Package ‘marginaleffects’

October 20, 2023

Title Predictions, Comparisons, Slopes, Marginal Means, and Hypothesis Tests

Version 0.16.0

Description Compute and plot predictions, slopes, marginal means, and comparisons (contrasts, risk ratios, odds, etc.) for over 100 classes of statistical and machine learning models in R. Conduct linear and non-linear hypothesis tests, or equivalence tests. Calculate uncertainty estimates using the delta method, bootstrapping, or simulation-based inference.

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Encoding UTF-8

URL https://marginaleffects.com/

BugReports https://github.com/vincentarelbundock/marginaleffects/issues

RoxygenNote 7.2.3.9000

Depends R (>= 3.6.0)

Imports checkmate, data.table, generics, insight (>= 0.19.1), methods, rlang, Rcpp (>= 1.0.0)

LinkingTo Rcpp, RcppEigen

Suggests AER, Amelia, afex, aod, bench, betareg, BH, bife, biglm, blme, boot, brglm2, brms, brmsmargins, broom, car, carData, causaldatar, collapse, conflicted, covr, crch, DALEXtra, DCchoice, distributional, dplyr, emmeans, equivalence, estimatr, fixest, fmeffects, fontquiver, future, fwb, gam, gamlss, gamlss.dist, geepack, ggdag, ggdist, ggokabeito, ggplot2, ggplot2, ggplot2, glmx, haven, here, itsadug, ivreg, kableExtra, knitr, lme4, lmerTest, logistf, magrittr, margins, MatchIt, MASS, mlogit, MCMCglmm, missRanger, mgcv, mhrdgle, mice, miceadds, mlogit, mlr3verse, modelbased, modelsummary, nlme, nnet, numDeriv, optmatch, ordinal, parameters, parsnip, patchwork, pkgdown, phylolm, plm, polspline, poorman, posterior, prediction, pscl, purrr, quantreg, Rchoice, remotes, rmarkdown, rms, robust, robustbase, robustlmm, rsample, rstanarm, rstantools, rsvg, sampleSelection, sandwich, scam,
spelling, speedglm, survey, survival, svglite, systemfonts,
tibble, tidymodels, tidyr, tidyverse, tinysnapshot, tinytest,
titanic, truncreg, tsModel, withr, workflows, yaml, xgboost,
testthat (>= 3.0.0)

Collate 'RcppExports.R' 'backtransform.R' 'bootstrap_boot.R'
'bootstrap_fwb.R' 'bootstrap_rsample.R' 'broom.R' 'by.R' 'ci.R'
'comparisons.R' 'complete_levels.R' 'conformal.R' 'datagrid.R'
'equivalence.R' 'get_averages.R' 'get_coef.R'
'get_contrast_data.R' 'get_contrast_data_character.R'
'get_contrast_data_factor.R' 'get_contrast_data_logical.R'
'get_contrast_data_numeric.R' 'get_contrasts.R'
'get_group_names.R' 'get_hypothesis.R' 'get_jacobian.R'
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'get_term_labels.R' 'get_vcov.R' 'github_issue.R' 'hush.R'
'hypotheses.R' 'hypotheses_joint.R' 'imputation.R'
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'plot.R' 'plot_build.R' 'plot_comparisons.R'
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'sanitize_condition.R' 'sanitize_conf_level.R'
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'sanitize_newdata.R' 'sanitize_numderiv.R' 'sanitize_type.R'
'sanitize_variables.R' 'sanitize_vcov.R' 'sanity.R'
'sanity_by.R' 'sanity_dots.R' 'settings.R' 'slopes.R' 'sort.R'
'summary.R' 'tinytest.R' 'type_dictionary.R'
'unpack_matrix_cols.R' 'utils.R'

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Description

Predict the outcome variable at different regressor values (e.g., college graduates vs. others), and compare those predictions by computing a difference, ratio, or some other function. comparisons() can return many quantities of interest, such as contrasts, differences, risk ratios, changes in log odds, lift, slopes, elasticities, etc.

- comparisons(): unit-level (conditional) estimates.
- avg_comparisons(): average (marginal) estimates.

variables identifies the focal regressors whose "effect" we are interested in. comparison determines how predictions with different regressor values are compared (difference, ratio, odds, etc.). The newdata argument and thedatagrid() function control where statistics are evaluated in the predictor space: "at observed values", "at the mean", "at representative values", etc.

See the comparisons vignette and package website for worked examples and case studies:

- https://marginaleffects.com/articles/comparisons.html
- https://marginaleffects.com/
Usage

comparisons(
    model,
    newdata = NULL,
    variables = NULL,
    comparison = "difference",
    type = NULL,
    vcov = TRUE,
    by = FALSE,
    conf_level = 0.95,
    transform = NULL,
    cross = FALSE,
    wts = NULL,
    hypothesis = NULL,
    equivalence = NULL,
    p_adjust = NULL,
    df = Inf,
    eps = NULL,
    numderiv = "fdforward",
    ...
)

avg_comparisons(
    model,
    newdata = NULL,
    variables = NULL,
    type = NULL,
    vcov = TRUE,
    by = TRUE,
    conf_level = 0.95,
    comparison = "difference",
    transform = NULL,
    cross = FALSE,
    wts = NULL,
    hypothesis = NULL,
    equivalence = NULL,
    p_adjust = NULL,
    df = Inf,
    eps = NULL,
    numderiv = "fdforward",
    ...
)

Arguments

model  Model object
newdata Grid of predictor values at which we evaluate the comparisons.
• **Warning**: Please avoid modifying your dataset between fitting the model and calling a `marginal_effects` function. This can sometimes lead to unexpected results.

• **NULL** (default): Unit-level contrasts for each observed value in the dataset (empirical distribution). The dataset is retrieved using `insight::get_data()`, which tries to extract data from the environment. This may produce unexpected results if the original data frame has been altered since fitting the model.

• **data frame**: Unit-level contrasts for each row of the `newdata` data frame.

• **string**:
  - "mean": Contrasts at the Mean. Contrasts when each predictor is held at its mean or mode.
  - "median": Contrasts at the Median. Contrasts when each predictor is held at its median or mode.
  - "marginalmeans": Contrasts at Marginal Means.
  - "tukey": Contrasts at Tukey’s 5 numbers.
  - "grid": Contrasts on a grid of representative numbers (Tukey’s 5 numbers and unique values of categorical predictors).

• `datagrid()` call to specify a custom grid of regressors. For example:
  - `newdata = datagrid(cyl = c(4, 6))`: `cyl` variable equal to 4 and 6 and other regressors fixed at their means or modes.
  - `newdata = datagrid(mpg = fivenum)`: `mpg` variable held at Tukey’s five numbers (using the `fivenum` function), and other regressors fixed at their means or modes.
  - See the Examples section and the `datagrid` documentation.

**variables**

• **NULL**: compute comparisons for all the variables in the model object (can be slow).

• **Character vector**: subset of variables (usually faster).

• **Named list**: names identify the subset of variables of interest, and values define the type of contrast to compute. Acceptable values depend on the variable type:
  - Factor or character variables:
    * "reference": Each factor level is compared to the factor reference (base) level
    * "all": All combinations of observed levels
    * "sequential": Each factor level is compared to the previous factor level
    * "pairwise": Each factor level is compared to all other levels
    * "minmax": The highest and lowest levels of a factor.
    * "revpairwise", "revreference", "revsequential": inverse of the corresponding hypotheses.
    * Vector of length 2 with the two values to compare.
  - Logical variables:
* NULL: contrast between TRUE and FALSE

- Numeric variables:
  * Numeric of length 1: Contrast for a gap of $x$, computed at the observed value plus and minus $x / 2$. For example, estimating a +1 contrast compares adjusted predictions when the regressor is equal to its observed value minus 0.5 and its observed value plus 0.5.
  * Numeric of length equal to the number of rows in newdata: Same as above, but the contrast can be customized for each row of newdata.
  * Numeric vector of length 2: Contrast between the 2nd element and the 1st element of the $x$ vector.
  * Data frame with the same number of rows as newdata, with two columns of "low" and "high" values to compare.
  * Function which accepts a numeric vector and returns a data frame with two columns of "low" and "high" values to compare. See examples below.
  * "iqr": Contrast across the interquartile range of the regressor.
  * "sd": Contrast across one standard deviation around the regressor mean.
  * "2sd": Contrast across two standard deviations around the regressor mean.
  * "minmax": Contrast between the maximum and the minimum values of the regressor.

- Examples:
  * variables = list(gear = "pairwise", hp = 10)
  * variables = list(gear = "sequential", hp = c(100, 120))
  * See the Examples section below for more.

### comparison

How should pairs of predictions be compared? Difference, ratio, odds ratio, or user-defined functions.

- string: shortcuts to common contrast functions.
  - Supported shortcuts strings: difference, differenceavg, differenceavgwts, dydx, eyex, eydx, dydxavg, eyexavg, eydxavg, dydxavgwts, eyexavgwts, eydxavgwts, dyexavgwts, ratio, ratioavg, ratioavgwts, lnratio, lnratioavg, lnratioavgwts, lnor, lnoravg, lnoravgwts, lift, liftavg, expdydx, expdydxavg, expdydxavgwts
  - See the Comparisons section below for definitions of each transformation.

- function: accept two equal-length numeric vectors of adjusted predictions (hi and lo) and returns a vector of contrasts of the same length, or a unique numeric value.
  - See the Transformations section below for examples of valid functions.

### type

string indicates the type (scale) of the predictions used to compute contrasts or slopes. This can differ based on the model type, but will typically be a string such as: "response", "link", "probs", or "zero". When an unsupported string is entered, the model-specific list of acceptable values is returned in an error message. When type is NULL, the first entry in the error message is used by default.
comparisons

vcov  Type of uncertainty estimates to report (e.g., for robust standard errors). Acceptable values:

- FALSE: Do not compute standard errors. This can speed up computation considerably.
- TRUE: Unit-level standard errors using the default vcov(model) variance-covariance matrix.
- String which indicates the kind of uncertainty estimates to return.
  - Heteroskedasticity-consistent: "HC", "HC0", "HC1", "HC2", "HC3", "HC4", "HC4m", "HC5". See ?sandwich::vcovHC
  - Heteroskedasticity and autocorrelation consistent: "HAC"
  - Mixed-Models degrees of freedom: "satterthwaite", "kenward-roger"
  - Other: "NeweyWest", "KernHAC", "OPG". See the sandwich package documentation.
- One-sided formula which indicates the name of cluster variables (e.g., ~unit_id). This formula is passed to the cluster argument of the sandwich::vcovCL function.
- Square covariance matrix
- Function which returns a covariance matrix (e.g., stats::vcov(model))

by  Aggregate unit-level estimates (aka, marginalize, average over). Valid inputs:

- FALSE: return the original unit-level estimates.
- TRUE: aggregate estimates for each term.
- Character vector of column names in newdata or in the data frame produced by calling the function without the by argument.
- Data frame with a by column of group labels, and merging columns shared by newdata or the data frame produced by calling the same function without the by argument.
- See examples below.
- For more complex aggregations, you can use the FUN argument of the hypotheses() function. See that function's documentation and the Hypothesis Test vignettes on the marginaleffects website.

conf_level  numeric value between 0 and 1. Confidence level to use to build a confidence interval.

transform  string or function. Transformation applied to unit-level estimates and confidence intervals just before the function returns results. Functions must accept a vector and return a vector of the same length. Support string shortcuts: "exp", "ln"

cross  • FALSE: Contrasts represent the change in adjusted predictions when one predictor changes and all other variables are held constant.
  • TRUE: Contrasts represent the changes in adjusted predictions when all the predictors specified in the variables argument are manipulated simultaneously (a "cross-contrast").

wts  string or numeric: weights to use when computing average contrasts or slopes. These weights only affect the averaging in avg_*() or with the by argument, and not the unit-level estimates themselves. Internally, estimates and weights are passed to the weighted.mean() function.
Comparisons

- **string**: column name of the weights variable in `newdata`. When supplying a column name to `wts`, it is recommended to supply the original data (including the weights variable) explicitly to `newdata`.

- **numeric**: vector of length equal to the number of rows in the original data or in `newdata` (if supplied).

**hypothesis**

Specify a hypothesis test or custom contrast using a numeric value, vector, or matrix, a string, or a string formula.

- **Numeric**:
  - Single value: the null hypothesis used in the computation of $Z$ and $p$ (before applying `transform`).
  - Vector: Weights to compute a linear combination of (custom contrast between) estimates. Length equal to the number of rows generated by the same function call, but without the hypothesis argument.
  - Matrix: Each column is a vector of weights, as describe above, used to compute a distinct linear combination of (contrast between) estimates. The column names of the matrix are used as labels in the output.

- **String formula** to specify linear or non-linear hypothesis tests. If the `term` column uniquely identifies rows, terms can be used in the formula. Otherwise, use `b1`, `b2`, etc. to identify the position of each parameter. The `b*` wildcard can be used to test hypotheses on all estimates. Examples:
  - `hp = drat`
  - `hp + drat = 12`
  - `b1 + b2 + b3 = 0`
  - `b* / b1 = 1`

- **String**:
  - "pairwise": pairwise differences between estimates in each row.
  - "reference": differences between the estimates in each row and the estimate in the first row.
  - "sequential": difference between an estimate and the estimate in the next row.
  - "revpairwise", "revreference", "revsequential": inverse of the corresponding hypotheses, as described above.

- See the Examples section below and the vignette: https://marginaleffects.com/articles/hypothesis.html

**equivalence**

Numeric vector of length 2: bounds used for the two-one-sided test (TOST) of equivalence, and for the non-inferiority and non-superiority tests. See Details section below.

**p_adjust**

Adjust p-values for multiple comparisons: "holm", "hochberg", "hommel", "bonferroni", "BH", "BY", or "fdr". See `stats::p.adjust`

**df**

Degrees of freedom used to compute p values and confidence intervals. A single numeric value between 1 and Inf. When `df` is `Inf`, the normal distribution is used. When `df` is finite, the t distribution is used. See `insight::get_df` for a convenient function to extract degrees of freedom. Ex: `slopes(model, df = insight::get_df(model))`
eps

NULL or numeric value which determines the step size to use when calculating numerical derivatives: \( (f(x+\text{eps})-f(x))/\text{eps} \). When \( \text{eps} \) is NULL, the step size is 0.0001 multiplied by the difference between the maximum and minimum values of the variable with respect to which we are taking the derivative. Changing \( \text{eps} \) may be necessary to avoid numerical problems in certain models.

numderiv

string or list of strings indicating the method to use to for the numeric differentiation used in to compute delta method standard errors.

- "fdforward": finite difference method with forward differences
- "fdcenter": finite difference method with central differences (default)
- "richardson": Richardson extrapolation method

Extra arguments can be specified by passing a list to the numderiv argument, with the name of the method first and named arguments following, ex: numderiv=list("fdcenter", eps = 1e-5). When an unknown argument is used, marginaleffects prints the list of valid arguments for each method.

Additional arguments are passed to the predict() method supplied by the modeling package. These arguments are particularly useful for mixed-effects or bayesian models (see the online vignettes on the marginaleffects website). Available arguments can vary from model to model, depending on the range of supported arguments by each modeling package. See the "Model-Specific Arguments" section of the ?marginaleffects documentation for a non-exhaustive list of available arguments.

Value

A data.frame with one row per observation (per term/group) and several columns:

- rowid: row number of the newdata data frame
- type: prediction type, as defined by the type argument
- group: (optional) value of the grouped outcome (e.g., categorical outcome models)
- term: the variable whose marginal effect is computed
- dydx: slope of the outcome with respect to the term, for a given combination of predictor values
- std.error: standard errors computed by via the delta method.
- p.value: p value associated to the estimate column. The null is determined by the hypothesis argument (0 by default), and p values are computed before applying the transform argument.
- s.value: Shannon information transforms of p values. How many consecutive "heads" tosses would provide the same amount of evidence (or "surprise") against the null hypothesis that the coin is fair? The purpose of S is to calibrate the analyst’s intuition about the strength of evidence encoded in p against a well-known physical phenomenon. See Greenland (2019) and Cole et al. (2020).
- conf.low: lower bound of the confidence interval (or equal-tailed interval for bayesian models)
- conf.high: upper bound of the confidence interval (or equal-tailed interval for bayesian models)

See ?print.marginaleffects for printing options.
Functions

- `avg_comparisons()`: Average comparisons

Standard errors using the delta method

Standard errors for all quantities estimated by `marginaleffects` can be obtained via the delta method. This requires differentiating a function with respect to the coefficients in the model using a finite difference approach. In some models, the delta method standard errors can be sensitive to various aspects of the numeric differentiation strategy, including the step size. By default, the step size is set to $1e^{-8}$, or to $1e^{-4}$ times the smallest absolute model coefficient, whichever is largest.

`marginaleffects` can delegate numeric differentiation to the `numDeriv` package, which allows more flexibility. To do this, users can pass arguments to the `numDeriv::jacobian` function through a global option. For example:

```
- options(marginaleffects_numDeriv = list(method = "simple", method.args = list(eps = 1e-6)))
- options(marginaleffects_numDeriv = list(method = "Richardson", method.args = list(eps = 1e-5)))
- options(marginaleffects_numDeriv = NULL)
```

See the "Standard Errors and Confidence Intervals" vignette on the `marginaleffects` website for more details on the computation of standard errors:

https://marginaleffects.com/articles/uncertainty.html

Note that the `inferences()` function can be used to compute uncertainty estimates using a bootstrap or simulation-based inference. See the vignette:

https://marginaleffects.com/articles/bootstrap.html

Model-Specific Arguments

Some model types allow model-specific arguments to modify the nature of marginal effects, predictions, marginal means, and contrasts. Please report other package-specific `predict()` arguments on Github so we can add them to the table below.

https://github.com/vincentarelbundock/marginaleffects/issues

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<td>MCMCglmm</td>
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Comparisons

Comparison argument functions

The following transformations can be applied by supplying one of the shortcut strings to the comparison argument. `hi` is a vector of adjusted predictions for the "high" side of the contrast. `lo` is a vector of adjusted predictions for the "low" side of the contrast. `y` is a vector of adjusted predictions for the original data. `x` is the predictor in the original data. `eps` is the step size to use to compute derivatives and elasticities.

<table>
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<th>Shortcut</th>
<th>Function</th>
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<tr>
<td>difference</td>
<td>((hi, lo) ) hi - lo</td>
</tr>
<tr>
<td>differenceavg</td>
<td>(\langle hi, lo \rangle mean(hi) - mean(lo))</td>
</tr>
<tr>
<td>dydx</td>
<td>((hi, lo, eps) (hi - lo)/eps)</td>
</tr>
<tr>
<td>eydx</td>
<td>((hi, lo, eps, y, x) (hi - lo)/eps \times (x/y))</td>
</tr>
<tr>
<td>eydxavg</td>
<td>(\langle hi, lo, eps, y, x \rangle ((hi - lo)/eps)/y)</td>
</tr>
<tr>
<td>dyex</td>
<td>((hi, lo, eps, x) ((hi - lo)/eps) \times x)</td>
</tr>
<tr>
<td>dydxavg</td>
<td>(\langle hi, lo, eps \rangle mean((hi - lo)/eps))</td>
</tr>
<tr>
<td>eysexavg</td>
<td>((hi, lo, eps, y, x) mean((hi - lo)/eps) \times (x/y))</td>
</tr>
<tr>
<td>eydxavg</td>
<td>(\langle hi, lo, eps, y, x \rangle mean((hi - lo)/eps)/y)</td>
</tr>
<tr>
<td>ratio</td>
<td>(\langle hi, lo \rangle hi/lo)</td>
</tr>
<tr>
<td>ratioavg</td>
<td>(\langle hi, lo \rangle mean(hi)/mean(lo))</td>
</tr>
<tr>
<td>lnratio</td>
<td>(\langle hi, lo \rangle log(hi/lo))</td>
</tr>
<tr>
<td>lnratioavg</td>
<td>(\langle hi, lo \rangle log(mean(hi)/mean(lo)))</td>
</tr>
<tr>
<td>lnor</td>
<td>(\langle hi, lo \rangle log((hi/(1 - hi))/(lo/(1 - lo))))</td>
</tr>
<tr>
<td>lnoravg</td>
<td>(\langle hi, lo \rangle log((mean(hi)/(1 - mean(hi)))/(mean(lo)/(1 - mean(lo)))))</td>
</tr>
<tr>
<td>lift</td>
<td>(\langle hi, lo \rangle (hi - lo)/lo)</td>
</tr>
<tr>
<td>lifavg</td>
<td>(\langle hi, lo \rangle (mean(hi) - mean(lo))/mean(lo))</td>
</tr>
<tr>
<td>expdydx</td>
<td>(\langle hi, lo, eps \rangle ((exp(hi) - exp(lo))/exp(eps))/eps)</td>
</tr>
<tr>
<td>expdydxavg</td>
<td>(\langle hi, lo, eps \rangle mean(((exp(hi) - exp(lo))/exp(eps))/eps))</td>
</tr>
</tbody>
</table>

Bayesian posterior summaries

By default, credible intervals in bayesian models are built as equal-tailed intervals. This can be changed to a highest density interval by setting a global option:

```r
options("marginaleffects_posterior_interval" = "eti")
```

```r
options("marginaleffects_posterior_interval" = "hdi")
```

By default, the center of the posterior distribution in bayesian models is identified by the median. Users can use a different summary function by setting a global option:

```r
options("marginaleffects_posterior_center" = "mean")
```

```r
options("marginaleffects_posterior_center" = "median")
```

When estimates are averaged using the `by` argument, the `tidy()` function, or the `summary()` function, the posterior distribution is marginalized twice over. First, we take the average across units but within each iteration of the MCMC chain, according to what the user requested in `by` argument or `tidy()`/`summary()` functions. Then, we identify the center of the resulting posterior using the function supplied to the "marginaleffects_posterior_center" option (the median by default).
**Equivalence, Inferiority, Superiority**

θ is an estimate, \(\sigma_\theta\) its estimated standard error, and \([a, b]\) are the bounds of the interval supplied to the equivalence argument.

Non-inferiority:

- \(H_0: \theta \leq a\)
- \(H_1: \theta > a\)
- \(t = (\theta - a)/\sigma_\theta\)
- \(p: \) Upper-tail probability

Non-superiority:

- \(H_0: \theta \geq b\)
- \(H_1: \theta < b\)
- \(t = (\theta - b)/\sigma_\theta\)
- \(p: \) Lower-tail probability

Equivalence: Two One-Sided Tests (TOST)

- \(p: \) Maximum of the non-inferiority and non-superiority \(p\) values.

Thanks to Russell V. Lenth for the excellent emmeans package and documentation which inspired this feature.

**Prediction types**

The type argument determines the scale of the predictions used to compute quantities of interest with functions from the marginaleffects package. Admissible values for type depend on the model object. When users specify an incorrect value for type, marginaleffects will raise an informative error with a list of valid type values for the specific model object. The first entry in the list in that error message is the default type.

The invlink(link) is a special type defined by marginaleffects. It is available for some (but not all) models and functions. With this link type, we first compute predictions on the link scale, then we use the inverse link function to backtransform the predictions to the response scale. This is useful for models with non-linear link functions as it can ensure that confidence intervals stay within desirable bounds, ex: \(0\) to \(1\) for a logit model. Note that an average of estimates with type="invlink(link)" will not always be equivalent to the average of estimates with type="response".

Some of the most common type values are:

response, link, E, Ep, average, class, conditional, count, cum.prob, cumprob, density, disp, expected, expvalue, fitted, invlink(link), latent, linear.predictor, linpred, location, lp, mean, numeric, p, pr, precision, prediction, prob, probability, probs, quantile, risk, scale, survival, unconditional, utility, variance, xb, zero, zlink, zprob
References

- Greenland S. 2019. ”Valid P-Values Behave Exactly as They Should: Some Misleading Criticisms of P-Values and Their Resolution With S-Values.” The American Statistician. 73(S1): 106–114.

Examples

```r
## Not run:
library(marginaleffects)

# Linear model
tmp <- mtcars
tmp$am <- as.logical(tmp$am)
mod <- lm(mpg ~ am + factor(cyl), tmp)
avg_comparisons(mod, variables = list(cyl = "reference"))
avg_comparisons(mod, variables = list(cyl = "sequential"))
avg_comparisons(mod, variables = list(cyl = "pairwise"))

# GLM with different scale types
mod <- glm(am ~ factor(gear), data = mtcars)
avg_comparisons(mod, type = "response")
avg_comparisons(mod, type = "link")

# Contrasts at the mean
comparisons(mod, newdata = "mean")

# Contrasts between marginal means
comparisons(mod, newdata = "marginalmeans")

# Contrasts at user-specified values
comparisons(mod, newdata = datagrid(am = 0, gear = tmp$gear))
comparisons(mod, newdata = datagrid(am = unique, gear = max))

m <- lm(mpg ~ hp + drat + factor(cyl) + factor(am), data = mtcars)
comparisons(m, variables = "hp", newdata = datagrid(FUN_factor = unique, FUN_numeric = median))

# Numeric contrasts
mod <- lm(mpg ~ hp, data = mtcars)
avg_comparisons(mod, variables = list(hp = 1))
avg_comparisons(mod, variables = list(hp = 5))
avg_comparisons(mod, variables = list(hp = c(90, 100)))
avg_comparisons(mod, variables = list(hp = "iqr"))
avg_comparisons(mod, variables = list(hp = "sd"))
avg_comparisons(mod, variables = list(hp = "minmax"))

# using a function to specify a custom difference in one regressor
dat <- mtcars
dat$new_hp <- 49 * (dat$hp - min(dat$hp)) / (max(dat$hp) - min(dat$hp)) + 1
modlog <- lm(mpg ~ log(new_hp) + factor(cyl), data = dat)
```
fdiff <- \( x \) data.frame(x, x + 10)

avg_comparisons(modlog, variables = list(new_hp = fdiff))

# Adjusted Risk Ratio: see the contrasts vignette
mod <- glm(vs ~ mpg, data = mtcars, family = binomial)

avg_comparisons(mod, comparison = "lnratioavg", transform = exp)

# Adjusted Risk Ratio: Manual specification of the `comparison`

avg_comparisons(
  mod,
  comparison = function(hi, lo) log(mean(hi) / mean(lo)),
  transform = exp)

# cross contrasts
mod <- lm(mpg ~ factor(cyl) * factor(gear) + hp, data = mtcars)

avg_comparisons(mod, variables = c("cyl", "gear"), cross = TRUE)

# variable-specific contrasts
avg_comparisons(mod, variables = list(gear = "sequential", hp = 10))

# hypothesis test: is the `hp` marginal effect at the mean equal to the `drat` marginal effect

mod <- lm(mpg ~ wt + drat, data = mtcars)

comparisons(
  mod,
  newdata = "mean",
  hypothesis = "wt = drat")

# same hypothesis test using row indices
comparisons(
  mod,
  newdata = "mean",
  hypothesis = "b1 - b2 = 0")

# same hypothesis test using numeric vector of weights
comparisons(
  mod,
  newdata = "mean",
  hypothesis = c(1, -1))

# two custom contrasts using a matrix of weights
lc <- matrix(c(1, -1,
  2, 3),
  ncol = 2)

comparisons(
  mod,
  newdata = "mean",
  hypothesis = lc)

# Effect of a 1 group-wise standard deviation change
# First we calculate the SD in each group of `cyl`
# Second, we use that SD as the treatment size in the `variables` argument
library(dplyr)
mod <- lm(mpg ~ hp + factor(cyl), mtcars)
tmp <- mtcars %>%
group_by(cyl) %>%
  mutate(hp_sd = sd(hp))
avg_comparisons(mod, variables = list(hp = tmp$hp_sd), by = "cyl")

# 'by' argument
mod <- lm(mpg ~ hp * am * vs, data = mtcars)
comparisons(mod, by = TRUE)

mod <- lm(mpg ~ hp + am + vs, data = mtcars)
avg_comparisons(mod, variables = "hp", by = c("vs", "am"))

library(nnet)
mod <- multinom(factor(gear) ~ mpg + am * vs, data = mtcars, trace = FALSE)
by <- data.frame(
  group = c("3", "4", "5"),
  by = c("3", "4", "5"))
comparisons(mod, type = "probs", by = by)

## End(Not run)

datagrid

**Datagrids**

**Description**

Generate a data grid of user-specified values for use in the `newdata` argument of the `predictions()`, `comparisons()`, and `slopes()` functions. This is useful to define where in the predictor space we want to evaluate the quantities of interest. Ex: the predicted outcome or slope for a 37 year old college graduate.

- `datagrid()` generates data frames with combinations of "typical" or user-supplied predictor values.
- `datagridcf()` generates "counter-factual" data frames, by replicating the entire dataset once for every combination of predictor values supplied by the user.

**Usage**

```r
datagrid(
  ..., 
  model = NULL, 
  newdata = NULL, 
  by = NULL, 
  FUN_character = get_mode, 
  FUN_factor = get_mode, 
  FUN_logical = get_mode, 
  FUN_numeric = function(x) mean(x, na.rm = TRUE),
)```
FUN_integer = function(x) round(mean(x, na.rm = TRUE)),
FUN_other = function(x) mean(x, na.rm = TRUE),
grid_type = "typical"
)

datagridcf(..., model = NULL, newdata = NULL)

Arguments

... named arguments with vectors of values or functions for user-specified variables.

- Functions are applied to the variable in the model dataset or newdata, and
  must return a vector of the appropriate type.
- Character vectors are automatically transformed to factors if necessary.
  +The output will include all combinations of these variables (see Examples below.)

model Model object
newdata data.frame (one and only one of the model and newdata arguments can be used.)
by character vector with grouping variables within which FUN_* functions are applied
to create "sub-grids" with unspecified variables.
FUN_character the function to be applied to character variables.
FUN_factor the function to be applied to factor variables.
FUN_logical the function to be applied to logical variables.
FUN_numeric the function to be applied to numeric variables.
FUN_integer the function to be applied to integer variables.
FUN_other the function to be applied to other variable types.
grid_type character

- "typical": variables whose values are not explicitly specified by the user in
  ... are set to their mean or mode, or to the output of the functions supplied
to FUN_type arguments.
- "counterfactual": the entire dataset is duplicated for each combination of
  the variable values specified in ... Variables not explicitly supplied to
datagrid() are set to their observed values in the original dataset.

Details

Ifdatagrid is used in a predictions(), comparisons(), or slopes() call as the newdata argument, the model is automatically inserted in the model argument of datagrid() call, and users do not need to specify either the model or newdata arguments.

If users supply a model, the data used to fit that model is retrieved using the insight::get_data function.

Value

A data.frame in which each row corresponds to one combination of the named predictors supplied by the user via the ... dots. Variables which are not explicitly defined are held at their mean or mode.
hypotheses

Functions

- datagridcf(): Counterfactual data grid

Examples

```r
# The output only has 2 rows, and all the variables except 'hp' are at their
# mean or mode.
datagrid(newdata = mtcars, hp = c(100, 110))

# We get the same result by feeding a model instead of a data.frame
mod <- lm(mpg ~ hp, mtcars)
datagrid(model = mod, hp = c(100, 110))

# Use in `marginaleffects` to compute "Typical Marginal Effects". When used
# in `slopes()` or `predictions()` we do not need to specify the
# `model` or `newdata` arguments.
slopes(mod, newdata = datagrid(hp = c(100, 110)))

# datagrid accepts functions
datagrid(hp = range, cyl = unique, newdata = mtcars)
comparisons(mod, newdata = datagrid(hp = fivenum))

# The full dataset is duplicated with each observation given counterfactual
# values of 100 and 110 for the 'hp' variable. The original 'mtcars' includes
# 32 rows, so the resulting dataset includes 64 rows.
dg <- datagrid(newdata = mtcars, hp = c(100, 110), grid_type = "counterfactual")
nrow(dg)

# We get the same result by feeding a model instead of a data.frame
mod <- lm(mpg ~ hp, mtcars)
dg <- datagrid(model = mod, hp = c(100, 110), grid_type = "counterfactual")
nrow(dg)
```

hypotheses

(Non-)Linear Tests for Null Hypotheses, Joint Hypotheses, Equivalence, Non Superiority, and Non Inferiority

Description

Uncertainty estimates are calculated as first-order approximate standard errors for linear or non-linear functions of a vector of random variables with known or estimated covariance matrix. In that sense, hypotheses emulates the behavior of the excellent and well-established car::deltaMethod and car::linearHypothesis functions, but it supports more models; requires fewer dependencies; expands the range of tests to equivalence and superiority/inferiority; and offers convenience features like robust standard errors.

To learn more, read the hypothesis tests vignette, visit the package website, or scroll down this page for a full list of vignettes:

- https://marginaleffects.com/articles/hypothesis.html
Warning #1: Tests are conducted directly on the scale defined by the type argument. For some models, it can make sense to conduct hypothesis or equivalence tests on the "link" scale instead of the "response" scale which is often the default.

Warning #2: For hypothesis tests on objects produced by the marginaleffects package, it is safer to use the hypothesis argument of the original function. Using hypotheses() may not work in certain environments, in lists, or when working programmatically with *apply style functions.

Warning #3: The tests assume that the hypothesis expression is (approximately) normally distributed, which for non-linear functions of the parameters may not be realistic. More reliable confidence intervals can be obtained using the inferences() function with method = "boot".

Usage

hypotheses(
  model,
  hypothesis = NULL,
  vcov = NULL,
  conf_level = 0.95,
  df = Inf,
  equivalence = NULL,
  joint = FALSE,
  joint_test = "f",
  FUN = NULL,
  numderiv = "fdforward",
  ...
)

Arguments

model Model object or object generated by the comparisons(), slopes(), predictions(), or marginal_means() functions.

hypothesis specify a hypothesis test or custom contrast using a numeric value, vector, or matrix, a string, or a string formula.

• Numeric:
  – Single value: the null hypothesis used in the computation of Z and p (before applying transform).
  – Vector: Weights to compute a linear combination of (custom contrast between) estimates. Length equal to the number of rows generated by the same function call, but without the hypothesis argument.
  – Matrix: Each column is a vector of weights, as describe above, used to compute a distinct linear combination of (contrast between) estimates. The column names of the matrix are used as labels in the output.

• String formula to specify linear or non-linear hypothesis tests. If the term column uniquely identifies rows, terms can be used in the formula. Otherwise, use b1, b2, etc. to identify the position of each parameter. The b* wildcard can be used to test hypotheses on all estimates. Examples:

  • String formula to specify linear or non-linear hypothesis tests. If the term column uniquely identifies rows, terms can be used in the formula. Otherwise, use b1, b2, etc. to identify the position of each parameter. The b* wildcard can be used to test hypotheses on all estimates. Examples:
- hp = drat
- hp + drat = 12
- b1 + b2 + b3 = 0
- b* / b1 = 1

• String:
  - "pairwise": pairwise differences between estimates in each row.
  - "reference": differences between the estimates in each row and the estimate in the first row.
  - "sequential": difference between an estimate and the estimate in the next row.
  - "revpairwise", "revreference", "revsequential": inverse of the corresponding hypotheses, as described above.

• See the Examples section below and the vignette: https://marginaleffects.com/articles/hypothesis.html

vcov
Type of uncertainty estimates to report (e.g., for robust standard errors). Acceptable values:

• FALSE: Do not compute standard errors. This can speed up computation considerably.
• TRUE: Unit-level standard errors using the default vcov(model) variance-covariance matrix.
• String which indicates the kind of uncertainty estimates to return.
  - Heteroskedasticity-consistent: "HC", "HC0", "HC1", "HC2", "HC3", "HC4", "HC4m", "HC5". See ?sandwich::vcovHC
  - Heteroskedasticity and autocorrelation consistent: "HAC"
  - Mixed-Models degrees of freedom: "satterthwaite", "kenward-roger"
  - Other: "NeweyWest", "KernHAC", "OPG". See the sandwich package documentation.

• One-sided formula which indicates the name of cluster variables (e.g., ~unit_id). This formula is passed to the cluster argument of the sandwich::vcovCL function.
• Square covariance matrix
• Function which returns a covariance matrix (e.g., stats::vcov(model))

conf_level
numeric value between 0 and 1. Confidence level to use to build a confidence interval.

df
Degrees of freedom used to compute p values and confidence intervals. A single numeric value between 1 and Inf. When df is Inf, the normal distribution is used. When df is finite, the t distribution is used. See insight::get_df for a convenient function to extract degrees of freedom. Ex: slopes(model, df = insight::get_df(model))

equivalence
Numeric vector of length 2: bounds used for the two-one-sided test (TOST) of equivalence, and for the non-inferiority and non-superiority tests. See Details section below.

joint
Joint test of statistical significance. The null hypothesis value can be set using the hypothesis argument.

• FALSE: Hypotheses are not tested jointly.
• TRUE: All parameters are tested jointly.
• String: A regular expression to match parameters to be tested jointly. `grep(joint, perl = TRUE)`
• Character vector of parameter names to be tested. Characters refer to the names of the vector returned by `coef(object)`.
• Integer vector of indices. Which parameters positions to test jointly.

`joint_test` A character string specifying the type of test, either "f" or "chisq". The null hypothesis is set by the `hypothesis` argument, with default null equal to 0 for all parameters.

`FUN` NULL or function.
• NULL (default): hypothesis test on a model’s coefficients, or on the quantities estimated by one of the `marginaleffects` package functions.
• Function which accepts a model object and returns a numeric vector or a data.frame with two columns called `term` and `estimate`. This argument can be useful when users want to conduct a hypothesis test on an arbitrary function of quantities held in a model object. See examples below.

`numderiv` string or list of strings indicating the method to use to for the numeric differentiation used in to compute delta method standard errors.
• "fdforward": finite difference method with forward differences
• "fdcenter": finite difference method with central differences (default)
• "richardson": Richardson extrapolation method
• Extra arguments can be specified by passing a list to the `numderiv` argument, with the name of the method first and named arguments following, ex: `numderiv=list("fdcenter", eps = 1e-5)`. When an unknown argument is used, `marginaleffects` prints the list of valid arguments for each method.

Additional arguments are passed to the `predict()` method supplied by the modeling package. These arguments are particularly useful for mixed-effects or bayesian models (see the online vignettes on the `marginaleffects` website). Available arguments can vary from model to model, depending on the range of supported arguments by each modeling package. See the "Model-Specific Arguments" section of the `?marginaleffects` documentation for a non-exhaustive list of available arguments.

**Joint hypothesis tests**

The test statistic for the joint Wald test is calculated as \((R * \theta_{\text{hat}} - r)' * \text{inv}(R * V_{\text{hat}} * R') * (R * \theta_{\text{hat}} - r) / Q\), where \(\theta_{\text{hat}}\) is the vector of estimated parameters, \(V_{\text{hat}}\) is the estimated covariance matrix, \(R\) is a \(Q \times P\) matrix for testing \(Q\) hypotheses on \(P\) parameters, \(r\) is a \(Q \times 1\) vector for the null hypothesis, and \(Q\) is the number of rows in \(R\). If the test is a Chi-squared test, the test statistic is not normalized.

The p-value is then calculated based on either the F-distribution (for F-test) or the Chi-squared distribution (for Chi-squared test). For the F-test, the degrees of freedom are \(Q\) and \((n - P)\), where \(n\) is the sample size and \(P\) is the number of parameters. For the Chi-squared test, the degrees of freedom are \(Q\).
**Equivalence, Inferiority, Superiority**

θ is an estimate, σθ its estimated standard error, and [a, b] are the bounds of the interval supplied to the equivalence argument.

Non-inferiority:
- \( H_0: \theta \leq a \)
- \( H_1: \theta > a \)
- \( t = (\theta - a)/\sigma_\theta \)
- \( p: \) Upper-tail probability

Non-superiority:
- \( H_0: \theta \geq b \)
- \( H_1: \theta < b \)
- \( t = (\theta - b)/\sigma_\theta \)
- \( p: \) Lower-tail probability

Equivalence: Two One-Sided Tests (TOST)
- \( p: \) Maximum of the non-inferiority and non-superiority \( p \) values.

Thanks to Russell V. Lenth for the excellent emmeans package and documentation which inspired this feature.

**Examples**

```r
library(marginaleffects)
mod <- lm(mpg ~ hp + wt + factor(cyl), data = mtcars)

# When 'FUN' and 'hypotheses' are 'NULL', 'hypotheses()' returns a data.frame of parameters
hypotheses(mod)

# Test of equality between coefficients
hypotheses(mod, hypothesis = "hp = wt")

# Non-linear function
hypotheses(mod, hypothesis = "exp(hp + wt) = 0.1")

# Robust standard errors
hypotheses(mod, hypothesis = "hp = wt", vcov = "HC3")

# b1, b2, ... shortcuts can be used to identify the position of the
# parameters of interest in the output of FUN
hypotheses(mod, hypothesis = "b2 = b3")

# wildcard
hypotheses(mod, hypothesis = "b* / b2 = 1")

# term names with special characters have to be enclosed in backticks
hypotheses(mod, hypothesis = "`factor(cyl)6` = `factor(cyl)8`")
```
mod2 <- lm(mpg ~ hp * drat, data = mtcars)
hypotheses(mod2, hypothesis = "\"hp:drat\" = drat")

# predictions(), comparisons(), and slopes()
mod <- glm(am ~ hp + mpg, data = mtcars, family = binomial)
cmp <- comparisons(mod, newdata = "mean")
hypotheses(cmp, hypothesis = "b1 = b2")

mfx <- slopes(mod, newdata = "mean")
hypotheses(mfx, hypothesis = "b2 = 0.2")

pre <- predictions(mod, newdata = datagrid(hp = 110, mpg = c(30, 35)))
hypotheses(pre, hypothesis = "b1 = b2")

# The 'FUN' argument can be used to compute standard errors for fitted values
mod <- glm(am ~ hp + mpg, data = mtcars, family = binomial)

f <- function(x) predict(x, type = "link", newdata = mtcars)
p <- hypotheses(mod, FUN = f)
head(p)

f <- function(x) predict(x, type = "response", newdata = mtcars)
p <- hypotheses(mod, FUN = f)
head(p)

# Complex aggregation
# Step 1: Collapse predicted probabilities by outcome level, for each individual
# Step 2: Take the mean of the collapsed probabilities by group and `cyl`
library(dplyr)
library(MASS)
library(dplyr)

dat <- transform(mtcars, gear = factor(gear))
mod <- polr(gear ~ factor(cyl) + hp, dat)

aggregation_fun <- function(model) {
  predictions(model, vcov = FALSE) |>
    mutate(group = ifelse(group %in% c("3", "4"), "3 & 4", "5")) |>
    summarize(estimate = sum(estimate), .by = c("rowid", "cyl", "group")) |>
    summarize(estimate = mean(estimate), .by = c("cyl", "group")) |>
    rename(term = cyl)
}

hypotheses(mod, FUN = aggregation_fun)

# Equivalence, non-inferiority, and non-superiority tests
mod <- lm(mpg ~ hp + factor(gear), data = mtcars)
p <- predictions(mod, newdata = "median")
hypotheses(p, equivalence = c(17, 18))

mfx <- avg_slopes(mod, variables = "hp")
hypotheses(mfx, equivalence = c(-.1, .1))
inferences

(Experimental) Bootstrap, Conformal, and Simulation-Based Inference

Description

Warning: This function is experimental. It may be renamed, the user interface may change, or the functionality may migrate to arguments in other marginaleffects functions.

Apply this function to a marginaleffects object to change the inferential method used to compute uncertainty estimates.

Usage

inferences(
  x,
  method,
  R = 1000,
  conf_type = "perc",
  conformal_test = NULL,
  conformal_calibration = NULL,
  conformal_score = "residual_abs",
  ...
)

cmp <- avg_comparisons(mod, variables = "gear", hypothesis = "pairwise")
hypotheses(cmp, equivalence = c(0, 10))

# joint hypotheses: character vector
model <- lm(mpg ~ as.factor(cyl) * hp, data = mtcars)
hypotheses(model, joint = c("as.factor(cyl)6:hp", "as.factor(cyl)8:hp"))

# joint hypotheses: regular expression
hypotheses(model, joint = "cyl")

# joint hypotheses: integer indices
hypotheses(model, joint = 2:3)

# joint hypotheses: different null hypotheses
hypotheses(model, joint = 2:3, hypothesis = 1)
hypotheses(model, joint = 2:3, hypothesis = 1:2)

# joint hypotheses: marginaleffects object
cmp <- avg_comparisons(model)
hypotheses(cmp, joint = "cyl")
Arguments

- **x**: Object produced by one of the core marginaleffects functions.
- **method**: String
  - "delta": delta method standard errors
  - "boot": package
  - "fwb": fractional weighted bootstrap
  - "rsample": package
  - "simulation" from a multivariate normal distribution (Krinsky & Robb, 1986)
  - "mi": multiple imputation for missing data
  - "conformal_split": prediction intervals using split conformal prediction (see Angelopoulos & Bates, 2022)
  - "conformal_cv+": prediction intervals using cross-validation+ conformal prediction (see Barber et al., 2020)
- **R**: Number of resamples, simulations, or cross-validation folds.
- **conf_type**: String: type of bootstrap interval to construct.
  - boot: "perc", "norm", "basic", or "bca"
  - fwb: "perc", "norm", "basic", "bc", or "bca"
  - rsample: "perc" or "bca"
  - simulation: argument ignored.
- **conformal_test**: Data frame of test data for conformal prediction.
- **conformal_calibration**: Data frame of calibration data for split conformal prediction (method="conformal_split").
- **conformal_score**: String. Warning: The type argument in predictions() must generate predictions which are on the same scale as the outcome variable. Typically, this means that type must be "response" or "probs".
  - "residual_abs" or "residual_sq" for regression tasks (numeric outcome)
  - "softmax" for classification tasks (when predictions() returns a group columns, such as multinomial or ordinal logit models).

... If method="boot", additional arguments are passed to boot::boot().
... If method="fwb", additional arguments are passed to fwb::fwb().
... If method="rsample", additional arguments are passed to rsample::bootstraps().
... Additional arguments are ignored for all other methods.

Details

When method="simulation", we conduct simulation-based inference following the method discussed in Krinsky & Robb (1986):

1. Draw R sets of simulated coefficients from a multivariate normal distribution with mean equal to the original model’s estimated coefficients and variance equal to the model’s variance-covariance matrix (classical, "HC3", or other).
2. Use the R sets of coefficients to compute R sets of estimands: predictions, comparisons, slopes, or hypotheses.
3. Take quantiles of the resulting distribution of estimands to obtain a confidence interval and the standard deviation of simulated estimates to estimate the standard error.

When method = "fwb", drawn weights are supplied to the model fitting function’s weights argument; if the model doesn’t accept non-integer weights, this method should not be used. If weights were included in the original model fit, they are extracted by `weights()` and multiplied by the drawn weights. These weights are supplied to the `wts` argument of the estimation function (e.g., `comparisons()`).

**Value**

A `marginaleffects` object with simulation or bootstrap resamples and objects attached.

**References**


**Examples**

```r
## Not run:
library(marginaleffects)
library(magrittr)
set.seed(1024)
mod <- lm(Sepal.Length ~ Sepal.Width * Species, data = iris)

# bootstrap
avg_predictions(mod, by = "Species") %>%
inferences(method = "boot")

avg_predictions(mod, by = "Species") %>%
inferences(method = "rsample")

# Fractional (bayesian) bootstrap
avg_slopes(mod, by = "Species") %>%
inferences(method = "fwb") %>%
posterior_draws("rvar") %>%
data.frame()

# Simulation-based inference
slopes(mod) %>%
inferences(method = "simulation") %>%
```
marginal_means

head()

## End(Not run)

marginal_means  Marginal Means

Description
Marginal means are adjusted predictions, averaged across a grid of categorical predictors, holding other numeric predictors at their means. To learn more, read the marginal means vignette, visit the package website, or scroll down this page for a full list of vignettes:

- [https://marginaleffects.com/articles/marginalmeans.html](https://marginaleffects.com/articles/marginalmeans.html)
- [https://marginaleffects.com/](https://marginaleffects.com/)

Usage
marginal_means(
  model,
  variables = NULL,
  newdata = NULL,
  vcov = TRUE,
  conf_level = 0.95,
  type = NULL,
  transform = NULL,
  cross = FALSE,
  hypothesis = NULL,
  equivalence = NULL,
  p_adjust = NULL,
  df = Inf,
  wts = "equal",
  by = NULL,
  numderiv = "fdforward",
  ...
)

Arguments

- **model**: Model object
- **variables**: Focal variables
  - Character vector of variable names: compute marginal means for each category of the listed variables.
  - NULL: calculate marginal means for all logical, character, or factor variables in the dataset used to fit model. Hint: Set cross=TRUE to compute marginal means for combinations of focal variables.
**newdata**

Grid of predictor values over which we marginalize.

- Warning: Please avoid modifying your dataset between fitting the model and calling a `marginal_effects` function. This can sometimes lead to unexpected results.
- **NULL** create a grid with all combinations of all categorical predictors in the model. Warning: can be expensive.
- Character vector: subset of categorical variables to use when building the balanced grid of predictors. Other variables are held to their mean or mode.
- Data frame: A data frame which includes all the predictors in the original model. The full dataset is replicated once for every combination of the focal variables in the `variables` argument, using the `datagridcf()` function.

**vcov**

Type of uncertainty estimates to report (e.g., for robust standard errors). Acceptable values:

- **FALSE**: Do not compute standard errors. This can speed up computation considerably.
- **TRUE**: Unit-level standard errors using the default `vcov(model)` variance-covariance matrix.
- String which indicates the kind of uncertainty estimates to return.
  - Heteroskedasticity-consistent: "HC", "HC0", "HC1", "HC2", "HC3", "HC4", "HC4m", "HC5". See `?sandwich::vcovHC`
  - Heteroskedasticity and autocorrelation consistent: "HAC"
  - Mixed-Models degrees of freedom: "satterthwaite", "kenward-roger"
  - Other: "NeweyWest", "KernHAC", "OPG". See the sandwich package documentation.
- One-sided formula which indicates the name of cluster variables (e.g., ~unit_id). This formula is passed to the `cluster` argument of the `sandwich::vcovCL` function.
- Square covariance matrix
- Function which returns a covariance matrix (e.g., `stats::vcov(model)`)

**conf_level**

Numeric value between 0 and 1. Confidence level to use to build a confidence interval.

**type**

String indicates the type (scale) of the predictions used to compute marginal effects or contrasts. This can differ based on the model type, but will typically be a string such as: "response", "link", "probs", or "zero". When an unsupported string is entered, the model-specific list of acceptable values is returned in an error message. When `type` is **NULL**, the first entry in the error message is used by default.

**transform**

A function applied to unit-level adjusted predictions and confidence intervals just before the function returns results. For bayesian models, this function is applied to individual draws from the posterior distribution, before computing summaries.

**cross**

**TRUE** or **FALSE**

- **FALSE** (default): Marginal means are computed for each predictor individually.
- **TRUE**: Marginal means are computed for each combination of predictors specified in the `variables` argument.

### hypothesis
specify a hypothesis test or custom contrast using a numeric value, vector, or matrix, a string, or a string formula.

- **Numeric**:
  - Single value: the null hypothesis used in the computation of Z and p (before applying transform).
  - Vector: Weights to compute a linear combination of (custom contrast between) estimates. Length equal to the number of rows generated by the same function call, but without the `hypothesis` argument.
  - Matrix: Each column is a vector of weights, as describe above, used to compute a distinct linear combination of (contrast between) estimates. The column names of the matrix are used as labels in the output.

- **String formula to specify linear or non-linear hypothesis tests.** If the `term` column uniquely identifies rows, terms can be used in the formula. Otherwise, use `b1`, `b2`, etc. to identify the position of each parameter. The `b*` wildcard can be used to test hypotheses on all estimates. Examples:
  - `hp = drat`
  - `hp + drat = 12`
  - `b1 + b2 + b3 = 0`
  - `b* / b1 = 1`

- **String**:
  - "pairwise": pairwise differences between estimates in each row.
  - "reference": differences between the estimates in each row and the estimate in the first row.
  - "sequential": difference between an estimate and the estimate in the next row.
  - "revpairwise", "revreference", "revsequential": inverse of the corresponding hypotheses, as described above.

- See the Examples section below and the vignette: https://marginaleffects.com/articles/hypothesis.html

### equivalence
Numeric vector of length 2: bounds used for the two-one-sided test (TOST) of equivalence, and for the non-inferiority and non-superiority tests. See Details section below.

### p_adjust
Adjust p-values for multiple comparisons: "holm", "hochberg", "hommel", "bonferroni", "BH", "BY", or "fdr". See `stats::p.adjust`

### df
Degrees of freedom used to compute p values and confidence intervals. A single numeric value between 1 and Inf. When `df` is Inf, the normal distribution is used. When `df` is finite, the t distribution is used. See `insight::get_df` for a convenient function to extract degrees of freedom. Ex: `slopes(model, df = insight::get_df(model))`

### wts
character value. Weights to use in the averaging.

- "equal": each combination of variables in `newdata` gets equal weight.
- "cells": each combination of values for the variables in the `newdata` gets a weight proportional to its frequency in the original data.
marginal_means

- "proportional": each combination of values for the variables in newdata – except for those in the variables argument – gets a weight proportional to its frequency in the original data.

by Collapse marginal means into categories. Data frame with a by column of group labels, and merging columns shared by newdata or the data frame produced by calling the same function without the by argument.

numderiv string or list of strings indicating the method to use to for the numeric differentiation used in to compute delta method standard errors.

- "fdforward": finite difference method with forward differences
- "fdcenter": finite difference method with central differences (default)
- "richardson": Richardson extrapolation method

Extra arguments can be specified by passing a list to the numDeriv argument, with the name of the method first and named arguments following. ex: numderiv=list("fdcenter", eps = 1e-5). When an unknown argument is used, marginaleffects prints the list of valid arguments for each method.

Additional arguments are passed to the predict() method supplied by the modeling package. These arguments are particularly useful for mixed-effects or bayesian models (see the online vignettes on the marginaleffects website). Available arguments can vary from model to model, depending on the range of supported arguments by each modeling package. See the "Model-Specific Arguments" section of the ?marginaleffects documentation for a non-exhaustive list of available arguments.

Details

This function begins by calling the predictions function to obtain a grid of predictors, and adjusted predictions for each cell. The grid includes all combinations of the categorical variables listed in the variables and newdata arguments, or all combinations of the categorical variables used to fit the model if newdata is NULL. In the prediction grid, numeric variables are held at their means.

After constructing the grid and filling the grid with adjusted predictions, marginal_means computes marginal means for the variables listed in the variables argument, by average across all categories in the grid.

marginal_means can only compute standard errors for linear models, or for predictions on the link scale, that is, with the type argument set to "link".

The marginaleffects website compares the output of this function to the popular emmeans package, which provides similar but more advanced functionality: https://marginaleffects.com/

Value

Data frame of marginal means with one row per variable-value combination.

Standard errors using the delta method

Standard errors for all quantities estimated by marginaleffects can be obtained via the delta method. This requires differentiating a function with respect to the coefficients in the model using
a finite difference approach. In some models, the delta method standard errors can be sensitive to various aspects of the numeric differentiation strategy, including the step size. By default, the step size is set to $1e^{-8}$, or to $1e^{-4}$ times the smallest absolute model coefficient, whichever is largest.

`marginalEffects` can delegate numeric differentiation to the `numDeriv` package, which allows more flexibility. To do this, users can pass arguments to the `numDeriv::jacobian` function through a global option. For example:

- `options(marginalEffects_numDeriv = list(method = "simple", method.args = list(eps = 1e-6)))`
- `options(marginalEffects_numDeriv = list(method = "Richardson", method.args = list(eps = 1e-5)))`
- `options(marginalEffects_numDeriv = NULL)`

See the "Standard Errors and Confidence Intervals" vignette on the `marginalEffects` website for more details on the computation of standard errors:

https://marginaleffects.com/articles/uncertainty.html

Note that the `inferences()` function can be used to compute uncertainty estimates using a bootstrap or simulation-based inference. See the vignette:

https://marginaleffects.com/articles/bootstrap.html

**Model-Specific Arguments**

Some model types allow model-specific arguments to modify the nature of marginal effects, predictions, marginal means, and contrasts. Please report other package-specific `predict()` arguments on Github so we can add them to the table below.

https://github.com/vincentarelbundock/marginaleffects/issues

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**Bayesian posterior summaries**

By default, credible intervals in bayesian models are built as equal-tailed intervals. This can be changed to a highest density interval by setting a global option:

- `options("marginalEffects_posterior_interval" = "eti")`
- `options("marginalEffects_posterior_interval" = "hdi")`
By default, the center of the posterior distribution in Bayesian models is identified by the median. Users can use a different summary function by setting a global option:

```
options("marginaleffects_posterior_center" = "mean")
```

```
options("marginaleffects_posterior_center" = "median")
```

When estimates are averaged using the `by` argument, the `tidy()` function, or the `summary()` function, the posterior distribution is marginalized twice over. First, we take the average across units but within each iteration of the MCMC chain, according to what the user requested in `by` argument or `tidy()`/`summary()` functions. Then, we identify the center of the resulting posterior using the function supplied to the "marginaleffects_posterior_center" option (the median by default).

**Equivalence, Inferiority, Superiority**

\( \theta \) is an estimate, \( \sigma_\theta \) its estimated standard error, and \([a, b]\) are the bounds of the interval supplied to the `equivalence` argument.

**Non-inferiority:**
- \( H_0: \theta \leq a \)
- \( H_1: \theta > a \)
- \( t = (\theta - a)/\sigma_\theta \)
- \( p: \) Upper-tail probability

**Non-superiority:**
- \( H_0: \theta \geq b \)
- \( H_1: \theta < b \)
- \( t = (\theta - b)/\sigma_\theta \)
- \( p: \) Lower-tail probability

**Equivalence: Two One-Sided Tests (TOST)**
- \( p: \) Maximum of the non-inferiority and non-superiority \( p \) values.

Thanks to Russell V. Lenth for the excellent `emmeans` package and documentation which inspired this feature.

**Prediction types**

The `type` argument determines the scale of the predictions used to compute quantities of interest with functions from the `marginaleffects` package. Admissible values for `type` depend on the model object. When users specify an incorrect value for `type`, `marginaleffects` will raise an informative error with a list of valid type values for the specific model object. The first entry in the list in that error message is the default type.

The `invlink(link)` is a special type defined by `marginaleffects`. It is available for some (but not all) models and functions. With this link type, we first compute predictions on the link scale, then we use the inverse link function to backtransform the predictions to the response scale. This is useful for models with non-linear link functions as it can ensure that confidence intervals stay within desirable bounds, ex: 0 to 1 for a logit model. Note that an average of estimates with `type="invlink(link)"` will not always be equivalent to the average of estimates with `type="response"`. 
Some of the most common type values are:

response, link, E, Ep, average, class, conditional, count, cum.prob, cumprob, density, disp, expected, expvalue, fitted, invlink(link), latent, linear.predictor, linpred, location, lp, mean, numeric, p, pr, precision, prediction, prob, probability, probs, quantile, risk, scale, survival, unconditional, utility, variance, xb, zero, zlink, zprob

References


Examples

```r
library(marginalmeans)

# simple marginal means for each level of 'cyl'
dat <- mtcars
dat$carb <- factor(dat$carb)
dat$cyl <- factor(dat$cyl)
dat$am <- as.logical(dat$am)
mod <- lm(mpg ~ carb + cyl + am, dat)
marginal_means(
  mod,
  variables = "cyl"
)

# collapse levels of cyl by averaging
by <- data.frame(
  cyl = c(4, 6, 8),
  by = c("4 & 6", "4 & 6", "8"))
marginal_means(mod, 
  variables = "cyl",
  by = by)

# pairwise differences between collapsed levels
marginal_means(mod, 
  variables = "cyl",
  by = by,
  hypothesis = "pairwise")

# cross
marginal_means(mod, 
  variables = c("cyl", "carb"), 
  cross = TRUE)

# collapsed cross
by <- expand.grid(
  cyl = unique(mtcars$cyl), 
  ...)
```
carb = unique(mtcars$carb))
by$by <- ifelse(by$cyl == 4,
paste("Control:", by$carb),
paste("Treatment:", by$carb))

# Convert numeric variables to categorical before fitting the model
dat <- mtcars
dat$am <- as.logical(dat$am)
dat$carb <- as.factor(dat$carb)
mod <- lm(mpg ~ hp + am + carb, data = dat)

# Compute and summarize marginal means
marginal_means(mod)

# Contrast between marginal means (carb2 - carb1), or "is the 1st marginal means equal to the 2nd?"
# see the vignette on "Hypothesis Tests and Custom Contrasts" on the `marginaleffects` website.
lc <- c(-1, 1, 0, 0, 0, 0)
marginal_means(mod, variables = "carb", hypothesis = "b2 = b1")
marginal_means(mod, variables = "carb", hypothesis = lc)

# Multiple custom contrasts
lc <- matrix(c(
  -2, 1, 1, 0, -1, 1,
  -1, 1, 0, 0, 0, 0
),
ncol = 2,
dimnames = list(NULL, c("A", "B")))
marginal_means(mod, variables = "carb", hypothesis = lc)

---

**plot_comparisons**  
*Plot Conditional or Marginal Comparisons*

**Description**

Plot comparisons on the y-axis against values of one or more predictors (x-axis, colors/shapes, and facets).

The by argument is used to plot marginal comparisons, that is, comparisons made on the original data, but averaged by subgroups. This is analogous to using the by argument in the comparisons() function.

The condition argument is used to plot conditional comparisons, that is, comparisons made on a user-specified grid. This is analogous to using the newdata argument and datagrid() function in a comparisons() call.

All unspecified variables are held at their mean or mode. This includes grouping variables in mixed-effects models, so analysts who fit such models may want to specify the groups of interest using the
variables argument, or supply model-specific arguments to compute population-level estimates. See details below. See the "Plots" vignette and website for tutorials and information on how to customize plots:

- https://marginaleffects.com/articles/plot.html
- https://marginaleffects.com

Usage

plot_comparisons(
  model,
  variables = NULL,
  condition = NULL,
  by = NULL,
  newdata = NULL,
  type = "response",
  vcov = NULL,
  conf_level = 0.95,
  wts = NULL,
  comparison = "difference",
  transform = NULL,
  rug = FALSE,
  gray = FALSE,
  draw = TRUE,
  ...
)

Arguments

model: Model object
variables: Name of the variable whose contrast we want to plot on the y-axis.
condition: Conditional slopes
  - Character vector (max length 3): Names of the predictors to display.
  - Named list (max length 3): List names correspond to predictors. List elements can be:
    - Numeric vector
    - Function which returns a numeric vector or a set of unique categorical values
    - Shortcut strings for common reference values: "minmax", "quartile", "threenum"
  - 1: x-axis. 2: color/shape. 3: facets.
  - Numeric variables in positions 2 and 3 are summarized by Tukey’s five numbers ?stats::fivenum.
by: Aggregate unit-level estimates (aka, marginalize, average over). Valid inputs:
  - FALSE: return the original unit-level estimates.
  - TRUE: aggregate estimates for each term.
- Character vector of column names in newdata or in the data frame produced by calling the function without the by argument.
- Data frame with a by column of group labels, and merging columns shared by newdata or the data frame produced by calling the same function without the by argument.
- See examples below.
- For more complex aggregations, you can use the FUN argument of the hypotheses() function. See that function’s documentation and the Hypothesis Test vignettes on the marginaleffects website.

newdata
When newdata is NULL, the grid is determined by the condition argument. When newdata is not NULL, the argument behaves in the same way as in the comparisons() function.

type
string indicates the type (scale) of the predictions used to compute contrasts or slopes. This can differ based on the model type, but will typically be a string such as: "response", "link", "probs", or "zero". When an unsupported string is entered, the model-specific list of acceptable values is returned in an error message. When type is NULL, the first entry in the error message is used by default.

vcov
Type of uncertainty estimates to report (e.g., for robust standard errors). Acceptable values:
- FALSE: Do not compute standard errors. This can speed up computation considerably.
- TRUE: Unit-level standard errors using the default vcov(model) variance-covariance matrix.
- String which indicates the kind of uncertainty estimates to return.
  - Heteroskedasticity-consistent: "HC", "HC0", "HC1", "HC2", "HC3", "HC4", "HC4m", "HC5". See ?sandwich::vcovHC
  - Heteroskedasticity and autocorrelation consistent: "HAC"
  - Mixed-Models degrees of freedom: "satterthwaite", "kenward-roger"
  - Other: "NeweyWest", "KernHAC", "OPG". See the sandwich package documentation.
- One-sided formula which indicates the name of cluster variables (e.g., ~unit_id). This formula is passed to the cluster argument of the sandwich::vcovCL function.
- Square covariance matrix
- Function which returns a covariance matrix (e.g., stats::vcov(model))

conf_level
numeric value between 0 and 1. Confidence level to use to build a confidence interval.

wts
string or numeric: weights to use when computing average contrasts or slopes. These weights only affect the averaging in avg_*() or with the by argument, and not the unit-level estimates themselves. Internally, estimates and weights are passed to the weighted.mean() function.
- string: column name of the weights variable in newdata. When supplying a column name to wts, it is recommended to supply the original data (including the weights variable) explicitly to newdata.
• numeric: vector of length equal to the number of rows in the original data or in newdata (if supplied).

comparison

How should pairs of predictions be compared? Difference, ratio, odds ratio, or user-defined functions.

• string: shortcuts to common contrast functions.
  – Supported shortcuts strings: difference, differenceavg, differenceavgwts, dydx, eyex, eydx, dydxavg, eyexavg, eydxavg, eydxavgwts, eyexavgwts, eydxavgwts, dyexavgwts, ratio, ratioavg, ratioavgwts, lnratio, lnratioavg, lnratioavgwts, lnor, lnoravg, lnoravgwts, lift, liftavg, expdydx, expdydxavg, expdydxavgwts
  – See the Comparisons section below for definitions of each transformation.

• function: accept two equal-length numeric vectors of adjusted predictions (hi and lo) and returns a vector of contrasts of the same length, or a unique numeric value.
  – See the Transformations section below for examples of valid functions.

transform

string or function. Transformation applied to unit-level estimates and confidence intervals just before the function returns results. Functions must accept a vector and return a vector of the same length. Support string shortcuts: "exp", "ln"

rug

TRUE displays tick marks on the axes to mark the distribution of raw data.

gray

FALSE grayscale or color plot

draw

TRUE returns a ggplot2 plot. FALSE returns a data.frame of the underlying data.

... Additional arguments are passed to the predict() method supplied by the modeling package. These arguments are particularly useful for mixed-effects or bayesian models (see the online vignettes on the marginaleffects website). Available arguments can vary from model to model, depending on the range of supported arguments by each modeling package. See the "Model-Specific Arguments" section of the ?marginaleffects documentation for a non-exhaustive list of available arguments.

Value

A ggplot2 object

Model-Specific Arguments

Some model types allow model-specific arguments to modify the nature of marginal effects, predictions, marginal means, and contrasts. Please report other package-specific predict() arguments on Github so we can add them to the table below.

https://github.com/vincentarelbundock/marginaleffects/issues

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<td>merMod</td>
<td>re.form</td>
<td>lme4::predict.merMod</td>
</tr>
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</table>
Examples

mod <- lm(mpg ~ hp * drat * factor(am), data = mtcars)
plot_comparisons(mod, variables = "hp", condition = "drat")
plot_comparisons(mod, variables = "hp", condition = c("drat", "am"))
plot_comparisons(mod, variables = "hp", condition = list("am", "drat" = 3:5))
plot_comparisons(mod, variables = "am", condition = list("hp", "drat" = range))
plot_comparisons(mod, variables = "am", condition = list("hp", "drat" = "threenum"))

Description

Plot predictions on the y-axis against values of one or more predictors (x-axis, colors/shapes, and facets).

The by argument is used to plot marginal predictions, that is, predictions made on the original data, but averaged by subgroups. This is analogous to using the by argument in the predictions() function.

The condition argument is used to plot conditional predictions, that is, predictions made on a user-specified grid. This is analogous to using the newdata argument anddatagrid() function in a predictions() call.

All unspecified variables are held at their mean or mode. This includes grouping variables in mixed-effects models, so analysts who fit such models may want to specify the groups of interest using the variables argument, or supply model-specific arguments to compute population-level estimates. See details below.

See the "Plots" vignette and website for tutorials and information on how to customize plots:

- https://marginaleffects.com/articles/plot.html
- https://marginaleffects.com
plot_predictions(  
  model,  
  condition = NULL,  
  by = NULL,  
  newdata = NULL,  
  type = NULL,  
  vcov = NULL,  
  conf_level = 0.95,  
  wts = NULL,  
  transform = NULL,  
  points = 0,  
  rug = FALSE,  
  gray = FALSE,  
  draw = TRUE,  
  ...  
)  

Arguments

model    Model object
condition Conditional predictions
  • Character vector (max length 3): Names of the predictors to display.
  • Named list (max length 3): List names correspond to predictors. List ele-
    ments can be:
    – Numeric vector
    – Function which returns a numeric vector or a set of unique categorical
      values
    – Shortcut strings for common reference values: "minmax", "quartile",  
      "threeunum"
  • 1: x-axis. 2: color/shape. 3: facets.
  • Numeric variables in positions 2 and 3 are summarized by Tukey's five  
    numbers ?stats::fivenum
by       Marginal predictions
  • Character vector (max length 3): Names of the categorical predictors to  
    marginalize across.
  • 1: x-axis. 2: color. 3: facets.
newdata  When newdata is NULL, the grid is determined by the condition argument.  
  When newdata is not NULL, the argument behaves in the same way as in the  
  predictions() function.
type     string indicates the type (scale) of the predictions used to compute contrasts or  
          slopes. This can differ based on the model type, but will typically be a string  
          such as: "response", "link", "probs", or "zero". When an unsupported string  
          is entered, the model-specific list of acceptable values is returned in an error  
          message. When type is NULL, the first entry in the error message is used by  
          default.
vcov
Type of uncertainty estimates to report (e.g., for robust standard errors). Acceptable values:
- FALSE: Do not compute standard errors. This can speed up computation considerably.
- TRUE: Unit-level standard errors using the default vcov(model) variance-covariance matrix.
- String which indicates the kind of uncertainty estimates to return.
  - Heteroskedasticity-consistent: "HC", "HC0", "HC1", "HC2", "HC3", "HC4", "HC4m", "HC5". See ?sandwich::vcovHC
  - Heteroskedasticity and autocorrelation consistent: "HAC"
  - Mixed-Models degrees of freedom: "satterthwaite", "kenward-roger"
  - Other: "NeweyWest", "KernHAC", "OPG". See the sandwich package documentation.
- One-sided formula which indicates the name of cluster variables (e.g., ~unit_id). This formula is passed to the cluster argument of the sandwich::vcovCL function.
- Square covariance matrix
- Function which returns a covariance matrix (e.g., stats::vcov(model))

conf_level
numeric value between 0 and 1. Confidence level to use to build a confidence interval.

wts
string or numeric: weights to use when computing average contrasts or slopes. These weights only affect the averaging in avg_*() or with the by argument, and not the unit-level estimates themselves. Internally, estimates and weights are passed to the weighted.mean() function.
- string: column name of the weights variable in newdata. When supplying a column name to wts, it is recommended to supply the original data (including the weights variable) explicitly to newdata.
- numeric: vector of length equal to the number of rows in the original data or in newdata (if supplied).

transform
A function applied to unit-level adjusted predictions and confidence intervals just before the function returns results. For bayesian models, this function is applied to individual draws from the posterior distribution, before computing summaries.

points
Number between 0 and 1 which controls the transparency of raw data points. 0 (default) does not display any points.

rug
TRUE displays tick marks on the axes to mark the distribution of raw data.

gray
FALSE grayscale or color plot

draw
TRUE returns a ggplot2 plot. FALSE returns a data.frame of the underlying data.

Additional arguments are passed to the predict() method supplied by the modeling package. These arguments are particularly useful for mixed-effects or bayesian models (see the online vignettes on the marginaleffects website). Available arguments can vary from model to model, depending on the range of supported arguments by each modeling package. See the "Model-Specific Arguments" section of the ?marginaleffects documentation for a non-exhaustive list of available arguments.
Value

A ggplot2 object or data frame (if draw=FALSE)

Model-Specific Arguments

Some model types allow model-specific arguments to modify the nature of marginal effects, predictions, marginal means, and contrasts. Please report other package-specific predict() arguments on Github so we can add them to the table below.

https://github.com/vincentarelbundock/marginaleffects/issues

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Examples

```r
mod <- lm(mpg ~ hp + wt, data = mtcars)
plot_predictions(mod, condition = "wt")
```

```r
mod <- lm(mpg ~ hp * wt * am, data = mtcars)
plot_predictions(mod, condition = c("hp", "wt"))
plot_predictions(mod, condition = list("hp", wt = "threenum"))
plot_predictions(mod, condition = list("hp", wt = range))
```

---

plot_slopes  

*Plot Conditional or Marginal Slopes*

Description

Plot slopes on the y-axis against values of one or more predictors (x-axis, colors/shapes, and facets). The by argument is used to plot marginal slopes, that is, slopes made on the original data, but averaged by subgroups. This is analogous to using the by argument in the slopes() function.
plot_slopes

The `condition` argument is used to plot conditional slopes, that is, slopes made on a user-specified grid. This is analogous to using the `newdata` argument and `datagrid()` function in a `slopes()` call.

All unspecified variables are held at their mean or mode. This includes grouping variables in mixed-effects models, so analysts who fit such models may want to specify the groups of interest using the `variables` argument, or supply model-specific arguments to compute population-level estimates. See details below. See the "Plots" vignette and website for tutorials and information on how to customize plots:

- [https://marginaleffects.com/articles/plot.html](https://marginaleffects.com/articles/plot.html)
- [https://marginaleffects.com](https://marginaleffects.com)

**Usage**

```r
plot_slopes(
  model, 
  variables = NULL, 
  condition = NULL, 
  by = NULL, 
  newdata = NULL, 
  type = "response", 
  vcov = NULL, 
  conf_level = 0.95, 
  wts = NULL, 
  slope = "dydx", 
  rug = FALSE, 
  gray = FALSE, 
  draw = TRUE, 
  ...
)
```

**Arguments**

- `model`: Model object
- `variables`: Name of the variable whose marginal effect (slope) we want to plot on the y-axis.
- `condition`: Conditional slopes
  - Character vector (max length 3): Names of the predictors to display.
  - Named list (max length 3): List names correspond to predictors. List elements can be:
    - Numeric vector
    - Function which returns a numeric vector or a set of unique categorical values
    - Shortcut strings for common reference values: "minmax", "quartile", "threenum"
  - 1: x-axis. 2: color/shape. 3: facets.
• Numeric variables in positions 2 and 3 are summarized by Tukey’s five numbers ?stats::fivenum.

by

Aggregate unit-level estimates (aka, marginalize, average over). Valid inputs:

• FALSE: return the original unit-level estimates.
• TRUE: aggregate estimates for each term.
• Character vector of column names in newdata or in the data frame produced by calling the function without the by argument.
• Data frame with a by column of group labels, and merging columns shared by newdata or the data frame produced by calling the same function without the by argument.
• See examples below.
• For more complex aggregations, you can use the FUN argument of the hypotheses() function. See that function’s documentation and the Hypothesis Test vignettes on the marginaleffects website.

newdata

When newdata is NULL, the grid is determined by the condition argument. When newdata is not NULL, the argument behaves in the same way as in the slopes() function.

type

string indicates the type (scale) of the predictions used to compute contrasts or slopes. This can differ based on the model type, but will typically be a string such as: "response", "link", "probs", or "zero". When an unsupported string is entered, the model-specific list of acceptable values is returned in an error message. When type is NULL, the first entry in the error message is used by default.

vcov

Type of uncertainty estimates to report (e.g., for robust standard errors). Acceptable values:

• FALSE: Do not compute standard errors. This can speed up computation considerably.
• TRUE: Unit-level standard errors using the default vcov(model) variance-covariance matrix.
• String which indicates the kind of uncertainty estimates to return.
  • Heteroskedasticity-consistent: "HC", "HC0", "HC1", "HC2", "HC3", "HC4", "HC4m", "HC5". See ?sandwich::vcovHC
  • Heteroskedasticity and autocorrelation consistent: "HAC"
  • Mixed-Models degrees of freedom: "satterthwaite", "kenward-roger"
  • Other: "NeweyWest", "KernHAC", "OPG". See the sandwich package documentation.
• One-sided formula which indicates the name of cluster variables (e.g., ~unit_id). This formula is passed to the cluster argument of the sandwich::vcovCL function.
• Square covariance matrix
• Function which returns a covariance matrix (e.g., stats::vcov(model))

cnf_level

numeric value between 0 and 1. Confidence level to use to build a confidence interval.
wts string or numeric: weights to use when computing average contrasts or slopes. These weights only affect the averaging in avg_*() or with the by argument, and not the unit-level estimates themselves. Internally, estimates and weights are passed to the weighted.mean() function.

- string: column name of the weights variable in newdata. When supplying a column name to wts, it is recommended to supply the original data (including the weights variable) explicitly to newdata.
- numeric: vector of length equal to the number of rows in the original data or in newdata (if supplied).

slope string indicates the type of slope or (semi-)elasticity to compute:

- "dydx": dY/dX
- "eyex": dY/dX * Y / X
- "eydx": dY/dX * Y
- "dyex": dY/dX / X

Y is the predicted value of the outcome; X is the observed value of the predictor.

rug TRUE displays tick marks on the axes to mark the distribution of raw data.

gray FALSE grayscale or color plot

draw TRUE returns a ggplot2 plot. FALSE returns a data.frame of the underlying data.

... Additional arguments are passed to the predict() method supplied by the modeling package. These arguments are particularly useful for mixed-effects or bayesian models (see the online vignettes on the marginaleffects website). Available arguments can vary from model to model, depending on the range of supported arguments by each modeling package. See the "Model-Specific Arguments" section of the marginaleffects documentation for a non-exhaustive list of available arguments.

Value

A ggplot2 object

Model-Specific Arguments

Some model types allow model-specific arguments to modify the nature of marginal effects, predictions, marginal means, and contrasts. Please report other package-specific predict() arguments on Github so we can add them to the table below.

https://github.com/vincentarelbundock/marginaleffects/issues

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</table>
Examples

library(marginaleffects)
mod <- lm(mpg ~ hp * drat * factor(am), data = mtcars)
plot_slopes(mod, variables = "hp", condition = "drat")
plot_slopes(mod, variables = "hp", condition = c("drat", "am"))
plot_slopes(mod, variables = "hp", condition = list("am", "drat" = 3:5))
plot_slopes(mod, variables = "am", condition = list("hp", "drat" = range))
plot_slopes(mod, variables = "am", condition = list("hp", "drat" = "threenum"))

Description

Extract Posterior Draws or Bootstrap Resamples from marginaleffects Objects

Usage

posterior_draws(x, shape = "long")

Arguments

x An object produced by a marginaleffects package function, such as predictions(), avg_slopes(), hypotheses(), etc.
shape string indicating the shape of the output format:
  • "long": long format data frame
  • "DxP": Matrix with draws as rows and parameters as columns
  • "PxD": Matrix with draws as rows and parameters as columns
  • "rvar": Random variable datatype (see posterior package documentation).

Value

A data.frame with drawid and draw columns.
predictions

Description

Outcome predicted by a fitted model on a specified scale for a given combination of values of the predictor variables, such as their observed values, their means, or factor levels (a.k.a. "reference grid").

- predictions(): unit-level (conditional) estimates.
- avg_predictions(): average (marginal) estimates.

The newdata argument and thedatagrid() function can be used to control where statistics are evaluated in the predictor space: "at observed values", "at the mean", "at representative values", etc.

See the predictions vignette and package website for worked examples and case studies:

- https://marginaleffects.com/articles/predictions.html
- https://marginaleffects.com/

Usage

predictions(
  model,
  newdata = NULL,
  variables = NULL,
  vcov = TRUE,
  conf_level = 0.95,
  type = NULL,
  by = FALSE,
  byfun = NULL,
  wts = NULL,
  transform = NULL,
  hypothesis = NULL,
  equivalence = NULL,
  p_adjust = NULL,
  df = Inf,
  numderiv = "fdforward",
  ...
)

avg_predictions(
  model,
  newdata = NULL,
  variables = NULL,
  vcov = TRUE,
  conf_level = 0.95,
  type = NULL,
by = TRUE,
byfun = NULL,
wts = NULL,
transform = NULL,
hypothesis = NULL,
equivalence = NULL,
p_adjust = NULL,
df = Inf,
numderiv = "fdforward",
...)

Arguments

model

Model object

newdata

Grid of predictor values at which we evaluate predictions.

- Warning: Please avoid modifying your dataset between fitting the model and calling a `marginaleffects` function. This can sometimes lead to unexpected results.
- NULL (default): Unit-level predictions for each observed value in the dataset (empirical distribution). The dataset is retrieved using `insight::get_data()`, which tries to extract data from the environment. This may produce unexpected results if the original data frame has been altered since fitting the model.
- string:
  - "mean": Predictions at the Mean. Predictions when each predictor is held at its mean or mode.
  - "median": Predictions at the Median. Predictions when each predictor is held at its median or mode.
  - "marginalmeans": Predictions at Marginal Means. See Details section below.
  - "tukey": Predictions at Tukey’s 5 numbers.
  - "grid": Predictions on a grid of representative numbers (Tukey’s 5 numbers and unique values of categorical predictors).

- `datagrid()` call to specify a custom grid of regressors. For example:
  - `newdata = datagrid(cyl = c(4, 6))`: cyl variable equal to 4 and 6 and other regressors fixed at their means or modes.

variables

Counterfactual variables.

- Output:
  - `predictions()`: The entire dataset is replicated once for each unique combination of `variables`, and predictions are made.
  - `avg_predictions()`: The entire dataset is replicated, predictions are made, and they are marginalized by `variables` categories.
  - Warning: This can be expensive in large datasets.
– Warning: Users who need "conditional" predictions should use the newdata argument instead of variables.

• Input:
  – NULL: computes one prediction per row of newdata
  – Character vector: the dataset is replicated once of every combination of unique values of the variables identified in variables.
  – Named list: names identify the subset of variables of interest and their values. For numeric variables, the variables argument supports functions and string shortcuts:
    * A function which returns a numeric value
    * Numeric vector: Contrast between the 2nd element and the 1st element of the x vector.
    * "iqr": Contrast across the interquartile range of the regressor.
    * "sd": Contrast across one standard deviation around the regressor mean.
    * "2sd": Contrast across two standard deviations around the regressor mean.
    * "minmax": Contrast between the maximum and the minimum values of the regressor.
    * "threenum": mean and 1 standard deviation on both sides
    * "fivenum": Tukey’s five numbers

vcov
Type of uncertainty estimates to report (e.g., for robust standard errors). Acceptable values:

• FALSE: Do not compute standard errors. This can speed up computation considerably.
• TRUE: Unit-level standard errors using the default vcov(model) variance-covariance matrix.
• String which indicates the kind of uncertainty estimates to return.
  – Heteroskedasticity-consistent: "HC", "HC0", "HC1", "HC2", "HC3", "HC4", "HC4m", "HC5". See ?sandwich::vcovHC
  – Heteroskedasticity and autocorrelation consistent: "HAC"
  – Mixed-Models degrees of freedom: "satterthwaite", "kenward-roger"
  – Other: "NeweyWest", "KernHAC", "OPG". See the sandwich package documentation.
• One-sided formula which indicates the name of cluster variables (e.g., ~unit_id). This formula is passed to the cluster argument of the sandwich::vcovCL function.
• Square covariance matrix
• Function which returns a covariance matrix (e.g., stats::vcov(model))

conf_level
numeric value between 0 and 1. Confidence level to use to build a confidence interval.

type
string indicates the type (scale) of the predictions used to compute contrasts or slopes. This can differ based on the model type, but will typically be a string such as: "response", "link", "probs", or "zero". When an unsupported string
is entered, the model-specific list of acceptable values is returned in an error message. When type is NULL, the first entry in the error message is used by default.

by

Aggregate unit-level estimates (aka, marginalize, average over). Valid inputs:

- FALSE: return the original unit-level estimates.
- TRUE: aggregate estimates for each term.
- Character vector of column names in newdata or in the data frame produced by calling the function without the by argument.
- Data frame with a by column of group labels, and merging columns shared by newdata or the data frame produced by calling the same function without the by argument.
- See examples below.
- For more complex aggregations, you can use the FUN argument of the hypotheses() function. See that function’s documentation and the Hypothesis Test vignettes on the marginaleffects website.

bypun

A function such as mean() or sum() used to aggregate estimates within the subgroups defined by the by argument. NULL uses the mean() function. Must accept a numeric vector and return a single numeric value. This is sometimes used to take the sum or mean of predicted probabilities across outcome or predictor levels. See examples section.

wts

string or numeric: weights to use when computing average contrasts or slopes. These weights only affect the averaging in avg_*() or with the by argument, and not the unit-level estimates themselves. Internally, estimates and weights are passed to the weighted.mean() function.

- string: column name of the weights variable in newdata. When supplying a column name to wts, it is recommended to supply the original data (including the weights variable) explicitly to newdata.
- numeric: vector of length equal to the number of rows in the original data or in newdata (if supplied).

transform

A function applied to unit-level adjusted predictions and confidence intervals just before the function returns results. For bayesian models, this function is applied to individual draws from the posterior distribution, before computing summaries.

hypothesis

specify a hypothesis test or custom contrast using a numeric value, vector, or matrix, a string, or a string formula.

- Numeric:
  - Single value: the null hypothesis used in the computation of Z and p (before applying transform).
  - Vector: Weights to compute a linear combination of (custom contrast between) estimates. Length equal to the number of rows generated by the same function call, but without the hypothesis argument.
  - Matrix: Each column is a vector of weights, as describe above, used to compute a distinct linear combination of (contrast between) estimates. The column names of the matrix are used as labels in the output.
• String formula to specify linear or non-linear hypothesis tests. If the term column uniquely identifies rows, terms can be used in the formula. Otherwise, use b1, b2, etc. to identify the position of each parameter. The b* wildcard can be used to test hypotheses on all estimates. Examples:
  – hp = drat
  – hp + drat = 12
  – b1 + b2 + b3 = 0
  – b* / b1 = 1
• String:
  – "pairwise": pairwise differences between estimates in each row.
  – "reference": differences between the estimates in each row and the estimate in the first row.
  – "sequential": difference between an estimate and the estimate in the next row.
  – "revpairwise", "revreference", "resequential": inverse of the corresponding hypotheses, as described above.
• See the Examples section below and the vignette: https://marginaleffects.com/articles/hypothesis.html

**equivalence**
Numerical vector of length 2: bounds used for the two-one-sided test (TOST) of equivalence, and for the non-inferiority and non-superiority tests. See Details section below.

**p_adjust**
Adjust p-values for multiple comparisons: "holm", "hochberg", "hommel", "bonferroni", "BH", "BY", or "fdr". See stats::p.adjust

**df**
Degrees of freedom used to compute p values and confidence intervals. A single numeric value between 1 and Inf. When df is Inf, the normal distribution is used. When df is finite, the t distribution is used. See insight::get_df for a convenient function to extract degrees of freedom. Ex: slopes(model, df = insight::get_df(model))

**numderiv**
string or list of strings indicating the method to use to for the numeric differentiation used in to compute delta method standard errors.
  • "fdforward": finite difference method with forward differences
  • "fdcenter": finite difference method with central differences (default)
  • "richardson": Richardson extrapolation method
  • Extra arguments can be specified by passing a list to the numDeriv argument, with the name of the method first and named arguments following, ex: numderiv=list("fdcenter", eps = 1e-5). When an unknown argument is used, marginaleffects prints the list of valid arguments for each method.

... Additional arguments are passed to the predict() method supplied by the modeling package. These arguments are particularly useful for mixed-effects or bayesian models (see the online vignettes on the marginaleffects website). Available arguments can vary from model to model, depending on the range of supported arguments by each modeling package. See the "Model-Specific Arguments" section of the ?marginaleffects documentation for a non-exhaustive list of available arguments.
Value

A `data.frame` with one row per observation and several columns:

- **rowid**: row number of the `newdata` data frame
- **type**: prediction type, as defined by the `type` argument
- **group**: (optional) value of the grouped outcome (e.g., categorical outcome models)
- **estimate**: predicted outcome
- **std.error**: standard errors computed using the delta method.
- **p.value**: p value associated to the `estimate` column. The null is determined by the `hypothesis` argument (0 by default), and p values are computed before applying the `transform` argument. For models of class `feglm`, `Gam`, `glm` and `negbin`, p values are computed on the link scale by default unless the `type` argument is specified explicitly.
- **s.value**: Shannon information transforms of p values. How many consecutive "heads" tosses would provide the same amount of evidence (or "surprise") against the null hypothesis that the coin is fair? The purpose of S is to calibrate the analyst’s intuition about the strength of evidence encoded in p against a well-known physical phenomenon. See Greenland (2019) and Cole et al. (2020).
- **conf.low**: lower bound of the confidence interval (or equal-tailed interval for bayesian models)
- **conf.high**: upper bound of the confidence interval (or equal-tailed interval for bayesian models)

See `?print.marginaleffects` for printing options.

Functions

- `avg_predictions()`: Average predictions

Standard errors using the delta method

Standard errors for all quantities estimated by `marginaleffects` can be obtained via the delta method. This requires differentiating a function with respect to the coefficients in the model using a finite difference approach. In some models, the delta method standard errors can be sensitive to various aspects of the numeric differentiation strategy, including the step size. By default, the step size is set to $1e^{-8}$, or to $1e^{-4}$ times the smallest absolute model coefficient, whichever is largest.

`marginaleffects` can delegate numeric differentiation to the `numDeriv` package, which allows more flexibility. To do this, users can pass arguments to the `numDeriv::jacobian` function through a global option. For example:

- `options(marginaleffects_numDeriv = list(method = "simple", method.args = list(eps = 1e-6)))`
- `options(marginaleffects_numDeriv = list(method = "Richardson", method.args = list(eps = 1e-5)))`
- `options(marginaleffects_numDeriv = NULL)`
See the "Standard Errors and Confidence Intervals" vignette on the marginaleffects website for more details on the computation of standard errors:
https://marginaleffects.com/articles/uncertainty.html

Note that the inferences() function can be used to compute uncertainty estimates using a bootstrap or simulation-based inference. See the vignette:
https://marginaleffects.com/articles/bootstrap.html

**Model-Specific Arguments**

Some model types allow model-specific arguments to modify the nature of marginal effects, predictions, marginal means, and contrasts. Please report other package-specific predict() arguments on Github so we can add them to the table below.

https://github.com/vincentarelbundock/marginaleffects/issues

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**Bayesian posterior summaries**

By default, credible intervals in bayesian models are built as equal-tailed intervals. This can be changed to a highest density interval by setting a global option:

options("marginaleffects_posterior_interval" = "eti")

options("marginaleffects_posterior_interval" = "hdi")

By default, the center of the posterior distribution in bayesian models is identified by the median. Users can use a different summary function by setting a global option:

options("marginaleffects_posterior_center" = "mean")

options("marginaleffects_posterior_center" = "median")

When estimates are averaged using the by argument, the tidy() function, or the summary() function, the posterior distribution is marginalized twice over. First, we take the average across units but within each iteration of the MCMC chain, according to what the user requested in by argument or tidy()/summary() functions. Then, we identify the center of the resulting posterior using the function supplied to the "marginaleffects_posterior_center" option (the median by default).
Equivalence, Inferiority, Superiority

θ is an estimate, σθ its estimated standard error, and [a, b] are the bounds of the interval supplied to the equivalence argument.

Non-inferiority:

• \( H_0: \theta \leq a \)
• \( H_1: \theta > a \)
• \( t = (\theta - a)/\sigma_\theta \)
• p: Upper-tail probability

Non-superiority:

• \( H_0: \theta \geq b \)
• \( H_1: \theta < b \)
• \( t = (\theta - b)/\sigma_\theta \)
• p: Lower-tail probability

Equivalence: Two One-Sided Tests (TOST)

• p: Maximum of the non-inferiority and non-superiority p values.

Thanks to Russell V. Lenth for the excellent emmeans package and documentation which inspired this feature.

Prediction types

The type argument determines the scale of the predictions used to compute quantities of interest with functions from the marginaleffects package. Admissible values for type depend on the model object. When users specify an incorrect value for type, marginaleffects will raise an informative error with a list of valid type values for the specific model object. The first entry in the list in that error message is the default type.

The invlink(link) is a special type defined by marginaleffects. It is available for some (but not all) models and functions. With this link type, we first compute predictions on the link scale, then we use the inverse link function to backtransform the predictions to the response scale. This is useful for models with non-linear link functions as it can ensure that confidence intervals stay within desirable bounds, ex: 0 to 1 for a logit model. Note that an average of estimates with type="invlink(link)" will not always be equivalent to the average of estimates with type="response".

Some of the most common type values are:

response, link, E, Ep, average, class, conditional, count, cum.prob, cumprob, density, disp, expected, expvalue, fitted, invlink(link), latent, linear.predictor, linpred, location, lp, mean, numeric, p, pr, precision, prediction, prob, probability, probs, quantile, risk, scale, survival, unconditional, utility, variance, xb, zero, zlink, zprob
References


Examples

```r
## Not run:
# Adjusted Prediction for every row of the original dataset
mod <- lm(mpg ~ hp + factor(cyl), data = mtcars)
pred <- predictions(mod)
head(pred)

# Adjusted Predictions at User-Specified Values of the Regressors
predictions(mod, newdata = datagrid(hp = c(100, 120), cyl = 4))

m <- lm(mpg ~ hp + drat + factor(cyl) + factor(am), data = mtcars)
predictions(m, newdata = datagrid(FUN_factor = unique, FUN_numeric = median))

# Average Adjusted Predictions (AAP)
library(dplyr)
mod <- lm(mpg ~ hp * am * vs, mtcars)
avg_predictions(mod)

# Conditional Adjusted Predictions
plot_predictions(mod, condition = "hp")

# Counterfactual predictions with the `variables` argument
# the `mtcars` dataset has 32 rows
mod <- lm(mpg ~ hp + am, data = mtcars)
p <- predictions(mod)
head(p)
nrow(p)

# average counterfactual predictions
avg_predictions(mod, variables = "am")

# counterfactual predictions obtained by replicating the entire for different
# values of the predictors
p <- predictions(mod, variables = list(hp = c(90, 110)))
nrow(p)

# hypothesis test: is the prediction in the 1st row equal to the prediction in the 2nd row
mod <- lm(mpg ~ wt + drat, data = mtcars)
```
predictions(
    mod,
    newdata = datagrid(wt = 2:3),
    hypothesis = "b1 = b2")

# same hypothesis test using row indices
predictions(
    mod,
    newdata = datagrid(wt = 2:3),
    hypothesis = "b1 - b2 = 0")

# same hypothesis test using numeric vector of weights
predictions(
    mod,
    newdata = datagrid(wt = 2:3),
    hypothesis = c(1, -1))

# two custom contrasts using a matrix of weights
lc <- matrix(c(
    1, -1,
    2, 3),
    ncol = 2)
predictions(
    mod,
    newdata = datagrid(wt = 2:3),
    hypothesis = lc)

# 'by' argument
mod <- lm(mpg ~ hp * am * vs, data = mtcars)
predictions(mod, by = c("am", "vs"))

library(nnet)
nom <- multinom(factor(gear) ~ mpg + am * vs, data = mtcars, trace = FALSE)

# first 5 raw predictions
predictions(nom, type = "probs") |> head()

# average predictions
avg_predictions(nom, type = "probs", by = "group")

by <- data.frame(
    group = c("3", "4", "5"),
    by = c("3,4", "3,4", "5"))
predictions(nom, type = "probs", by = by)

# sum of predicted probabilities for combined response levels
mod <- multinom(factor(cyl) ~ mpg + am, data = mtcars, trace = FALSE)
by <- data.frame(
    by = c("4,6", "4,6", "8"),
    group = as.character(c(4, 6, 8)))
print.marginaleffects  Print marginaleffects objects

Description

This function controls the text which is printed to the console when one of the core marginaleffects functions is called and the object is returned: predictions(), comparisons(), slopes(), marginal_means(), hypotheses(), avg_predictions(), avg_comparisons(), avg_slopes().

All of those functions return standard data frames. Columns can be extracted by name, predictions(model)$estimate, and all the usual data manipulation functions work out-of-the-box: colnames(), head(), subset(), dplyr::filter(), dplyr::arrange(), etc.

Some of the data columns are not printed by default. You can disable pretty printing and print the full results as a standard data frame using the style argument or by applying as.data.frame() on the object. See examples below.

Usage

## S3 method for class 'marginaleffects'
print(
  x,
  digits = getOption("marginaleffects_print_digits", default = 3),
  p_eps = getOption("marginaleffects_print_p_eps", default = 0.001),
  topn = getOption("marginaleffects_print_topn", default = 5),
  nrows = getOption("marginaleffects_print_nrows", default = 30),
  ncols = getOption("marginaleffects_print_ncols", default = 30),
  style = getOption("marginaleffects_print_style", default = "summary"),
  type = getOption("marginaleffects_print_type", default = TRUE),
  column_names = getOption("marginaleffects_print_column_names", default = TRUE),
  ...
)

Arguments

x  
An object produced by one of the marginaleffects package functions.

digits  
The number of digits to display.

p_eps  
p values smaller than this number are printed in "<0.001" style.

topn  
The number of rows to be printed from the beginning and end of tables with more than nrows rows.

nrows  
The number of rows which will be printed before truncation.

ncols  
The maximum number of column names to display at the bottom of the printed output.
slopes

**Description**

Partial derivative of the regression equation with respect to a regressor of interest.

- `slopes()`: unit-level (conditional) estimates.
- `avg_slopes()`: average (marginal) estimates.

The `newdata` argument and the `datagrid()` function can be used to control where statistics are evaluated in the predictor space: "at observed values", "at the mean", "at representative values", etc.

See the `slopes` vignette and package website for worked examples and case studies:

- [https://marginaleffects.com/articles/slopes.html](https://marginaleffects.com/articles/slopes.html)
- [https://marginaleffects.com/](https://marginaleffects.com/)

**Usage**

```r
slopes(
  model,  # model
  newdata = NULL,  # newdata
  variables = NULL,  # variables
  type = NULL,  # type
  by = FALSE,  # by
  vcov = TRUE,  # vcov
  conf_level = 0.95,  # confidence level
  slope = "dydx",  # slope
)```
slopes

wts = NULL,
hypothesis = NULL,
equivalence = NULL,
p_adjust = NULL,
df = Inf,
eps = NULL,
numderiv = "fdforward",
...
)

avg_slopes(
  model,
  newdata = NULL,
  variables = NULL,
  type = NULL,
  by = TRUE,
  vcov = TRUE,
  conf_level = 0.95,
  slope = "dydx",
  wts = NULL,
  hypothesis = NULL,
  equivalence = NULL,
  p_adjust = NULL,
  df = Inf,
  eps = NULL,
  numderiv = "fdforward",
  ...
)

Arguments

model                     Model object
newdata                   Grid of predictor values at which we evaluate the slopes.

• Warning: Please avoid modifying your dataset between fitting the model and calling a `marginaleffects` function. This can sometimes lead to unexpected results.
• NULL (default): Unit-level slopes for each observed value in the dataset (empirical distribution). The dataset is retrieved using `insight::get_data()`, which tries to extract data from the environment. This may produce unexpected results if the original data frame has been altered since fitting the model.
• `datagrid()` call to specify a custom grid of regressors. For example:
  - newdata = `datagrid(cyl = c(4, 6))`: cyl variable equal to 4 and 6 and other regressors fixed at their means or modes.
  - See the Examples section and the `datagrid()` documentation.
• string:
  - "mean": Marginal Effects at the Mean. Slopes when each predictor is held at its mean or mode.
slopes

- "median": Marginal Effects at the Median. Slopes when each predictor is held at its median or mode.
- "marginalmeans": Marginal Effects at Marginal Means. See Details section below.
- "tukey": Marginal Effects at Tukey’s 5 numbers.
- "grid": Marginal Effects on a grid of representative numbers (Tukey’s 5 numbers and unique values of categorical predictors).

variables

Focal variables

- **NULL**: compute slopes or comparisons for all the variables in the model object (can be slow).
- Character vector: subset of variables (usually faster).

**type**

string indicates the type (scale) of the predictions used to compute contrasts or slopes. This can differ based on the model type, but will typically be a string such as: "response", "link", "probs", or "zero". When an unsupported string is entered, the model-specific list of acceptable values is returned in an error message. When type is **NULL**, the first entry in the error message is used by default.

by

Aggregate unit-level estimates (aka, marginalize, average over). Valid inputs:

- **FALSE**: return the original unit-level estimates.
- **TRUE**: aggregate estimates for each term.
- Character vector of column names in newdata or in the data frame produced by calling the function without the by argument.
- Data frame with a by column of group labels, and merging columns shared by newdata or the data frame produced by calling the same function without the by argument.
- See examples below.
- For more complex aggregations, you can use the **FUN** argument of the hypotheses() function. See that function’s documentation and the Hypothesis Test vignettes on the marginaleffects website.

vcov

Type of uncertainty estimates to report (e.g., for robust standard errors). Acceptable values:

- **FALSE**: Do not compute standard errors. This can speed up computation considerably.
- **TRUE**: Unit-level standard errors using the default vcov(model) variance-covariance matrix.
- String which indicates the kind of uncertainty estimates to return.
  - Heteroskedasticity-consistent: "HC", "HC0", "HC1", "HC2", "HC3", "HC4", "HC4m", "HC5". See `?sandwich::vcovHC`
  - Heteroskedasticity and autocorrelation consistent: "HAC"
  - Mixed-Models degrees of freedom: "satterthwaite", "kenward-roger"
  - Other: "NeweyWest", "KernHAC", "OPG". See the sandwich package documentation.
- One-sided formula which indicates the name of cluster variables (e.g., ~unit_id). This formula is passed to the cluster argument of the sandwich::vcovCL function.
• Square covariance matrix
• Function which returns a covariance matrix (e.g., \texttt{stats::vcov(model)})

\textbf{conf\_level} numeric value between 0 and 1. Confidence level to use to build a confidence interval.

\textbf{slope} string indicates the type of slope or (semi-)elasticity to compute:
• "dydx": \( \frac{dY}{dX} \)
• "eyex": \( \frac{dY}{dX} \times \frac{Y}{X} \)
• "eydx": \( \frac{dY}{dX} \times Y \)
• "dyex": \( \frac{dY}{dX} \div X \)

• \( Y \) is the predicted value of the outcome; \( X \) is the observed value of the predictor.

\textbf{wts} string or numeric: weights to use when computing average contrasts or slopes. These weights only affect the averaging in \texttt{avg\_\*()} or with the by argument, and not the unit-level estimates themselves. Internally, estimates and weights are passed to the \texttt{weighted.mean()} function.
• string: column name of the weights variable in \texttt{newdata}. When supplying a column name to \texttt{wts}, it is recommended to supply the original data (including the weights variable) explicitly to \texttt{newdata}.
• numeric: vector of length equal to the number of rows in the original data or in \texttt{newdata} (if supplied).

\textbf{hypothesis} specify a hypothesis test or custom contrast using a numeric value, vector, or matrix, a string, or a string formula.
• Numeric:
  – Single value: the null hypothesis used in the computation of \( Z \) and \( p \) (before applying \texttt{transform}).
  – Vector: Weights to compute a linear combination of (custom contrast between) estimates. Length equal to the number of rows generated by the same function call, but without the \texttt{hypothesis} argument.
  – Matrix: Each column is a vector of weights, as describe above, used to compute a distinct linear combination of (contrast between) estimates. The column names of the matrix are used as labels in the output.
• String formula to specify linear or non-linear hypothesis tests. If the term column uniquely identifies rows, terms can be used in the formula. Otherwise, use \texttt{b1}, \texttt{b2}, etc. to identify the position of each parameter. The \texttt{b*} wildcard can be used to test hypotheses on all estimates. Examples:
  – \texttt{hp = drat}
  – \texttt{hp + drat = 12}
  – \texttt{b1 + b2 + b3 = 0}
  – \texttt{b* / b1 = 1}
• String:
  – "pairwise": pairwise differences between estimates in each row.
  – "reference": differences between the estimates in each row and the estimate in the first row.
- "sequential": difference between an estimate and the estimate in the next row.
- "revpairwise", "revreference", "revsequential": inverse of the corresponding hypotheses, as described above.

- See the Examples section below and the vignette: https://marginaleffects.com/articles/hypothesis.html

**equivalence**
Numeric vector of length 2: bounds used for the two-one-sided test (TOST) of equivalence, and for the non-inferiority and non-superiority tests. See Details section below.

**p_adjust**
Adjust p-values for multiple comparisons: "holm", "hochberg", "hommel", "bonferroni", "BH", "BY", or "fdr". See stats::p.adjust

**df**
Degrees of freedom used to compute p values and confidence intervals. A single numeric value between 1 and Inf. When df is Inf, the normal distribution is used. When df is finite, the t distribution is used. See insight::get_df for a convenient function to extract degrees of freedom. Ex: slopes(model, df = insight::get_df(model))

**eps**
NULL or numeric value which determines the step size to use when calculating numerical derivatives: \((f(x+\varepsilon)-f(x))/\varepsilon\). When eps is NULL, the step size is 0.0001 multiplied by the difference between the maximum and minimum values of the variable with respect to which we are taking the derivative. Changing eps may be necessary to avoid numerical problems in certain models.

**numderiv**
String or list of strings indicating the method to use to for the numeric differentiation used in to compute delta method standard errors.

- "fdforward": finite difference method with forward differences
- "fdcenter": finite difference method with central differences (default)
- "richardson": Richardson extrapolation method

- Extra arguments can be specified by passing a list to the numDeriv argument, with the name of the method first and named arguments following, ex: numderiv=list("fdcenter", eps = 1e-5). When an unknown argument is used, marginaleffects prints the list of valid arguments for each method.

... Additional arguments are passed to the predict() method supplied by the modeling package. These arguments are particularly useful for mixed-effects or bayesian models (see the online vignettes on the marginaleffects website). Available arguments can vary from model to model, depending on the range of supported arguments by each modeling package. See the "Model-Specific Arguments" section of the ?marginaleffects documentation for a non-exhaustive list of available arguments.

**Details**
A "slope" or "marginal effect" is the partial derivative of the regression equation with respect to a variable in the model. This function uses automatic differentiation to compute slopes for a vast array of models, including non-linear models with transformations (e.g., polynomials). Uncertainty estimates are computed using the delta method.

Numerical derivatives for the slopes function are calculated using a simple epsilon difference approach: \(\partial Y / \partial X = (f(X + \varepsilon/2) - f(X - \varepsilon/2))/\varepsilon\), where \(f\) is the predict() method associated with the model class, and \(\varepsilon\) is determined by the eps argument.
slopes

Value

A data.frame with one row per observation (per term/group) and several columns:

- **rowid**: row number of the newdata data frame
- **type**: prediction type, as defined by the type argument
- **group**: (optional) value of the grouped outcome (e.g., categorical outcome models)
- **term**: the variable whose marginal effect is computed
- **dydx**: slope of the outcome with respect to the term, for a given combination of predictor values
- **std.error**: standard errors computed by via the delta method.
- **p.value**: p value associated to the estimate column. The null is determined by the hypothesis argument (0 by default), and p values are computed before applying the transform argument. For models of class feglm, Gam, glm and negbin, p values are computed on the link scale by default unless the type argument is specified explicitly.
- **s.value**: Shannon information transforms of p values. How many consecutive "heads" tosses would provide the same amount of evidence (or "surprise") against the null hypothesis that the coin is fair? The purpose of S is to calibrate the analyst’s intuition about the strength of evidence encoded in p against a well-known physical phenomenon. See Greenland (2019) and Cole et al. (2020).
- **conf.low**: lower bound of the confidence interval (or equal-tailed interval for bayesian models)
- **conf.high**: upper bound of the confidence interval (or equal-tailed interval for bayesian models)

See ?print.marginaleffects for printing options.

Functions

- **avg_slopes()**: Average slopes

Standard errors using the delta method

Standard errors for all quantities estimated by marginaleffects can be obtained via the delta method. This requires differentiating a function with respect to the coefficients in the model using a finite difference approach. In some models, the delta method standard errors can be sensitive to various aspects of the numeric differentiation strategy, including the step size. By default, the step size is set to 1e-8, or to 1e-4 times the smallest absolute model coefficient, whichever is largest.

marginaleffects can delegate numeric differentiation to the numDeriv package, which allows more flexibility. To do this, users can pass arguments to the numDeriv::jacobian function through a global option. For example:

- **options(marginaleffects_numDeriv = list(method = "simple", method.args = list(eps = 1e-6)))**
- **options(marginaleffects_numDeriv = list(method = "Richardson", method.args = list(eps = 1e-5)))**
- **options(marginaleffects_numDeriv = NULL)**
See the "Standard Errors and Confidence Intervals" vignette on the marginaleffects website for more details on the computation of standard errors:
https://marginaleffects.com/articles/uncertainty.html

Note that the `inferences()` function can be used to compute uncertainty estimates using a bootstrap or simulation-based inference. See the vignette:
https://marginaleffects.com/articles/bootstrap.html

**Model-Specific Arguments**

Some model types allow model-specific arguments to modify the nature of marginal effects, predictions, marginal means, and contrasts. Please report other package-specific `predict()` arguments on Github so we can add them to the table below.

https://github.com/vincentarelbundock/marginaleffects/issues

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**Bayesian posterior summaries**

By default, credible intervals in bayesian models are built as equal-tailed intervals. This can be changed to a highest density interval by setting a global option:

```r
options("marginaleffects_posterior_interval" = "etri")
options("marginaleffects_posterior_interval" = "hdi")
```

By default, the center of the posterior distribution in bayesian models is identified by the median. Users can use a different summary function by setting a global option:

```r
options("marginaleffects_posterior_center" = "mean")
options("marginaleffects_posterior_center" = "median")
```

When estimates are averaged using the `by` argument, the `tidy()` function, or the `summary()` function, the posterior distribution is marginalized twice over. First, we take the average across units but *within* each iteration of the MCMC chain, according to what the user requested in `by` argument or `tidy()`/`summary()` functions. Then, we identify the center of the resulting posterior using the function supplied to the "marginaleffects_posterior_center" option (the median by default).
Equivalence, Inferiority, Superiority

θ is an estimate, \( \sigma_\theta \) its estimated standard error, and \([a, b]\) are the bounds of the interval supplied to the equivalence argument.

Non-inferiority:

- \( H_0: \theta \leq a \)
- \( H_1: \theta > a \)
- \( t = (\theta - a)/\sigma_\theta \)
- \( p: \) Upper-tail probability

Non-superiority:

- \( H_0: \theta \geq b \)
- \( H_1: \theta < b \)
- \( t = (\theta - b)/\sigma_\theta \)
- \( p: \) Lower-tail probability

Equivalence: Two One-Sided Tests (TOST)

- \( p: \) Maximum of the non-inferiority and non-superiority \( p \) values.

Thanks to Russell V. Lenth for the excellent \texttt{emmeans} package and documentation which inspired this feature.

Prediction types

The \texttt{type} argument determines the scale of the predictions used to compute quantities of interest with functions from the \texttt{marginaleffects} package. Admissible values for \texttt{type} depend on the model object. When users specify an incorrect value for \texttt{type}, \texttt{marginaleffects} will raise an informative error with a list of valid \texttt{type} values for the specific model object. The first entry in the list in that error message is the default type.

The \texttt{invlink(link)} is a special type defined by \texttt{marginaleffects}. It is available for some (but not all) models and functions. With this link type, we first compute predictions on the link scale, then we use the inverse link function to backtransform the predictions to the response scale. This is useful for models with non-linear link functions as it can ensure that confidence intervals stay within desirable bounds, \texttt{ex: 0 to 1} for a logit model. Note that an average of estimates with \texttt{type=“invlink(link)"} will not always be equivalent to the average of estimates with \texttt{type=“response”}.

Some of the most common \texttt{type} values are:

- \texttt{response}, \texttt{link}, \texttt{E}, \texttt{Ep}, \texttt{average}, \texttt{class}, \texttt{conditional}, \texttt{count}, \texttt{cum.prob}, \texttt{cumprob}, \texttt{density}, \texttt{disp}, \texttt{expected}, \texttt{expvalue}, \texttt{fitted}, \texttt{invlink(link)}, \texttt{latent}, \texttt{linear.predictor}, \texttt{linpred}, \texttt{location}, \texttt{lp}, \texttt{mean}, \texttt{numeric}, \texttt{p}, \texttt{pr}, \texttt{precision}, \texttt{prediction}, \texttt{prob}, \texttt{probability}, \texttt{probs}, \texttt{quantile}, \texttt{risk}, \texttt{scale}, \texttt{survival}, \texttt{unconditional}, \texttt{utility}, \texttt{variance}, \texttt{xb}, \texttt{zero}, \texttt{zlink}, \texttt{zprob}
References


Examples

```r
## Not run:

# Unit-level (conditional) Marginal Effects
mod <- glm(am ~ hp * wt, data = mtcars, family = binomial)
mfx <- slopes(mod)
head(mfx)

# Average Marginal Effect (AME)
avg_slopes(mod, by = TRUE)

# Marginal Effect at the Mean (MEM)
slopes(mod, newdata = datagrid())

# Marginal Effect at User-Specified Values
# Variables not explicitly included in `datagrid()` are held at their means
slopes(mod, newdata = datagrid(hp = c(100, 110)))

# Group-Average Marginal Effects (G-AME)
# Calculate marginal effects for each observation, and then take the average
# marginal effect within each subset of observations with different observed
# values for the `cyl` variable:
mod2 <- lm(mpg ~ hp * cyl, data = mtcars)
avg_slopes(mod2, variables = "hp", by = "cyl")

# Marginal Effects at User-Specified Values (counterfactual)
# Variables not explicitly included in `datagrid()` are held at their
# original values, and the whole dataset is duplicated once for each
# combination of the values in `datagrid()`
mfx <- slopes(mod,
  newdata = datagrid(hp = c(100, 110),
                    grid_type = "counterfactual"))
head(mfx)

# Heteroskedasticity robust standard errors
mfx <- slopes(mod, vcov = sandwich::vcovHC(mod))
head(mfx)

# hypothesis test: is the `hp` marginal effect at the mean equal to the `drat` marginal effect
mod <- lm(mpg ~ wt + drat, data = mtcars)
```
```r
slopes(
  mod,
  newdata = "mean",
  hypothesis = "wt = drat"
)

# same hypothesis test using row indices
slopes(
  mod,
  newdata = "mean",
  hypothesis = "b1 - b2 = 0"
)

# same hypothesis test using numeric vector of weights
slopes(
  mod,
  newdata = "mean",
  hypothesis = c(1, -1))

# two custom contrasts using a matrix of weights
lc <- matrix(c(
  1, -1,
  2, 3),
  ncol = 2)
colnames(lc) <- c("Contrast A", "Contrast B")
slopes(
  mod,
  newdata = "mean",
  hypothesis = lc)

## End(Not run)
```
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