Package 'feisr'

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Title Estimating Fixed Effects Individual Slope Models

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Description Provides the function feis() to estimate fixed effects individual slope (FEIS) models. The FEIS model constitutes a more general version of the often-used fixed effects (FE) panel model, as implemented in the package 'plm' by Croissant and Millo (2008) <doi:10.18637/jss.v027.i02>. In FEIS models, data are not only person demeaned like in conventional FE models, but detrended by the predicted individual slope of each person or group. Estimation is performed by applying least squares lm() to the transformed data. For more details on FEIS models see Bruederl and Ludwig (2015, ISBN:1446252442); Frees (2001) <doi:10.2307/3316008>; Polachek and Kim (1994) <doi:10.1016/0304-4076(94)90075-2>; Ruettenauer and Ludwig (2020) <doi:10.1177/0049124120926211>; Wooldridge (2010, ISBN:0262294354). To test consistency of conventional FE and random effects estimators against heterogeneous slopes, the package also provides the functions feistest() for an artificial regression test and bsfeistest() for a bootstrapped version of the Hausman test.

Depends R (>= 3.4.0)

License GPL (>= 2)

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`feisr-package` *Estimating Fixed Effects Individual Slope Models*

Description

The main purpose of the package `feisr` is the estimation of fixed effects individual slopes models and respective test statistics. The fixed effects individual slopes (FEIS) estimator is a more general version of the well-known fixed effects estimator (FE), which allows to control for heterogeneous slopes in addition to time-constant heterogeneity (Bruederl and Ludwig 2015; Ruettenauer and Ludwig 2020; Wooldridge 2010). This is done by running an `lm()` model on pre-transformed data, where we (1) estimate the individual-specific predicted values for the dependent variable and each covariate based on an individual intercept and the additional slope variables, (2) detrend the original data by these individual-specific predicted values, and (3) run an OLS model on the residual data. The package also provides two specification test for heterogeneous slopes (more details and examples can be found in Ruettenauer and Ludwig 2020).

Details

The main functions of the `feisr` package are:

- `feis()`: fixed effects individual slopes estimator by applying `lm` to detrended data.

- `feistest()`: regression-based Hausman test for fixed effects individual slope models.

- `bsfeistest()`: bootstrapped Hausman test for fixed effects individual slope models.

The functions included in the R package `feisr` are also available in the xtfeis ado (`https://ideas.repec.org/c/boc/bocode/s458045.html`) for Stata. The `plm-package` provides functions for estimation of related models, like the mean group (MG) or common correlated effects mean groups (CCEMG) estimator via `pmg` or models with variable coefficients via `pvcm`.

Author(s)

Tobias Ruettenauer

Volker Ludwig

References

Bruederl J, Ludwig V (2015). "Fixed-Effects Panel Regression." In Best H, Wolf C (eds.), *The Sage Handbook of Regression Analysis and Causal Inference*, 327–357. Sage, Los Angeles. ISBN 1446252442.

Ruettenauer T, Ludwig V (2020). "Fixed Effects Individual Slopes: Accounting and Testing for Heterogeneous Effects in Panel Data or Other Multilevel Models." *Sociological Methods and Research*, **OnlineFirst**. ISSN 0049-1241, doi: 10.1177/0049124120926211.

Wooldridge JM (2010). *Econometric Analysis of Cross Section and Panel Data*. MIT Press, Cambridge, Mass. ISBN 0262294354.

See Also

plm, pvcm, pmg

`bsfeistest` *Bootstrapped Regression Test*

Description

Estimates a bootstrapped Hausman test for fixed effects individual slope models.

Usage

```
bsfeistest(
  model = NA,
  type = c("all", "bs1", "bs2", "bs3"),
  terms = NULL,
  rep = 500,
  seed = NULL,
  prog = TRUE,
  ...
)
```

Arguments

`model`	an object of class "`feis`".
`type`	one of "`all`" (the Default), "`bs1`" for test of FEIS against FE only, "`bs2`" for test of FE against RE only, and "`bs3`" for test of FEIS against RE only (see also Details).

terms	An optional character vector specifying which coefficients should be jointly tested. By default, all covariates are included in the Wchi-squared test. For "type=art2", the slope variable is always included in "terms".
rep	the number of repetitions to be used in bootstrapping (default is 500).
seed	the seed used for random sampling in bootstrapping. Needs to be a valid integer. If not specified, the current seed is used.
prog	... logical. If TRUE (the Default) shows the progress in the output window.
...	further arguments.

Details

The function computes a bootstrapped version of the Hausman test (Hausman 1978). Pairs cluster bootstrapping (Cameron et al. 2008; Ruettenauer and Ludwig 2020) is used to obtain the empirical variance-covariance matrix of the estimators, either for FEIS and conventional FE, convention FE and RE, or FEIS and RE.

type="bs1" estimates a bootstrapped Hausman test comparing fixed effects individual slope models and conventional fixed effects models. In this case, bsfeistest tests for inconsistency of the convetional FE model due to heterogeneous slopes. type="bs2" estimates a bootstrapped version of the well-known Hausman test comparing conventional fixed effects models against random effects models. type="bs3" estimates a bootstrapped Hausman directly comparing FEIS against RE, thereby testing for inconsistency of the RE model due to either heterogeneous slopes or time-constant omitted heterogeneity. Bootstrapping is perfomed by resampling with replacement while keeping the number of groups identical to the number of groups in the original dataset. wald.test is used to perform a Wald chi-squared test on the differences between coefficients.

Value

An object of class "feistest", containing the following elements:

wald_feis	an object of class "wald.test" (see wald.test) testing the fixed effects individual slopes model against the conventional fixed effects model (type="bs1").
wald_fe	an object of class "wald.test" (see wald.test) testing the fixed effects model against the random effects model (type="bs2").
wald_re	an object of class "wald.test" (see wald.test) testing the fixed effects individual slopes model against the random effects model (type="bs3").
vcov1	the empirical (bootstrapped) variance-covariance matrix of the coefficients obtained from FEIS and FE (type="bs1").
vcov2	the empirical (bootstrapped) variance-covariance matrix of the coefficients obtained from FE and RE (type="bs2").
vcov3	the empirical (bootstrapped) variance-covariance matrix of the coefficients obtained from FEIS and RE (type="bs3").
bscoef.feis	a matrix containing the estimated FEIS coefficients of each bootstrap run.
bscoef.fe	a matrix containing the estimated FE coefficients of each bootstrap run.
bscoef.re	a matrix containing the estimated RE coefficients of each bootstrap run.
call	the matched call.

formula	an object of class "Formula" describing the model.
type	the type of performed test(s).
sample	a list containing the IDs sampled in each run.
seed	the seed used for bootstrapping.
terms	character vector of covariates are included in the Wchi-squared test.

References

Cameron AC, Gelbach JB, Miller DL (2008). "Bootstrap-Based Improvements for Inference with Clustered Errors." *Review of Economics and Statistics*, **90**(3), 414–427. ISSN 0034-6535, doi: 10.1162/rest.90.3.414.

Hausman JA (1978). "Specification Tests in Econometrics." *Econometrica*, **46**(6), 1251–1271. ISSN 00129682.

Ruettenauer T, Ludwig V (2020). "Fixed Effects Individual Slopes: Accounting and Testing for Heterogeneous Effects in Panel Data or Other Multilevel Models." *Sociological Methods and Research*, **OnlineFirst**. ISSN 0049-1241, doi: 10.1177/0049124120926211.

See Also

summary.feistest, feistest, feis, plm, wald.test, phtest

Examples

```
data("mwp", package = "feisr")
feis.mod <- feis(lnw ~ marry + enrol | year,
                 data = mwp, id = "id", robust = TRUE)
bsht <- bsfeistest(feis.mod, type = "bs1", rep = 5, seed = 1234, prog = FALSE)
summary(bsht)
```

---

feis *Fixed Effects Individual Slope Estimator*

Description

Estimates fixed effects individual slope estimators by applying linear lm models to "detrended" data.

Usage

```
feis(
  formula,
  data,
  id,
  robust = FALSE,
  intercept = FALSE,
```

```
  dropgroups = FALSE,
  tol = .Machine$double.eps,
  ...
)

## S3 method for class 'feis'
formula(x, lhs = NULL, rhs = NULL, ...)

## S3 method for class 'feis'
terms(x, lhs = NULL, rhs = NULL, ...)

## S3 method for class 'feis'
residuals(object, ...)

## S3 method for class 'feis'
df.residual(object, ...)

## S3 method for class 'feis'
coef(object, ...)

## S3 method for class 'feis'
sigma(object, ...)

## S3 method for class 'feis'
deviance(object, ...)

## S3 method for class 'feis'
nobs(object, ...)

## S3 method for class 'feis'
fitted(object, ...)

## S3 method for class 'feis'
predict(object, newdata = NULL, ...)

## S3 method for class 'feis'
hatvalues(model, ...)
```

Arguments

formula	a symbolic description for the model to be fitted (see Details).
data	a data.frame containing the specified variables.
id	the name of a unique group / person identifier (as string).
robust	logical. If TRUE estimates cluster robust standard errors (default is FALSE).
intercept	logical. If TRUE estimates the model with an intercept (default is FALSE).
dropgroups	logical. If TRUE groups without any within variance on a slope variable are dropped , if FALSE those variables are omitted for the respective groups only (default is FALSE).

tol	the tolerance for detecting linear dependencies in the residual maker transformation (see solve). The argument is forwarded to bsfeistest.
...	further arguments.
lhs, rhs	indexes of the left- and right-hand side for the methods formula and terms.
object, x, model	an object of class "feis".
newdata	the new data set for the predict method.

Details

feis is a special function to estimate linear fixed effects models with individual-specific slopes. In contrast to conventional fixed effects models, data are not person "demeaned", but "detrended" by the predicted individual slope of each person (Bruederl and Ludwig 2015; Ruettenauer and Ludwig 2020; Wooldridge 2010).

Estimation requires at least q+1 observations per unit, where q is the number of slope parameters (including a constant). feis automatically selects only those groups from the current data set which have at least q+1 observations. The function returns a warning if units with <q+1 observations are dropped.

The function requires a two-part formula, in which the second part indicates the slope parameter(s). If, for example, the model is y ~ x1 + x2, with the slope variables x3 and x4, the model can be estimated with:

- formula = y ~ x1 + x2 | x3 + x4

If the second part is not specified (and individual "slopes" are estimated only by an intercept), the model reduces to a conventional fixed effects (within) model. In this case please use the well-established plm (model="within") function instead of feis.

If specified, feis estimates panel-robust standard errors. Panel-robust standard errors are robust to arbitrary forms of serial correlation within groups formed by id as well as heteroscedasticity across groups (see Wooldridge 2010, pp. 379-381).

The model output can be exported using the texreg package.

Value

An object of class "feis", containing the following elements:

coefficients	the vector of coefficients.
vcov	the scaled (if specified, robust) variance-covariance matrix of the coefficients. See vcov.feis for unscaled vcov
.	
residuals	the vector of residuals (computed from the "detrended" data).
df.residual	degrees of freedom of the residuals.
formula	an object of class "Formula" describing the model.
model	the original model frame as a data.frame containing the original variables used for estimation.

modelhat	a constructed model frame as a data.frame containing the predicted values from the first stage regression using the slope variable(s) as predictor(s).
modeltrans	a constructed model frame as a data.frame containing the "detrended" variables used for the final model estimation and the untransformed slope variables.
response	the vector of the "detrended" response variable.
fitted.values	the vector of fitted values (computed from the "detrended" data).
id	a vector containing the unique person identifier.
call	the matched call.
assign	assign attributes of the formula.
na.omit	(where relevant) a vector of the omitted observations. The only handling method of NAs is "omit".
contrasts	(only where relevant) the contrasts used.
arg	a list containing the used methods. Only "feis" and "individual" effects available.
slopevars	a character vector containing the names of the slope variables.
r2	R squared of the "detrended" model.
adj.r2	adjusted R squared of the "detrended" model.
vcov_arg	a character containing the method used to compute the variance-covariance matrix.
tol	the tolerance parameter (for use in bsfeistest).

References

Bruederl J, Ludwig V (2015). "Fixed-Effects Panel Regression." In Best H, Wolf C (eds.), *The Sage Handbook of Regression Analysis and Causal Inference*, 327–357. Sage, Los Angeles. ISBN 1446252442.

Ruettenauer T, Ludwig V (2020). "Fixed Effects Individual Slopes: Accounting and Testing for Heterogeneous Effects in Panel Data or Other Multilevel Models." *Sociological Methods and Research*, **OnlineFirst**. ISSN 0049-1241, doi: 10.1177/0049124120926211.

Wooldridge JM (2010). *Econometric Analysis of Cross Section and Panel Data*. MIT Press, Cambridge, Mass. ISBN 0262294354.

See Also

summary.feis, plm, pvcm, pmg, feistest

Examples

```
data("mwp", package = "feisr")
feis.mod <- feis(lnw ~ marry + enrol + as.factor(yeargr) | exp + I(exp^2),
                 data = mwp, id = "id", robust = TRUE)
summary(feis.mod)
```

feistest *Artificial Regression Test*

Description

Estimates a regression-based Hausman test for fixed effects individual slope models.

Usage

```
feistest(
  model = NA,
  robust = FALSE,
  type = c("all", "art1", "art2", "art3"),
  terms = NULL,
  ...
)
```

Arguments

model	an object of class "feis".
robust	logical. If TRUE uses cluster robust standard errors (Default is FALSE).
type	one of "all" (the Default), "art1" for test of FEIS against FE only, "art2" for test of FE against RE only, and "art3" for test of FEIS against RE only (see also Details).
terms	An optional character vector specifying which coefficients should be jointly tested. By default, all covariates are included in the Wchi-squared test. For "type=art2", the slope variable is always included in "terms".
...	further arguments.

Details

The Hausman test can be computed by estimating a correlated random effects model (see Wooldridge 2010, pp. 328-334, Ruettenauer and Ludwig 2020). This is achieved by estimating a Mundlak (Mundlak 1978) specification using random effects models with plm. Subsequently, feistest tests whether the time-constant variables / slope variables are correlated with the unobserved heterogeneity by using a Wald chi-squared test with wald.test.

type="art1" estimates an extended regression-based Hausman test comparing fixed effects individual slope models and conventional fixed effects models. For art1 the Mundlak-specification (Mundlak 1978) includes the person-specific averages, but additionally the person-specific slope estimates used for "detrending" in feis. This allows to test whether we can omit the estimated values based on the slopes and reduce the model to a conventional FE model. The Wald test of type="art1" is applied to the slope variables only. type="art2" estimates the conventional regression-based Hausman test (as described in Wooldridge 2010, pp. 328-334) comparing conventional fixed effects models against random effects models. type="art3" estimates a regression-based Hausman test comparing FEIS directly against RE, thereby testing for inconsistency of the RE model due to either heterogeneous slopes or time-constant omitted heterogeneity. For art3

the Mundlak-specification includes only the person-specific slopes, and no averages. This allows to test whether we can omit the estimated values based on the slopes and reduce the model to a conventional RE model. (for a formal description please see Ruettenauer and Ludwig 2020).

Currently, the `tol` option in `feis()` is only forwarded in bsfeistest, but not in feistest.

If specified (`robust=TRUE`), `feistest` uses panel-robust standard errors.

Value

An object of class "`feistest`", containing the following elements:

`wald_feis`	an object of class "`wald.test`" (see `wald.test`) testing the fixed effects individual slopes model against the conventional fixed effects model (`type="art1"`).
`wald_fe`	an object of class "`wald.test`" (see `wald.test`) testing the fixed effects model against the random effects model (`type="art2"`).
`wald_re`	an object of class "`wald.test`" (see `wald.test`) testing the fixed effects individual slopes model against the random effects model (`type="art3"`).
`vcov1`	the variance-covariance matrix of CREIS (`type="art1"`).
`vcov2`	the variance-covariance matrix of CRE (`type="art2"`).
`vcov3`	the variance-covariance matrix of CREIS without the means (`type="art3"`).
`CREIS`	an object of class "`plm`" (see `plm`) estimating a Correlated Random Effect Individual Slope model (`type="art1"`).
`CRE`	an object of class "`plm`" (see `plm`) estimating a Correlated Random Effect model (`type="art2"`).
`CREIS2`	an object of class "`plm`" (see `plm`) estimating a Correlated Random Effect Individual Slope model without including the covariates' means (`type="art3"`).
`call`	the matched call.
`robust`	logical. If `TRUE` cluster robust standard errors were used (Default is `FALSE`.
`formula`	an object of class "`Formula`" describing the model.
`type`	the type of performed test(s).
`terms`	character vector of covariates are included in the Wchi-squared test.

References

Mundlak Y (1978). "On the Pooling of Time Series and Cross Section Data." *Econometrica*, **46**(1), 69. ISSN 00129682.

Ruettenauer T, Ludwig V (2020). "Fixed Effects Individual Slopes: Accounting and Testing for Heterogeneous Effects in Panel Data or Other Multilevel Models." *Sociological Methods and Research*, **OnlineFirst**. ISSN 0049-1241, doi: 10.1177/0049124120926211.

Wooldridge JM (2010). *Econometric Analysis of Cross Section and Panel Data*. MIT Press, Cambridge, Mass. ISBN 0262294354.

See Also

`summary.feistest`, `bsfeistest`, `feis`, `plm`, `wald.test`, `phtest`

Examples

```
data("mwp", package = "feisr")
feis.mod <- feis(lnw ~ marry + enrol | year,
                 data = mwp, id = "id", robust = TRUE)
ht <- feistest(feis.mod, robust = TRUE, type = "all")
summary(ht)
# Only for marry coefficient
ht2 <- feistest(feis.mod, robust = TRUE, type = "all", terms = c("marry"))
summary(ht2)
```

`model.matrix.feis` *model.matrix for feis objects*

Description

Methods to extract transformed model matrix for "`feis`" objects.

Usage

```
## S3 method for class 'feis'
model.matrix(object, ...)
```

Arguments

`object`	an object of class "`feis`".
`...`	further arguments.

Details

`model.matrix` for `feis` objects returns the model or design matrix of the respective FEIS model. This is the transformed (detrended) data, which is used for estimation of the model in `lm()`.

Value

An object of class "`matrix`" for `model.matrix`.

See Also

`feis`, `model.matrix`

Examples

```
data("mwp", package = "feisr")
feis.mod <- feis(lnw ~ marry + as.factor(yeargr) | exp,
                 data = mwp, id = "id")
mm <- model.matrix(feis.mod)
```

mwp *Panel data including wages and family status*

Description

A random sample from the National Longitudinal Survey of Youth (Bureau of Labor Statistics 2014). It contains information on wages, family status, and work experience for a random sample of men. For a description of the original dataset and variable construction see Ludwig and Bruederl (2018).

Usage

```
mwp
```

Format

A data frame with 3100 observations and 17 variables:

id unique person identifier

year survey year

lnw natural log of hourly wage rate

exp work experience in current job, in years

expq work experience in current job squared

marry family status (=0 if not married, =1 if married)

evermarry indicator if ever married (=0 if never married, =1 if married at some point)

enrol current erolment in education (=0 not enroled, =1 enroled)

yeduc years of formal education

age respondents current age

cohort respondents birth cohort

yeargr grouped year (1=1979-1980, 2=1981-1985, 3=1986-1990, 4=1991-1995, 5=1996-2000)

yeargr1 dummy indicating grouped year=1

yeargr2 dummy indicating grouped year=2

yeargr3 dummy indicating grouped year=3

yeargr4 dummy indicating grouped year=4

yeargr5 dummy indicating grouped year=5

Source

Ludwig and Bruederl (2018)

References

Bureau of Labor Statistics (2014). *National Longitudinal Survey of Youth 1979 Cohort, 1979-2012 (rounds 1-23)*. Center for Human Resource Research, The Ohio State University, Columbus, OH.

Ludwig V, Bruederl J (2018). "Is There a Male Marital Wage Premium? New Evidence from the United States." *American Sociological Review*, **83**(4), 744–770. ISSN 0003-1224, doi: 10.1177/0003122418784909.

`slopes` *Extract individual slopes*

Description

Extracts the individual slopes (`alpha_i`) from a `feis` object created by `feis`.

Usage

```
slopes(model = NA, ...)
```

Arguments

`model`	an object of class "`feis`".
`...`	further arguments.

Details

The function extracts a matrix containing the individual slope parameters (`alpha_i`), which equals the coefficient(s) of regressing the depenent variable on the slope parameter(s).

If slope variables are perfectly collinear within a cluster, one variable is dropped and the function returns `0` for the respective slope and cluster.

Value

An `N` x `J` matrix containing the individual slopes for each cluster unit `N` and slope variable `J`. Rownames indicate the cluster id.

Examples

```
data("Produc", package = "plm")
feis.mod <- feis("log(gsp) ~ log(pcap) + log(pc) + log(emp) + unemp | year",
                 data = Produc, id = "state", robust = TRUE)
slps <- slopes(feis.mod)
```

summary.feis *Summary for feis objects*

Description

The summary method for feis objects generates some additional information about estimated feis models.

Usage

```
## S3 method for class 'feis'
summary(object, vcov = NULL, ...)

## S3 method for class 'summary.feis'
print(
  x,
  digits = max(3, getOption("digits") - 2),
  width = getOption("width"),
  subset = NULL,
  ...
)
```

Arguments

object	an object of class "feis".
vcov	a variance-covariance matrix furnished by the user or a function to calculate one.
...	further arguments.
x	an object of class "summary.feis".
digits	number of digits for printed output.
width	the maximum length of the lines in the printed output.
subset	a character or numeric vector indicating a subset of the table of coefficients to be printed.

Value

An object of class "summary.feis", containing the elements of the feis object (see feis). The object is forwarded to print method. The following objects are modified:

coefficients	a matrix with the estimated coefficients, standard errors, t-values, and p-values, if argument vcov is NULL the standard errors are calculated by the vcov in the input object.
r.squared	a vector containing R squared and adjusted R squared.

See Also

feis

Examples

```
data("mwp", package = "feisr")
feis.mod <- feis(lnw ~ marry | exp,
                 data = mwp, id = "id")
summary(feis.mod)
```

`summary.feistest` *Summary for feistest and bsfeistest objects*

Description

The summary method for feistest and bsfeistest objects prints the results of Artificial Regression Tests or Bootstrapped Hausman Tests for FEIS models.

Usage

```
## S3 method for class 'feistest'
summary(object, ...)

## S3 method for class 'summary.feistest'
print(
  x,
  digits = max(3, getOption("digits") - 2),
  width = getOption("width"),
  ...
)

## S3 method for class 'bsfeistest'
summary(object, ...)

## S3 method for class 'summary.bsfeistest'
print(
  x,
  digits = max(3, getOption("digits") - 2),
  width = getOption("width"),
  ...
)
```

Arguments

`object`	an object of class "`feistest`" or "`bsfeistest`".
`...`	further arguments.
`x`	an object of class "`summary.feistest`" or "`summary.bsfeistest`".
`digits`	number of digits for printed output.
`width`	the maximum length of the lines in the printed output.

Value

An object of class "summary.feistest" or "summary.bsfeistest", equal to the original input object (see feistest and bsfeistest). The object is forwarded to print method.

See Also

feistest, bsfeistest

Examples

```
data("mwp", package = "feisr")
feis.mod <- feis(lnw ~ marry | exp,
                 data = mwp, id = "id")
ht <- feistest(feis.mod, robust = TRUE, type = "all")
summary(ht)
```

---

vcov.feis *Calculate Variance-Covariance Matrix for a feis object*

Description

Returns the variance-covariance matrix of the main parameters of an object of class "feis". By default, this is the unscaled variance-covariance matrix.

Usage

```
## S3 method for class 'feis'
vcov(object, ..., scale = FALSE)
```

Arguments

object	an object of class "feis", fitted model.
...	further arguments.
scale	logical. If TRUE returns scaled vcov by sigma^2 (default is FALSE).

Details

By default, vcov() return the unscaled variance-covariance matrix of the fitted FEIS model. If set to scale = TRUE, the vcov is scaled by the nuisance parameter sigma^2 (as is object$vcov). Note that corrections for clustering (i.e. robust = TRUE in the fitted model) are ignored in vcov(). In this case, object$vcov will return the vcov with corrections for clustering.

Value

A matrix of the estimated covariances between the parameter estimates in the fitted FEIS model.

See Also

feis, vcov, sigma

Examples

```
data("mwp", package = "feisr")
feis.mod <- feis(lnw ~ marry + enrol | exp,
                 data = mwp, id = "id")
vcov(feis.mod)
all.equal(vcov(feis.mod), feis.mod$vcov) # FALSE: not equal, because vcov() unscaled
all.equal(vcov(feis.mod, scale = TRUE), feis.mod$vcov) # equal
```

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