Package ‘rr’

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Version 1.4.1

Title Statistical Methods for the Randomized Response Technique

Depends R (>= 3.0.0), utils

Imports MASS, arm, coda, magic

Description Enables researchers to conduct multivariate statistical analyses of survey data with randomized response technique items from several designs, including mirrored question, forced question, and unrelated question. This includes regression with the randomized response as the outcome and logistic regression with the randomized response item as a predictor. In addition, tools for conducting power analysis for designing randomized response items are included. The package implements methods described in Blair, Imai, and Zhou (2015) "Design and Analysis of the Randomized Response Technique," Journal of the American Statistical Association <https://graemeblair.com/papers/randresp.pdf>.

LazyLoad yes

LazyData yes

License GPL (>= 3)

Suggests testthat

Encoding UTF-8

RoxygenNote 7.1.2

NeedsCompilation yes

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**Description**

`rr` implements methods developed by Blair, Imai, and Zhou (2015) such as multivariate regression and power analysis for the randomized response technique. Randomized response is a survey technique that introduces random noise to reduce potential bias from non-response and social desirability when asking questions about sensitive behaviors and beliefs. The current version of this package conducts multivariate regression analyses for the sensitive item under four standard randomized response designs: mirrored question, forced response, disguised response, and unrelated question. Second, it generates predicted probabilities of answering affirmatively to the sensitive item for each respondent. Third, it also allows users to use the sensitive item as a predictor in an outcome regression under the forced response design. Additionally, it implements power analyses to help improve research design. In future versions, this package will extend to new modified designs that are based on less stringent assumptions than those of the standard designs, specifically to allow for non-compliance and unknown distribution to the unrelated question under the unrelated question design.

**Details**

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nigeria

Description

This data set is a subset of the data from the randomized response technique survey experiment conducted in Nigeria to study civilian contact with armed groups. The survey was implemented by Blair (2014).

Usage

data(nigeria)

Format

A data frame containing 2457 observations. The variables are:

- **Quesid**: Survey ID of civilian respondent.
- **rr.q1**: Randomized response survey item using the Forced Response Design asking the respondent whether they hold direct social connections with members of armed groups. 0 if no connection; 1 if connection.
- **cov.age**: Age of the respondent.
- **cov.asset.index**: The number of assets owned by the respondent from an index of nine assets including radio, T.V., motorbike, car, mobile phone, refrigerator, goat, chicken, and cow.
- **cov.married**: Marital status. 0 if single; 1 if married.
- **cov.education**: Education level of the respondent. 1 if no school; 2 if started primary school; 3 if finished primary school; 4 if started secondary school; 5 if finished secondary school; 6 if started polytechnic or college; 7 if finished polytechnic or college; 8 if started university; 9 if finished university; 10 if received graduate (masters or Ph.D) education.
nigeria-data

- \texttt{cov\_female}: Gender. 0 if male; 1 if female.
- \texttt{civic}: Whether or not the respondent is a member of a civic group in their communities, such as youth groups, women’s groups, or community development committees.

\textbf{Source}

\textbf{References}

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- \texttt{cov.asset.index}: The number of assets owned by the respondent from an index of nine assets including radio, T.V., motorbike, car, mobile phone, refrigerator, goat, chicken, and cow.
- \texttt{cov.married}: Marital status. 0 if single; 1 if married.
• **cov.education**: Education level of the respondent. 1 if no school; 2 if started primary school; 3 if finished primary school; 4 if started secondary school; 5 if finished secondary school; 6 if started polytechnic or college; 7 if finished polytechnic or college; 8 if started university; 9 if finished university; 10 if received graduate (masters or Ph.D) education.

• **cov.female**: Gender. 0 if male; 1 if female.

• **civic**: Whether or not the respondent is a member of a civic group in their communities, such as youth groups, women’s groups, or community development committees.

**Source**


**References**


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**power.rr.plot**

*Power Analysis Plot for Randomized Response*

**Description**

`power.rr.plot` generates a power analysis plot for randomized response survey designs.

**Usage**

```r
power.rr.plot(p, p0, p1, q, design, n.seq, r, presp.seq, presp.null = NULL, sig.level, prespT.seq, prespC.seq, prespT.null = NULL, prespC.null, type = c("one.sample", "two.sample"), alternative = c("one.sided", "two.sided"), solve.tolerance = .Machine$double.eps, legend = TRUE, legend.x = "bottomright", legend.y, par = TRUE, ...)
```

**Arguments**

- `p`: The probability of receiving the sensitive question (Mirrored Question Design, Unrelated Question Design); the probability of answering truthfully (Forced Response Design); the probability of selecting a red card from the 'yes' stack (Disguised Response Design).

- `p0`: The probability of forced 'no' (Forced Response Design).

- `p1`: The probability of forced 'yes' (Forced Response Design).

- `q`: The probability of answering 'yes' to the unrelated question, which is assumed to be independent of covariates (Unrelated Question Design).
Call of design (including modified designs) used: "forced-known", "mirrored", "disguised", "unrelated-known", "forced-unknown", and "unrelated-unknown".

A sequence of number of observations or sample sizes.

For the modified designs only (i.e. "forced-unknown" for Forced Response with Unknown Probability and "unrelated-unknown" for Unrelated Question with Unknown Probability), \( r \) is the proportion of respondents allocated to the first group, which is the group that is directed to answer the sensitive question truthfully with probability \( p \) as opposed to the second group which is directed to answer the sensitive question truthfully with probability \( 1-p \).

For a one sample test, a sequence of probabilities of possessing the sensitive trait under the alternative hypothesis.

For a one sample test, the probability of possessing the sensitive trait under the null hypothesis. The default is NULL meaning zero probability of possessing the sensitive trait.

Significance level (Type I error probability).

For a two sample test, a sequence of probabilities of the treated group possessing the sensitive trait under the alternative hypothesis.

For a two sample test, a sequence of probabilities of the control group possessing the sensitive trait under the alternative hypothesis.

For a two sample test, the probability of the treated group possessing the sensitive trait under the null hypothesis. The default is NULL meaning there is no difference between the treated and control groups, specifically that \( \text{prespT.null} \) is the same as \( \text{prespC.null} \), the probability of the control group possessing the sensitive trait under the null hypothesis.

For a two sample test, the probability of the control group possessing the sensitive trait under the null hypothesis.

One or two sample test. For a two sample test, the alternative and null hypotheses refer to the difference between the two samples of the probabilities of possessing the sensitive trait.

One or two sided test.

When standard errors are calculated, this option specifies the tolerance of the matrix inversion operation solve.

Indicator of whether to include a legend of sample sizes. The default is TRUE.

Placement on the x-axis of the legend. The default is "bottomright".

Placement on the y-axis of the legend.

Option to set or query graphical parameters within the function. The default is TRUE.

Additional arguments to be passed to par()

This function generates a power analysis plot for randomized response survey designs, both for the standard designs ("forced-known", "mirrored", "disguised", "unrelated-known") and modified designs ("forced-unknown", and "unrelated-unknown"). The x-axis shows the population proportions.
with the sensitive trait; the y-axis shows the statistical power; and different sample sizes are shown as different lines in grayscale.

Value

Power curve plot

References


Examples

```r
## Generate a power plot for the forced design with known probabilities of 2/3 in truth-telling group, 1/6 forced to say "yes" and 1/6 forced to say "no", varying the number of respondents from 250 to 2500 and the population proportion of respondents possessing the sensitive trait from 0 to .15.

presp.seq <- seq(from = 0, to = .15, by = .0025)
n.seq <- c(250, 500, 1000, 2000, 2500)
power.rr.plot(p = 2/3, p1 = 1/6, p0 = 1/6, n.seq = n.seq, presp.seq = presp.seq, presp.null = 0, design = "forced-known", sig.level = .01, type = "one.sample", alternative = "one.sided", legend = TRUE)

## Replicates the results for Figure 2 in Blair, Imai, and Zhou (2014)
```

power.rr.test

Power Analysis for Randomized Response

Description

`power.rr.test` is used to conduct power analysis for randomized response survey designs.

Usage

```
power.rr.test(p, p0, p1, q, design, n = NULL, r, presp, presp.null = NULL, sig.level, prespT, prespC, prespT.null = NULL, prespC.null, power = NULL, type = c("one.sample", "two.sample"), alternative = c("one.sided", "two.sided"), solve.tolerance = .Machine$double.eps)
```
Arguments

- **p**: The probability of receiving the sensitive question (Mirrored Question Design, Unrelated Question Design); the probability of answering truthfully (Forced Response Design); the probability of selecting a red card from the 'yes' stack (Disguised Response Design).
- **p0**: The probability of forced 'no' (Forced Response Design).
- **p1**: The probability of forced 'yes' (Forced Response Design).
- **q**: The probability of answering 'yes' to the unrelated question, which is assumed to be independent of covariates (Unrelated Question Design).
- **design**: Call of design (including modified designs) used: "forced-known", "mirrored", "disguised", "unrelated-known", "forced-unknown", and "unrelated-unknown".
- **n**: Number of observations. Exactly one of 'n' or 'power' must be NULL.
- **r**: For the modified designs only (i.e. "forced-unknown" for Forced Response with Unknown Probability and "unrelated-unknown" for Unrelated Question with Unknown Probability), r is the proportion of respondents allocated to the first group, which is the group that is directed to answer the sensitive question truthfully with probability p as opposed to the second group which is directed to answer the sensitive question truthfully with probability 1-p.
- **presp**: For a one sample test, the probability of possessing the sensitive trait under the alternative hypothesis.
- **presp.null**: For a one sample test, the probability of possessing the sensitive trait under the null hypothesis. The default is NULL meaning zero probability of possessing the sensitive trait.
- **sig.level**: Significance level (Type I error probability).
- **prespT**: For a two sample test, the probability of the treated group possessing the sensitive trait under the alternative hypothesis.
- **prespC**: For a two sample test, the probability of the control group possessing the sensitive trait under the alternative hypothesis.
- **prespT.null**: For a two sample test, the probability of the treated group possessing the sensitive trait under the null hypothesis. The default is NULL meaning there is no difference between the treated and control groups, specifically that prespT.null is the same as prespC.null, the probability of the control group possessing the sensitive trait under the null hypothesis.
- **prespC.null**: For a two sample test, the probability of the control group possessing the sensitive trait under the null hypothesis.
- **power**: Power of test (Type II error probability). Exactly one of 'n' or 'power' must be NULL.
- **type**: One or two sample test. For a two sample test, the alternative and null hypotheses refer to the difference between the two samples of the probabilities of possessing the sensitive trait.
- **alternative**: One or two sided test.
- **solve.tolerance**: When standard errors are calculated, this option specifies the tolerance of the matrix inversion operation solve.
Details

This function allows users to conduct power analysis for randomized response survey designs, both for the standard designs ("forced-known", "mirrored", "disguised", "unrelated-known") and modified designs ("forced-unknown", and "unrelated-unknown").

Value

`power.rr.test` contains the following components (the inclusion of some components such as the design parameters are dependent upon the design used):

- **n**: Point estimates for the effects of covariates on the randomized response item.
- **r**: Standard errors for estimates of the effects of covariates on the randomized response item.
- **presp**: For a one sample test, the probability of possessing the sensitive trait under the alternative hypothesis. For a two sample test, the difference between the probabilities of possessing the sensitive trait for the treated and control groups under the alternative hypothesis.
- **presp.null**: For a one sample test, the probability of possessing the sensitive trait under the null hypothesis. For a two sample test, the difference between the probabilities of possessing the sensitive trait for the treated and control groups under the null hypothesis.
- **sig.level**: Significance level (Type I error probability).
- **power**: Power of test (Type II error probability).
- **type**: One or two sample test.
- **alternative**: One or two sided test.

References


Examples

```r
## Calculate the power to detect a sensitive item proportion of .2
## with the forced design with known probabilities of 2/3 in truth-telling group,
## 1/6 forced to say "yes" and 1/6 forced to say "no" and sample size of 200.

power.rr.test(p = 2/3, p1 = 1/6, p0 = 1/6, n = 200,
             presp = .2, presp.null = 0,
             design = "forced-known", sig.level = .01,
             type = "one.sample", alternative = "one.sided")
```
predict.rrreg

Description

predict.rrreg is used to generate predicted probabilities from a multivariate regression object of survey data using randomized response methods.

Usage

```r
## S3 method for class 'rrreg'
predict(object, given.y = FALSE, alpha = .05, n.sims = 1000, avg = FALSE, newdata = NULL, quasi.bayes = FALSE, keep.draws = FALSE, ...)
```

Arguments

- `object`: An object of class "rrreg" generated by the `rrreg()` function.
- `given.y`: Indicator of whether to use "y" the response vector to calculate the posterior prediction of latent responses. Default is FALSE, which simply generates fitted values using the logistic regression.
- `alpha`: Confidence level for the hypothesis test to generate upper and lower confidence intervals. Default is .05.
- `n.sims`: Number of sampled draws for quasi-bayesian predicted probability estimation. Default is 1000.
- `avg`: Whether to output the mean of the predicted probabilities and uncertainty estimates. Default is FALSE.
- `newdata`: Optional new data frame of covariates provided by the user. Otherwise, the original data frame from the "rreg" object is used.
- `quasi.bayes`: Option to use Monte Carlo simulations to generate uncertainty estimates for predicted probabilities. Default is FALSE.
- `keep.draws`: Option to return the Monte Carlo draws of the quantity of interest, for use in calculating differences for example.
- `...`: Further arguments to be passed to `predict.rrreg()` command.

Details

This function allows users to generate predicted probabilities for the randomized response item given an object of class "rrreg" from the `rrreg()` function. Four standard designs are accepted by this function: mirrored question, forced response, disguised response, and unrelated question. The design, already specified in the "rrreg" object, is then directly inputted into this function.
predict.rreg

Value

predict.rreg returns predicted probabilities either for each observation in the data frame or the average over all observations. The output is a list that contains the following components:

- **est**: Predicted probabilities for the randomized response item generated either using fitted values, posterior predictions, or quasi-Bayesian simulations. If `avg` is set to TRUE, the output will only include the mean estimate.
- **se**: Standard errors for the predicted probabilities of the randomized response item generated using Monte Carlo simulations. If `quasi.bayes` is set to FALSE, no standard errors will be outputted.
- **ci.lower**: Estimates for the lower confidence interval. If `quasi.bayes` is set to FALSE, no confidence interval estimate will be outputted.
- **ci.upper**: Estimates for the upper confidence interval. If `quasi.bayes` is set to FALSE, no confidence interval estimate will be outputted.
- **qoi.draws**: Monte Carlos draws of the quantity of interest, returned only if `keep.draws` is set to TRUE.

References


See Also

**rrreg** to conduct multivariate regression analyses in order to generate predicted probabilities for the randomized response item.

Examples

data(nigeria)

set.seed(1)

## Define design parameters
p <- 2/3  # probability of answering honestly in Forced Response Design
p1 <- 1/6 # probability of forced 'yes'
0 <- 1/6 # probability of forced 'no'

## Fit linear regression on the randomized response item of
## whether citizen respondents had direct social contacts to armed groups
rr.q1.reg.obj <- rrreg(rr.q1 ~ cov.asset.index + cov.married + I(cov.age/10) +
                       I((cov.age/10)^2) + cov.education + cov.female,
                       data = nigeria, p = p, p1 = p1,  = p0,
                       design = "forced-known")

## Generate the mean predicted probability of having social contacts to
## armed groups across respondents using quasi-Bayesian simulations.

```r
rr.q1.reg.pred <- predict(rr.q1.reg.obj, given.y = FALSE,
                           avg = TRUE, quasi.bayes = TRUE,
                           n.sims = 10000)
```

## Replicates Table 3 in Blair, Imai, and Zhou (2014)

---

### predict.rrreg.predictor

**Predicted Probabilities for Randomized Response as a Regression Predictor**

#### Description

`predict.rrreg.predictor` is used to generate predicted probabilities from a multivariate regression object of survey data using the randomized response item as a predictor for an additional outcome.

#### Usage

```r
## S3 method for class 'rrreg.predictor'
predict(object, fix.z = NULL, alpha = .05,
         n.sims = 1000, avg = FALSE, newdata = NULL, quasi.bayes = FALSE, keep.draws = FALSE, ...)
```

#### Arguments

- **object**: An object of class "rrreg.predictor" generated by the `rrreg.predictor()` function.
- **fix.z**: An optional value or vector of values between 0 and 1 that the user inputs as the proportion of respondents with the sensitive trait or probability that each respondent has the sensitive trait, respectively. If the user inputs a vector of values, the vector must be the length of the data from the "rrreg.predictor" object. Default is `NULL` in which case predicted probabilities are generated for the randomized response item.
- **alpha**: Confidence level for the hypothesis test to generate upper and lower confidence intervals. Default is `.05`.
- **n.sims**: Number of sampled draws for quasi-bayesian predicted probability estimation. Default is `1000`.
- **avg**: Whether to output the mean of the predicted probabilities and uncertainty estimates. Default is `FALSE`.
- **newdata**: Optional new data frame of covariates provided by the user. Otherwise, the original data frame from the "rrreg" object is used.
predict_rrreg(predictor)

quasi.bayes Option to use Monte Carlo simulations to generate uncertainty estimates for predicted probabilities. Default is FALSE meaning no uncertainty estimates are outputted.

keep.draws Option to return the Monte Carlo draws of the quantity of interest, for use in calculating differences for example.

... Further arguments to be passed to predict_rrreg(predictor()) command.

Details

This function allows users to generate predicted probabilities for the additional outcome variables with the randomized response item as a covariate given an object of class "rrreg.predictor" from the rrreg.predictor() function. Four standard designs are accepted by this function: mirrored question, forced response, disguised response, and unrelated question. The design, already specified in the "rrreg.predictor" object, is then directly inputted into this function.

Value

predict_rrreg(predictor) returns predicted probabilities either for each observation in the data frame or the average over all observations. The output is a list that contains the following components:

est Predicted probabilities of the additional outcome variable given the randomized response item as a predictor generated either using fitted values or quasi-Bayesian simulations. If avg is set to TRUE, the output will only include the mean estimate.

se Standard errors for the predicted probabilities of the additional outcome variable given the randomized response item as a predictor generated using Monte Carlo simulations. If quasi.bayes is set to FALSE, no standard errors will be outputted.

ci.lower Estimates for the lower confidence interval. If quasi.bayes is set to FALSE, no confidence interval estimate will be outputted.

ci.upper Estimates for the upper confidence interval. If quasi.bayes is set to FALSE, no confidence interval estimate will be outputted.

qoi.draws Monte Carlo draws of the quantity of interest, returned only if keep.draws is set to TRUE.

References


See Also

rrreg.predictor to conduct multivariate regression analyses with the randomized response as predictor in order to generate predicted probabilities.
Examples

data(nigeria)

## Define design parameters

set.seed(44)
p <- 2/3  # probability of answering honestly in Forced Response Design
p1 <- 1/6  # probability of forced 'yes'
p0 <- 1/6  # probability of forced 'no'

## Fit joint model of responses to an outcome regression of joining a civic
## group and the randomized response item of having a militant social connection

rr.q1.pred.obj <-
  rrreg.predictor(civic ~ cov.asset.index + cov.married + I(cov.age/10) +
  I((cov.age/10)^2) + cov.education + cov.female
  + rr.q1, rr.item = "rr.q1", parstart = FALSE, estconv = TRUE,
  data = nigeria, verbose = FALSE, optim = TRUE,
  p = p, p1 = p1, p0 = p0, design = "forced-known")

## Generate predicted probabilities for the likelihood of joining
## a civic group across respondents using quasi-Bayesian simulations.

rr.q1.rrreg.predictor.pred <- predict(rr.q1.pred.obj,
  avg = TRUE, quasi.bayes = TRUE,
  n.sims = 1000)

---

rrreg  

Randomized Response Regression

Description

rrreg is used to conduct multivariate regression analyses of survey data using randomized response methods.

Usage

rrreg(formula, p, p0, p1, q, design, data, start = NULL,
  h = NULL, group = NULL, matrixMethod = "efficient",
  maxIter = 10000, verbose = FALSE, optim = FALSE, em.converge = 10^-8,
  glmMaxIter = 10000, solve.tolerance = .Machine$double.eps)
Arguments

**formula**
An object of class "formula": a symbolic description of the model to be fitted.

**p**
The probability of receiving the sensitive question (Mirrored Question Design, Unrelated Question Design); the probability of answering truthfully (Forced Response Design); the probability of selecting a red card from the 'yes' stack (Disguised Response Design). For "mirrored" and "disguised" designs, p cannot equal .5.

**p0**
The probability of forced 'no' (Forced Response Design).

**p1**
The probability of forced 'yes' (Forced Response Design).

**q**
The probability of answering 'yes' to the unrelated question, which is assumed to be independent of covariates (Unrelated Question Design).

**design**
One of the four standard designs: "forced-known", "mirrored", "disguised", or "unrelated-known".

**data**
A data frame containing the variables in the model.

**start**
Optional starting values of coefficient estimates for the Expectation-Maximization (EM) algorithm.

**h**
Auxiliary data functionality. Optional named numeric vector with length equal to number of groups. Names correspond to group labels and values correspond to auxiliary moments.

**group**
Auxiliary data functionality. Optional character vector of group labels with length equal to number of observations.

**matrixMethod**
Auxiliary data functionality. Procedure for estimating optimal weighting matrix for generalized method of moments. One of "efficient" for two-step feasible and "cue" for continuously updating. Default is "efficient". Only relevant if h and group are specified.

**maxIter**
Maximum number of iterations for the Expectation-Maximization algorithm. The default is 10000.

**verbose**
A logical value indicating whether model diagnostics counting the number of EM iterations are printed out. The default is FALSE.

**optim**
A logical value indicating whether to use the quasi-Newton "BFGS" method to calculate the variance-covariance matrix and standard errors. The default is FALSE.

**em.converge**
A value specifying the satisfactory degree of convergence under the EM algorithm. The default is $10^{-8}$.

**glmMaxIter**
A value specifying the maximum number of iterations to run the EM algorithm. The default is 10000.

**solve.tolerance**
When standard errors are calculated, this option specifies the tolerance of the matrix inversion operation solve.

Details

This function allows users to perform multivariate regression analysis on data from the randomized response technique. Four standard designs are accepted by this function: mirrored question, forced response, disguised response, and unrelated question. The method implemented by this function is the Maximum Likelihood (ML) estimation for the Expectation-Maximization (EM) algorithm.
Value

`rrreg` returns an object of class "rrreg". The function `summary` is used to obtain a table of the results. The object `rrreg` is a list that contains the following components (the inclusion of some components such as the design parameters are dependent upon the design used):

- `est`: Point estimates for the effects of covariates on the randomized response item.
- `vcov`: Variance-covariance matrix for the effects of covariates on the randomized response item.
- `se`: Standard errors for estimates of the effects of covariates on the randomized response item.
- `data`: The data argument.
- `coef.names`: Variable names as defined in the data frame.
- `x`: The model matrix of covariates.
- `y`: The randomized response vector.
- `design`: Call of standard design used: "forced-known", "mirrored", "disguised", or "unrelated-known".
- `p`: The p argument.
- `p0`: The p0 argument.
- `p1`: The p1 argument.
- `q`: The q argument.
- `call`: The matched call.

References


See Also

`predict.rrreg` for predicted probabilities.

Examples

data(nigeria)

set.seed(1)

## Define design parameters
p <- 2/3  # probability of answering honestly in Forced Response Design
p1 <- 1/6 # probability of forced 'yes'
p0 <- 1/6 # probability of forced 'no'

## Fit linear regression on the randomized response item of whether
## citizen respondents had direct social contacts to armed groups
rr.q1.reg.obj <- rrreg(rr.q1 ~ cov.asset.index + cov.married +
    I(cov.age/10) + I((cov.age/10)^2) + cov.education + cov.female,
    data = nigeria, p = p, p1 = p1, p0 = p0,
    design = "forced-known")

summary(rr.q1.reg.obj)

## Replicates Table 3 in Blair, Imai, and Zhou (2014)

### rrreg.bayes

**Bayesian Randomized Response Regression**

**Description**

Function to conduct multivariate regression analyses of survey data with the randomized response technique using Bayesian MCMC.

**Usage**

`rrreg.bayes(formula, p, p0, p1, design, data, group.mixed,
  formula.mixed = ~1, verbose = FALSE, n.draws = 10000, burnin = 5000, thin =
  1, beta.start, beta.mu0, beta.A0, beta.tune, Psi.start, Psi.df, Psi.scale,
  Psi.tune)`

**Arguments**

- **formula**: An object of class "formula": a symbolic description of the model to be fitted.
- **p**: The probability of receiving the sensitive question (Mirrored Question Design, Unrelated Question Design); the probability of answering truthfully (Forced Response Design); the probability of selecting a red card from the 'yes' stack (Disguised Response Design).
- **p0**: The probability of forced 'no' (Forced Response Design).
- **p1**: The probability of forced 'yes' (Forced Response Design).
- **design**: Character indicating the design. Currently only "forced-known" is supported.
- **data**: A data frame containing the variables in the model.
- **group.mixed**: A string indicating the variable name of a numerical group indicator specifying which group each individual belongs to for a mixed effects model.
- **formula.mixed**: To specify a mixed effects model, include this formula object for the group-level fit. ~1 allows intercepts to vary, and including covariates in the formula allows the slopes to vary also.
- **verbose**: A logical value indicating whether model diagnostics are printed out during fitting.
- **n.draws**: Number of MCMC iterations.
**burnin**
The number of initial MCMC iterations that are discarded.

**thin**
The interval of thinning between consecutive retained iterations (1 for no thinning).

**beta.start**
Optional starting values for the sensitive item fit. This should be a vector of length the number of covariates.

**beta.mu0**
Optional vector of prior means for the sensitive item fit parameters, a vector of length the number of covariates.

**beta.A0**
Optional matrix of prior precisions for the sensitive item fit parameters, a matrix of dimension the number of covariates.

**beta.tune**
A required vector of tuning parameters for the Metropolis algorithm for the sensitive item fit. This must be set and refined by the user until the acceptance ratios are approximately .4 (reported in the output).

**Psi.start**
Optional starting values for the variance of the random effects in the mixed effects models. This should be a scalar.

**Psi.df**
Optional prior degrees of freedom parameter for the variance of the random effects in the mixed effects models.

**Psi.scale**
Optional prior scale parameter for the variance of the random effects in the mixed effects models.

**Psi.tune**
A required vector of tuning parameters for the Metropolis algorithm for variance of the random effects in the mixed effects models. This must be set and refined by the user until the acceptance ratios are approximately .4 (reported in the output).

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**Details**

This function allows the user to perform regression analysis on data from the randomized response technique using a Bayesian MCMC algorithm.

The Metropolis algorithm for the Bayesian MCMC estimators in this function must be tuned to work correctly. The beta.tune and, for the mixed effects model Psi.tune, are required, and the values, one for each estimated parameter, will need to be manipulated. The output of the rrreg.bayes function displays the acceptance ratios from the Metropolis algorithm. If these values are far from 0.4, the tuning parameters should be changed until the ratios approach 0.4.

Convergence is at times difficult to achieve, so we recommend running multiple chains from overdispersed starting values by, for example, running an MLE using the rrreg() function, and then generating a set of overdispersed starting values using those estimates and their estimated variance-covariance matrix. An example is provided below for each of the possible designs. Running summary() after such a procedure will output the Gelman-Rubin convergence statistics in addition to the estimates. If the G-R statistics are all below 1.1, the model is said to have converged.

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**Value**

**rrreg.bayes** returns an object of class "rrreg.bayes". The function summary is used to obtain a table of the results.

**beta**
The coefficients for the sensitive item fit. An object of class "mcmc" that can be analyzed using the coda package.
data The data argument.
coef.names Variable names as defined in the data frame.
x The model matrix of covariates.
y The randomized response vector.
design Call of standard design used: "forced-known", "mirrored", "disguised", or "unrelated-known".
p The p argument.
p0 The p0 argument.
p1 The p1 argument.
beta.tune The beta.tune argument.
mixed Indicator for whether a mixed effects model was run.
call the matched call.

If a mixed-effects model is used, then several additional objects are included:

Psi The coefficients for the group-level fit. An object of class "mcmc" that can be analyzed using the coda package.
gamma The random effects estimates. An object of class "mcmc" that can be analyzed using the coda package.
coef.names.mixed Variable names for the predictors for the second-level model
z The predictors for the second-level model.
groups A vector of group indicators.
Psi.tune The Psi.tune argument.

References

Examples

data(nigeria)

## Define design parameters
p <- 2/3 # probability of answering honestly in Forced Response Design
p1 <- 1/6 # probability of forced 'yes'
p0 <- 1/6 # probability of forced 'no'

## run three chains with overdispersed starting values
set.seed(1)

## starting values constructed from MLE model
library(MASS)
draws <- mvrnorm(n = 3, mu = coef(mle.estimates),
                 Sigma = vcov(mle.estimates) * 9)

## run three chains
bayes.1 <- rrreg.bayes(rr.q1 ~ cov.asset.index + cov.married +
                        I(cov.age/10) + I((cov.age/10)^2) + cov.education + cov.female,
data = nigeria, p = p, pl = pl, p0 = p0,
               beta.tune = .0001, beta.start = draws[1,],
               design = "forced-known")
bayes.2 <- rrreg.bayes(rr.q1 ~ cov.asset.index + cov.married +
                        I(cov.age/10) + I((cov.age/10)^2) + cov.education + cov.female,
data = nigeria, p = p, pl = pl, p0 = p0,
               beta.tune = .0001, beta.start = draws[2,],
               design = "forced-known")
bayes.3 <- rrreg.bayes(rr.q1 ~ cov.asset.index + cov.married +
                        I(cov.age/10) + I((cov.age/10)^2) + cov.education + cov.female,
data = nigeria, p = p, pl = pl, p0 = p0,
               beta.tune = .0001, beta.start = draws[3,],
               design = "forced-known")
bayes <- as.list(bayes.1, bayes.2, bayes.3)
summary(bayes)

---

**rrreg.predictor**

*Randomized Response as a Regression Predictor*

**Description**

`rrreg.predictor` is used to jointly model the randomized response item as both outcome and predictor for an additional outcome given a set of covariates.

**Usage**

```r
rrreg.predictor(formula, p, p0, p1, q, design, data, rr.item,
                 model.outcome = "logistic", fit.sens = "bayesglm", fit.outcome = "bayesglm",
                 bstart = NULL, tstart = NULL, parstart = TRUE, maxIter = 10000, verbose =
```
FALSE, optim = FALSE, em.converge = 10^(-4), glmMaxIter = 20000, estconv = TRUE, solve.tolerance = .Machine$double.eps)

Arguments

formula An object of class "formula": a symbolic description of the model to be fitted with the randomized response item as one of the covariates.

p The probability of receiving the sensitive question (Mirrored Question Design, Unrelated Question Design); the probability of answering truthfully (Forced Response Design); the probability of selecting a red card from the 'yes' stack (Disguised Response Design).

p0 The probability of forced 'no' (Forced Response Design).

p1 The probability of forced 'yes' (Forced Response Design).

q The probability of answering 'yes' to the unrelated question, which is assumed to be independent of covariates (Unrelated Question Design).

design One of the four standard designs: "forced-known", "mirrored", "disguised", or "unrelated-known".

data A data frame containing the variables in the model. Observations with missingness are list-wise deleted.

rr.item A string containing the name of the randomized response item variable in the data frame.

model.outcome Currently the function only allows for logistic regression, meaning the outcome variable must be binary.

fit.sens Indicator for whether to use Bayesian generalized linear modeling (bayesglm) in the Maximization step for the Expectation-Maximization (EM) algorithm to generate coefficients for the randomized response item as the outcome. Default is "bayesglm"; otherwise input "glm".

fit.outcome Indicator for whether to use Bayesian generalized linear modeling (bayesglm) in the Maximization step for the EM algorithm to generate coefficients for the outcome variable given in the formula with the randomized response item as a covariate. Default is "bayesglm"; otherwise input "glm".

bstart Optional starting values of coefficient estimates for the randomized response item as outcome for the EM algorithm.

tstart Optional starting values of coefficient estimates for the outcome variable given in the formula for the EM algorithm.

parstart Option to use the function rrreg to generate starting values of coefficient estimates for the randomized response item as outcome for the EM algorithm. The default is TRUE, but if starting estimates are inputted by the user in bstart, this option is overridden.

maxIter Maximum number of iterations for the Expectation-Maximization algorithm. The default is 10000.

verbose A logical value indicating whether model diagnostics counting the number of EM iterations are printed out. The default is FALSE.
optim  A logical value indicating whether to use the quasi-Newton "BFGS" method to calculate the variance-covariance matrix and standard errors. The default is FALSE.

em.converge  A value specifying the satisfactory degree of convergence under the EM algorithm. The default is $10^{-4}$.

glmMaxIter  A value specifying the maximum number of iterations to run the EM algorithm. The default is 20000.

estconv  Option to base convergence on the absolute value of the difference between subsequent coefficients generated through the EM algorithm rather than the subsequent log-likelihoods. The default is TRUE.

solve.tolerance  When standard errors are calculated, this option specifies the tolerance of the matrix inversion operation solve.

Details

This function allows users to perform multivariate regression analysis with the randomized response item as a predictor for a separate outcome of interest. It does so by jointly modeling the randomized response item as both outcome and predictor for an additional outcome given the same set of covariates. Four standard designs are accepted by this function: mirrored question, forced response, disguised response, and unrelated question.

Value

rrreg.predictor returns an object of class "rrpredreg" associated with the randomized response item as predictor. The object rrpredreg is a list that contains the following components (the inclusion of some components such as the design parameters are dependent upon the design used):

est.t  Point estimates for the effects of the randomized response item as predictor and other covariates on the separate outcome variable specified in the formula.

se.t  Standard errors for estimates of the effects of the randomized response item as predictor and other covariates on the separate outcome variable specified in formula.

est.b  Point estimates for the effects of covariates on the randomized response item.

vcov  Variance-covariance matrix for estimates of the effects of the randomized response item as predictor and other covariates on the separate outcome variable specified in formula as well as for estimates of the effects of covariates on the randomized response item.

se.b  Standard errors for estimates of the effects of covariates on the randomized response item.

data  The data argument.

coef.names  Variable names as defined in the data frame.

x  The model matrix of covariates.

y  The randomized response vector.

o  The separate outcome of interest vector.
design Call of standard design used: "forced-known", "mirrored", "disguised", or "unrelated-known".

\( p \) The \( p \) argument.

\( p0 \) The \( p0 \) argument.

\( p1 \) The \( p1 \) argument.

\( q \) The \( q \) argument.

call The matched call.

References


See Also

\texttt{rrreg} for multivariate regression.

Examples

data(nigeria)

## Define design parameters
set.seed(44)

\( p \leftarrow 2/3 \) # probability of answering honestly in Forced Response Design
\( p1 \leftarrow 1/6 \) # probability of forced 'yes'
\( p0 \leftarrow 1/6 \) # probability of forced 'no'

## Fit joint model of responses to an outcome regression of joining a civic group and the randomized response item of having a militant social connection
rr.q1.pred.obj <- rrreg.predictor(civic ~ cov.asset.index + cov.married + I(cov.age/10) + I((cov.age/10)^2) + cov.education + cov.female + rr.q1, rr.item = "rr.q1", parstart = FALSE, estconv = TRUE, data = nigeria, verbose = FALSE, optim = TRUE, p = p, p1 = p1, p0 = p0, design = "forced-known")

summary(rr.q1.pred.obj)

## Replicates Table 4 in Blair, Imai, and Zhou (2014)
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