

Regression Functions Supported by the **effects** Package And How to Support Other Classes of Regression Models

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2022-07-07

1 Introduction

Effect plots, as implemented in the **effects** package, represent the “effects” (in the not necessarily causal sense of “partial relationship”) of one or more predictors on a response variable, in regression models in which the response depends on a *linear predictor*—a linear combination of main effects and interactions among the predictors (Fox and Weisberg, 2019, Sec. 4.6.3). `Effect()` is the basic generic function in the **effects** package; `Effect()` is called directly or indirectly by several other functions in the package, such as `predictorEffects()` and `allEffects()`.

Table 1 provides a list of regression modeling functions in R that can be used with the **effects** package. This list, which is almost surely incomplete, includes functions that are directly supported by `Effect()` methods supplied by the **effects** package, by `Effect()` methods supplied by other CRAN packages, or by the default `Effect()` method, which works with many classes of regression models.

The most basic type of model for which `Effect()` is appropriate is a standard linear model fit by the `lm()` function; for example:

```
library("effects")
Prestige$type <- factor(Prestige$type, c("bc", "wc", "prof")) # reorder levels
g1 <- lm(prestige ~ education + type + education:type, data = Prestige)
# equivalent to lm(prestige ~ education*type, data = Prestige)
plot(predictorEffects(g1), lines=list(multiline=TRUE))
```

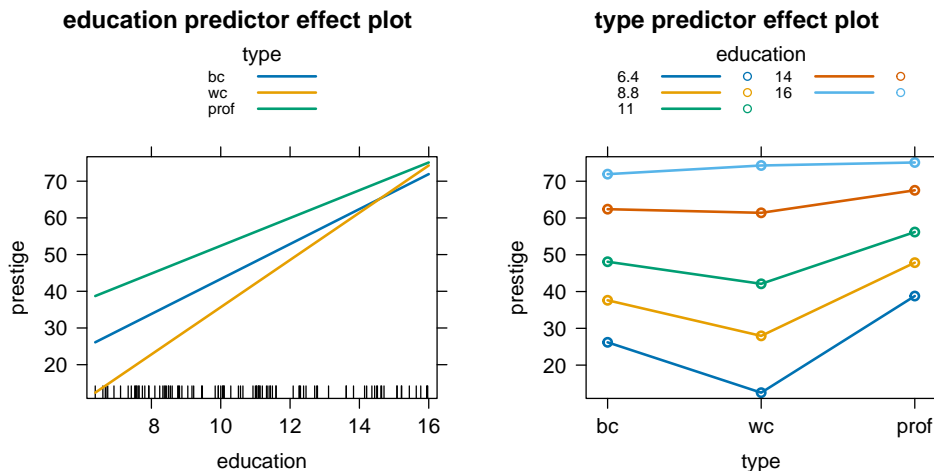


Table 1: R regression functions known to be compatible with the `Effect()` function. The name before the double-colon is the package that includes the function; for example `stats::lm()` means that `lm()` is in the `stats` package. In some cases, `Effect()` may support only a subset of regression models fit by a particular function. Effects for mixed-effects models represent the fixed-effects part of the model.

Function	Comments
glm-type models	
<code>stats::lm()</code>	Standard linear regression models fit by least-squares or weighted least-squares. A multivariate response, generating a multivariate linear model, is permitted, and in this case effects are computed for each response separately.
<code>stats::glm()</code>	Generalized linear models.
<code>nlme::lme()</code>	Linear mixed-effects models.
<code>nlme::gls()</code>	Linear models fit by generalized least squares.
<code>lmer::lmer()</code>	Linear mixed-effects models.
<code>lmer::glmer()</code>	Generalized linear mixed-effects models.
<code>survey::svyglm()</code>	Generalized linear models for complex survey designs.
<code>MASS::rlm()</code>	Linear regression models estimated by robust M or MM regression.
<code>MASS::glmPQL()</code>	Generalized linear mixed-effects models via partial quadratic likelihood.
<code>robustlmm::rlmer()</code>	Robust linear mixed-effects models.
<code>betareg::betareg()</code>	Beta regression models for rates and proportions.
<code>ivreg::ivreg()</code>	Linear regression models estimated by instrumental variables (2SLS regression).
<code>glmmTMB::glmmTMB()</code>	Generalized linear mixed-effects regression models (similar to <code>lmer::glmer()</code> but accommodating a broader selection of models).
multinom-type models	
<code>nnet::multinom()</code>	Multinomial logistic-regression models. If the response has K categories, the response for <code>nnet::multinom()</code> can be a factor with K levels or a matrix with K columns, which will be interpreted as counts for each of K categories. Effects plots require the response to be a factor, not a matrix.
<code>poLCA::poLCA()</code>	Latent class analysis regression models for polytomous outcomes. Latent class analysis has a similar structure to multinomial regression, except that class membership of observations is unobserved but estimated in the analysis.
polr-type models	
<code>MASS::polr()</code>	Ordinal logistic (proportional-odds) and probit regression models.
<code>ordinal::clm()</code>	Cumulative-link regression models (similar to, but more extensive than, <code>polr()</code>).
<code>ordinal::clm2()</code>	Updated version of <code>ordinal::clm()</code> .
<code>ordinal::clmm()</code>	Cumulative-link regression models with random effects.

In this example the response `prestige` is modeled as a linear function of years of `education`, the factor `type`, with levels blue collar ("`bc`"), white collar ("`wc`"), and professional ("`prof`"), and their interaction. Because of the interaction, the estimated partial relationship of `prestige` to `education` (depicted in the *predictor effect plot* for `education`, at the left) is different for each level of `type`, and the partial relationship of `prestige` to `type` (depicted in the predictor effect plot for `type`, at the right) varies with the value `education`.

A linear mixed-effects model is a more complicated regression model, fit, for example, by the `lmer()` function in the `lme4` package (Bates et al., 2015):

```
data(Orthodont, package="nlme")
g2 <- lme4::lmer(distance ~ age + Sex + (1 | Subject), data = Orthodont)
summary(g2)
```

```
Linear mixed model fit by REML ['lmerMod']
Formula: distance ~ age + Sex + (1 | Subject)
Data: Orthodont
```

```
REML criterion at convergence: 437.5
```

```
Scaled residuals:
```

```
      Min       1Q   Median       3Q      Max
-3.7489 -0.5503 -0.0252  0.4534  3.6575
```

```
Random effects:
```

```
Groups   Name             Variance Std.Dev.
Subject (Intercept)  3.267   1.807
Residual                    2.049   1.432
Number of obs: 108, groups: Subject, 27
```

```
Fixed effects:
```

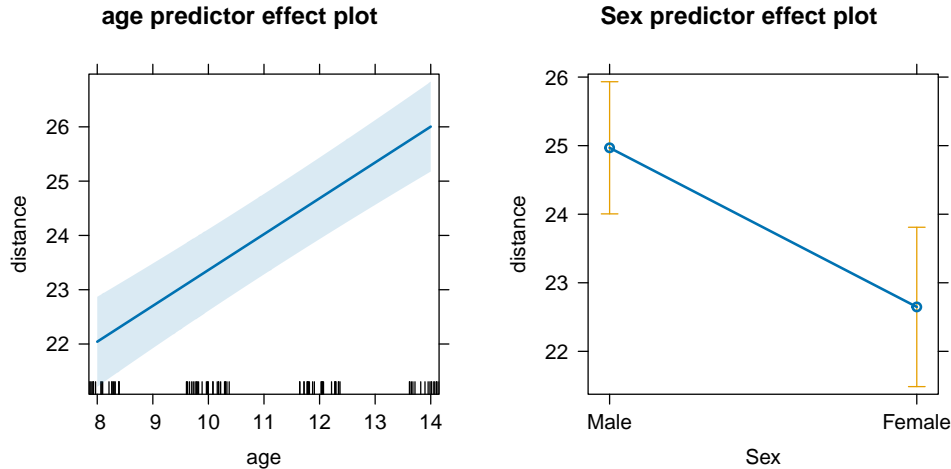
```
              Estimate Std. Error t value
(Intercept) 17.70671    0.83392  21.233
age          0.66019    0.06161  10.716
SexFemale   -2.32102    0.76142  -3.048
```

```
Correlation of Fixed Effects:
```

```
          (Intr) age
age      -0.813
SexFemale -0.372  0.000
```

This model has a fixed effect part, with response `distance` and predictors `age` and `Sex`. The random intercept (represented by 1) varies by `Subject`. Effect plots for mixed-effects models are based only on the estimated fixed-effects in the model:

```
plot(predictorEffects(g2))
```



2 Basic Types of Regression Models in the effects Package

The `Effects()` function supports three basic types of regression models:

- The preceding examples that use the `lm()` and `lmer()` functions are examples of `glm`-type models, which express, via a link function, the dependence of a discrete or continuous numeric response or of a binary response on a set of main effects and interactions among fixed-effect predictors comprising a linear predictor. The `glm()` function is the prototype for this kind of model. As shown in Table 1, most of the regression functions currently supported by the `effects` package are of this type.
- `multinom`-type models are multinomial regression models that arise when the response is an unordered multi-category variable, also modeled, via a suitable multivariate link function, as a linear function of fixed-effect main effects and interactions. The prototype for `multinom`-type models is the `multinom()` function in the `nnet` package (Venables and Ripley, 2002).
- `polr`-type models (i.e., ordinal regression models) are used for an ordered polytomous response variable. The prototype for `polr`-type models is the `polr()` function in the `MASS` package (Venables and Ripley, 2002).

3 Supporting Specific Regression Functions

To support a specific class of regression models, say of class "foo" produced by the function `foo()`, one *could* write a method `Effect.foo()` for the S3 generic `Effect()` function. That approach is generally undesirable, for two reasons: (1) writing an `Effect()` method from scratch is a complicated endeavor; (2) the resulting object may not work properly with other functions in the `effects` package, such as `plot()` methods.

The `effects` package defines and exports several methods for the `Effect()` function, including a default method, and three specific methods corresponding to the three types of regression models introduced in the preceding section: `Effect.lm()` (which is also inherited by models of class "glm"), `Effect.multinom()`, and `Effect.polr()`. Moreover, `Effect.default()` works by setting up a call

to one of the three specific `Effect()` methods.¹

The three basic `Effect()` methods collect information from the regression model of interest via a suitable method for the generic `effects::effSources()` function, and then use that information to compute effects and their standard errors. The required information is summarized in Table 2.

The default `effSources()` method simply returns `NULL`, which corresponds to selecting all of the defaults in Table 2. If that doesn't work, it usually suffices to provide a suitable `effSources()` method. We illustrate by a few examples.

3.1 Examples

The following examples, with the exception of the last, are drawn directly from the `effects` package.

3.1.1 `glmmPQL()`

Objects of class "`glmmPQL`", produced by `MASS::glmmPQL()` do not respond to the generic `family()` function, but the name of the family can be obtained from the call; thus:

```
effSources.glmmPQL <- function(mod) {
  list(family = mod$family)
}
```

3.1.2 `gls()`

The `weights` argument has different meaning for `gls()` in the `nlme` package (Pinheiro et al., 2018) and for the standard R `glm()` function, and consequently the `call` must be modified to set `weights` to `NULL`:

```
effSources.gls <- function(mod){
  cl <- mod$call
  cl$weights <- NULL
  list(call = cl)
}
```

3.1.3 `betareg()`

The `betareg` function in the `betareg` package (Grün et al., 2012) fits response data similar to a binomial regression but with beta errors. Adapting these models for use with `Effect()` is considerably more complex than the two previous examples:

```
effSources.gls <- function(mod){
  coef <- mod$coefficients$mean
  vco <- vcov(mod)[1:length(coef), 1:length(coef)]
# betareg uses beta errors with mean link given in mod$link$mean.
# Construct a family based on the binomial() family
  fam <- binomial(link=mod$link$mean)
```

¹There are, as well, two additional specific `Effect()` methods provided by the `effects` package: `Effect.merMod()` for models produced by the `lmer()` and `glmer()` functions in the `lme4` package; and `Effect.svyglm()` for models produced by the `svyglm()` function in the `survey` package (Lumley, 2004). To see the code for these methods, enter the commands `getAnywhere("Effect.merMod")` and `getAnywhere("Effect.svyglm")`, after loading the `effects` package.

Table 2: Values supplied by `effSources()` methods. In the table, the regression model object is called `m`. For functions cited in the **insight** package see Lüdtke et al. (2019).

Argument	Description
<code>type</code>	The type of the regression model: one of "glm" (the default if <code>type</code> isn't supplied), "multinom", or "polr".
<code>call</code>	The call that created the regression model, which is generally returned by either <code>m\$call</code> or <code>m@call</code> or <code>insight::get_call(m)</code> . The call is used to find the usual <code>data</code> and <code>subset</code> arguments that <code>Effect()</code> needs to perform the computation. See the discussion of <code>nlme::gls()</code> below for an example where the <code>call</code> must be modified.
<code>formula</code>	The formula for the fixed-effects linear predictor, which is often returned by <code>stats::formula(m)</code> or <code>insight::find_formula(m)\$conditional</code> .
<code>family</code>	Many glm-type models include a family, with an error distribution and a link function. These are often returned by the default <code>stats::family(m)</code> or <code>insight::get_family(m)</code> .
<code>coefficients</code>	The vector of fixed-effect parameter estimates, often returned by <code>coef(m)</code> . Alternatively <code>b <- insight::get_parameters(m)</code> returns the coefficient estimates as a two-column matrix with parameter names in the first column, so <code>stats::setNames(b[,2], b[,1])</code> returns the estimates as a vector. For a polr-type model, coefficients should return the regression coefficients excluding the thresholds.
<code>vcov</code>	The estimated covariance matrix of the fixed-effect estimates, often given by <code>stats::vcov(m)</code> or <code>insight::get_varcov(m)</code> . For a polr-type model, the covariance matrix should include both the regression coefficients and the thresholds, with the regression coefficients <i>preceding</i> the thresholds.
<code>zeta</code>	The vector of estimated thresholds for a polr-type model, one fewer than the number of levels of the response. The default for a polr-type model is <code>zeta = m\$zeta</code> .
<code>method</code>	For a polr-type model, the name of a link supported by the <code>MASS::polr()</code> function: one of "logistic", "probit", "loglog", "cloglog", or "cauchit". The default for a polr-type model is <code>method = "logistic"</code> .

```

# adjust the variance function to account for beta variance
fam$variance <- function(mu)
  f0 <- function(mu, eta) (1-mu)*mu/(1+eta)
  do.call("f0", list(mu, mod$coefficient$precision))
# adjust initialize
fam$initialize <- expression(mustart <- y)
# collect arguments
args <- list(
  call = mod$call,
  formula = formula(mod),
  family=fam,
  coefficients = coef,
  vcov = vco)
args
}

```

3.1.4 clm2()

The `clm2()` function in the **ordinal** package (Christensen, 2015) fits ordinal regression models, and so the aim is to create **polr**-type effects:

```

effSources.clm2 <- function(mod){
  if (!requireNamespace("MASS", quietly=TRUE))
    stop("MASS package is required")
  polr.methods <- c("logistic", "probit", "loglog",
                   "cloglog", "cauchit")

  method <- mod$link
  if(!(method %in% polr.methods))
    stop("'link' must be a 'method' supported by polr; see help(polr)")
  if(is.null(mod$Hessian)){
    message("Re-fitting to get Hessian")
    mod <- update(mod, Hess=TRUE)
  }
  if(mod$threshold != "flexible")
    stop("Effects only supports the flexible threshold")
  numTheta <- length(mod$Theta)
  numBeta <- length(mod$beta)
  or <- c( (numTheta+1):(numTheta + numBeta), 1:(numTheta))
  list(
    type = "polr",
    formula = mod$call$location,
    coefficients = mod$beta,
    zeta = mod$Theta,
    method=method,
    vcov = as.matrix(vcov(mod)[or, or]))
}

```

3.1.5 `ivreg::ivreg()`

Sometimes it doesn't suffice to define an appropriate `effSources()` method, but it is still possible to avoid writing a detailed `Effect()` method. We use the `ivreg()` function (for instrumental-variables regression) in the `ivreg` package (Fox et al., 2021) as an example; that package defines the following `Effect.ivreg()` method:

```
Effect.ivreg <- function (focal.predictors, mod, ...) {  
  mod$contrasts <- mod$contrasts$regressors  
  NextMethod()  
}
```

Here it is sufficient to set the `contrasts` element of the model object to conform to the way it is defined in "lm" objects. That works because "ivreg" objects inherit from class `lm`, and thus `Effect.lm()` is called by `NextMethod()`.

References

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