in gridrho.
ci.rho0	Confidence interval for partial correlation assuming that the sensitivity parameter(s) is 0.
ci	Confidence intervals for partial correlation for different values of the sensitivity parameter(s) in gridrho.
ui	Uncertainty interval for partial correlation. An interval from the minimum lower bound to the maximum upper bound of estimated confidence intervals.

Author(s)

Tetiana Gorbach

References

Gorbach, T., de Luna, X. (2018). Inference for partial correlation when data are missing not at random. *Statistics & Probability Letters*, 141, 82-89.

Examples

```
library(MASS)
n <- 1000
rho <- 0.1
error <- mvrnorm(n, mu = c(0, 0, 0), Sigma = diag(c(1.16, 0.028^2 * (1 - rho^2), 1)))
X3 <- rnorm(n, mean = 67, sd = 7)
X4 <- rbinom(n, 1, prob = 0.3)
X2 <- 2.313 - 0.042 * X3 - 0.216 * X4 + error[, 1]
X1 <- 1.092 + 0.01 * X2 - 0.002 * X3 - 0.006 * X4 + 0.028 * rho * error[, 3] + error[, 2]
Z <- as.numeric(2.708 + 0.548 * X2 - 0.036 * X3 - 0.042 * X4 + error[, 3] > 0)
X1[Z == 0] <- NA
data <- data.frame(X1, X2, X3, X4)
ui <-  ui_pcor(
 out_formula = X1 ~ X2 + X3 + X4,
 data = data,
 rho = c(0.1, 0.5),
 alpha = 0.05,
 gridn = 10
)
 ui
```

`ui_probit` *Uncertainty intervals for probit regression*

Description

This function allows you to derive uncertainty intervals for probit regression when there is missing data in the binary outcome. The uncertainty intervals can be used as a sensitivity analysis to ignorability (missing at random), and are derived by maximum likelihood. Note that `rho=0` render the same results as a complete case analysis.

Usage

```
ui_probit(
  out_formula,
  mis_formula = NULL,
  data,
  rho = c(-0.3, 0.3),
```

```
  progress = TRUE,
  max_grid = 0.1,
  alpha = 0.05,
  method = "NR"
)
```

Arguments

out_formula	Formula for outcome regression.
mis_formula	Formula for missingness mechanism. If NULL the same covariates as in the outcome regression will be used.
data	data.frame containing the variables in the formula.
rho	Vector containing the values of rho for which we want to fit the likelihood.
progress	If TRUE prints out process time for each maximization of the likelihood.
max_grid	Maximum distance between two elements in rho, if two wide there can difficulties with convergence of the maximum likelihood.
alpha	Default 0.05 corresponding to a confidence level of 95 for CI and UI.
method	Maximization method to be passed through maxLik

Details

In order to visualize the results, you can use plot.uiprobit or profile.uiprobit.

Value

A list containing:

coef	Estimated coefficients (outcome regression) for different values of rho.
rho	The values of rho for which the likelihood is maximized.
vcov	Covariance matrix.
ci	Confidence intervals for different values of rho.
ui	Uncertainty intervals.
out_model	Outcome regression model when rho=0.
mis_model	Regression model for missingness mechanism (selection).
se	Standard errors from outcome regression.
value	Value of maximum likelihood for different values of rho.
y	Outcome vector.
z	Indicator variable of observed outcome.
Xy	Covariate matrix for outcome regression.
Xz	Covariate matrix for missingness mechanism (selection regression model).
max.info	Information about the maximization procedure. Includes whether it converged, message, method and number of iterations.

Author(s)

Minna Genbäck

References

Genbäck, M., Ng, N., Stanghellini, E., de Luna, X. (2018). Predictors of Decline in Self-reported Health: Addressing Non-ignorable Dropout in Longitudinal Studies of Aging. *European journal of ageing*, 15(2), 211-220.

Examples

```
library(MASS)
n<-500

delta<-c(0.5,0.6,0.1,-1,1)
beta<-c(-0.3,-0.5,0,-0.4,-0.3)

X<-cbind(rep(1,n),rnorm(n),runif(n),rbinom(n,2,0.5),rbinom(n,1,0.5))
x<-X[,-1]
rho=0.4
error<-mvrnorm(n,c(0,0),matrix(c(1,rho,rho,1),2))

zstar<-X%*%delta+error[,1]
z<-as.numeric(zstar>0)

ystar<-X%*%beta+error[,2]
y<-as.integer(ystar>0)
y[z==0]<-NA
data=data.frame(y=y,x1=x[,1],x2=x[,2],x3=x[,3],x4=x[,4])

m<-ui_probit(y~x1+x2+x3+x4,data=data,rho=c(0,0.4))
m
plot(m)
profile(m)
```

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