# Package 'ui'

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**Title** Uncertainty Intervals and Sensitivity Analysis for Missing Data

**Version** 0.1.1

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**Description** Implements functions to derive uncertainty intervals for (i) regression (linear and probit) parameters when outcome is missing not at random (non-ignorable missingness) introduced in Genbaeck, M., Stanghellini, E., de Luna, X. (2015) <doi:10.1007/s00362-014-0610-x> and Genbaeck, M., Ng, N., Stanghellini, E., de Luna, X. (2018) <doi:10.1007/s10433-017-0448-x>; and (ii) double robust and outcome regression estimators of average causal effects (on the treated) with possibly unobserved confounding introduced in Genbaeck, M., de Luna, X. (2018) <doi:10.1111/biom.13001>.

**Depends** R (>= 3.5)

**Imports** Matrix, maxLik, mvtnorm, numDeriv, graphics, stats

**Suggests** MASS

**Encoding** UTF-8

**LazyData** true

**License** GPL-2

**RoxygenNote** 6.1.1

**NeedsCompilation** no

**Repository** CRAN

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## R topics documented:

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`gridrho.f` *Support function for* `ui.causal`

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## 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, X.z = X.z, X.y = X.y, y = y, z = z)
```

### Arguments

| | |
|---|---|
| `par` | Coefficients. |
| `rho` | Rho. |
| `X.z` | Covariate matrix for missingness. |
| `X.y` | 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, X.z = X.z, X.y = X.y, y = y, z = z)
```

### Arguments

| | |
|---|---|
| `par` | Coefficients. |
| `rho` | Rho. |
| `X.z` | Covariate matrix for missingness. |
| `X.y` | 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, X.z = X.z, X.y = X.y, y = y, z = z)
```

### Arguments

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

## Logl.sandACT *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.sandACT(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 = NULL, data, rho = c(-0.5, 0.5),
  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.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'
plot(x, DR = TRUE, main = "", xlab = NULL,
  ylab = "", ...)
```

### Arguments

| | |
|---|---|
| x | An object of class uicausal |
| DR | If TRUE the doubly robust estimator is plotted, otherwise the outcome regression estimator is plotted. |
| main | Main title, default is no title. |
| xlab | Title for xaxis, default is expression(rho). |
| ylab | Title for y axis, default is no title. |
| ... | Additional arguments, use is discouraged. |

## plot.uiols *Plot of UI and CI*

### Description

Plot function for objects returned from `ui.ols`. Plots confidence intervals, coefficients and significans 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", "red"), ...)
```

### 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 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 significans 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", "red"), ...)
```

### 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 confidence intervals (default black) and uncertainty intervals (default red). |
| ... | Additional arguments, use is discouraged. |

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

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### 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.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.uicausal *Plot of UI and CI*

### Description

Plot function for objects returned from `ui.causal`. Plots confidence intervals for different values of rho0=rho1=rho.

### Usage

```
## S3 method for class 'uicausal'
profile(fitted, DR = TRUE, main = "", xlab = NULL,
  ylab = "", ...)
```

### Arguments

| | |
|---|---|
| `fitted` | An object of class uicausal |
| `DR` | If TRUE, plots both DR if FALSE OR. |
| `main` | Main title, default is no title. |
| `xlab` | Title for x-axis, default is `expression(rho)`. |
| `ylab` | Title for y-axis, default is the variable names. |
| `...` | Additional arguments, use is discouraged. |

## 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(fitted, plot.all = TRUE, which = NA,
  intercept = FALSE, xlab = NULL, ylab = NULL, ...)
```

### Arguments

| | |
|---|---|
| fitted | 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. |
| ... | Additional arguments, for instance margins. |

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## profile.uiprobit *Plot of UI and CI*

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### 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(fitted, plot.all = TRUE, which = NA,
  intercept = FALSE, xlab = NULL, ylab = NULL, cex.lab = 2,
  mar = c(6, 6, 2, 2), ...)
```

### Arguments

| | |
|---|---|
| fitted | 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. |
| cex.lab | Size of lables. |
| mar | Margin around panels in plot. |
| ... | Additional arguments, use is discouraged. |

## sandACT — *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

```
sandACT(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. |

## sandImpACE — *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 regression imputation estimator.

### Usage

```
sandImpACE(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. |

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## sandImpACT *Calculates standard error of Average causal effect on the treated*

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### Description

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

### Usage

```
sandImpACT(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, sigmaOLScor, u, gridrho)
```

### Arguments

| | |
|---|---|
| `X` | Covariate matrix. |
| `sigmaOLScor` | Output from sigmaOLScor1 |
| `u` | Fitted values from mis.model. |
| `gridrho` | Values of rho. |

## sigmaOLScor0 *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

```
sigmaOLScor0(X, sigmaOLS, n, p, u, gridrho)
```

### Arguments

| | |
|---|---|
| `X` | Covariate matrix outcome. |
| `sigmaOLS` | 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. |

## sigmaOLScor1 *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

```
sigmaOLScor1(X, sigmaOLS, n, p, u, gridrho)
```

### Arguments

| | |
|---|---|
| `X` | Covariate matrix outcome. |
| `sigmaOLS` | 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 plot.uicausal. |
| rho.plotrange | an interval larger than rho for the plot using plot.uicausal. |
| alpha | Default 0.05 corresponding to a confidence level of 95 for CI and UI. |

## Details

In order to visualize the results, you can use plot.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 interval, 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 interval, 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
plot(ui)
profile(ui)
mean(y1-y0)

ui<-ui.causal(y~x, z~x, data=data, rho=c(0,0.3), ACT=TRUE)
ui
plot(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)
```

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## ui.probit *Uncertainty intervals for probit regression*

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### 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. |
| X.y | Covariate matrix for outcome regression. |
| X.z | 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(0,0.5))
m
plot(m)
profile(m)
```

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