Package ‘lmtest’

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bgtest

Description

bgtest performs the Breusch-Godfrey test for higher-order serial correlation.

Usage

```
bgtest(formula, order = 1, order.by = NULL, type = c("Chisq", "F"),
       data = list(), fill = 0)
```

Arguments

- `formula`: a symbolic description for the model to be tested (or a fitted "lm" object).
- `order`: integer. maximal order of serial correlation to be tested.
- `order.by`: Either a vector z or a formula with a single explanatory variable like ~ z. The observations in the model are ordered by the size of z. If set to NULL (the default) the observations are assumed to be ordered (e.g., a time series).
- `type`: the type of test statistic to be returned. Either "Chisq" for the Chi-squared test statistic or "F" for the F test statistic.
- `data`: an optional data frame containing the variables in the model. By default the variables are taken from the environment which bgtest is called from.
starting values for the lagged residuals in the auxiliary regression. By default 0 but can also be set to NA.

Details

Under $H_0$ the test statistic is asymptotically Chi-squared with degrees of freedom as given in parameter. If type is set to "F" the function returns a finite sample version of the test statistic, employing an $F$ distribution with degrees of freedom as given in parameter.

By default, the starting values for the lagged residuals in the auxiliary regression are chosen to be 0 (as in Godfrey 1978) but could also be set to NA to omit them.

bgtest also returns the coefficients and estimated covariance matrix from the auxiliary regression that includes the lagged residuals. Hence, coeftest can be used to inspect the results. (Note, however, that standard theory does not always apply to the standard errors and t-statistics in this regression.)

Value

A list with class "bgtest" inheriting from "htest" containing the following components:

- statistic: the value of the test statistic.
- p.value: the p-value of the test.
- parameter: degrees of freedom.
- method: a character string indicating what type of test was performed.
- data.name: a character string giving the name(s) of the data.
- coefficients: coefficient estimates from the auxiliary regression.
- vcov: corresponding covariance matrix estimate.

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References


See Also

dwtest
Examples

```r
## Generate a stationary and an AR(1) series
x <- rep(c(1, -1), 50)

y1 <- 1 + x + rnorm(100)

## Perform Breusch-Godfrey test for first-order serial correlation:
bgtest(y1 ~ x)
## or for fourth-order serial correlation
bgtest(y1 ~ x, order = 4)
## Compare with Durbin-Watson test results:
dwtest(y1 ~ x)

y2 <- filter(y1, 0.5, method = "recursive")
bgtest(y2 ~ x)
bg4 <- bgtest(y2 ~ x, order = 4)
bg4
coeftest(bg4)
```

### bondyield

#### Bond Yield

**Description**

Bond Yield Data.

**Usage**

data(bondyield)

**Format**

A multivariate quarterly time series from 1961(1) to 1975(4) with variables

- **RAARUS** difference of interest rate on government and corporate bonds,
- **MOOD** measure of consumer sentiment,
- **EPI** index of employment pressure,
- **EXP** interest rate expectations,
- **Y** artificial time series based on RAARUS,
- **K** artificial time series based on RAARUS.

**Source**

The data was originally studied by Cook and Hendershott (1978) and Yawitz and Marshall (1981), the data set is given in Krämer and Sonnberger (1986). Below we replicate a few examples given in their book. Some of these results differ more or less seriously and are sometimes parameterized differently.
References


Examples

data(bondyield)

## page 134, fit Cook-Hendershott OLS model and Yawitz-Marshall OLS model
## third and last line in Table 6.5

modelCH <- RAARUS ~ MOOD + EPI + EXP + RUS
lm(modelCH, data=bondyield)
dwtest(modelCH, data=bondyield)
## wrong sign of RUS coefficient

modelYM <- RAARUS ~ MOOD + Y + K
lm(modelYM, data=bondyield)
dwtest(modelYM, data=bondyield)
## coefficient of Y and K differ by factor 100

## page 135, fit test statistics in Table 6.6 b)

## Chow 1971(1)
if(require(strucchange, quietly = TRUE)) {
sctest(modelCH, point=c(1971,1), data=bondyield, type="Chow")
}

## Breusch-Pagan
bptest(modelCH, data=bondyield, studentize=FALSE)
bptest(modelCH, data=bondyield)

## Fluctuation test
if(require(strucchange, quietly = TRUE)) {
sctest(modelCH, type="fluctuation", data=bondyield, rescale=FALSE)
}

## RESET
reset(modelCH, data=bondyield)
reset(modelCH, power=2, type="regressor", data=bondyield)
reset(modelCH, type="princomp", data=bondyield)

## Harvey-Collier
harvtest(modelCH, order.by= ~ MOOD, data=bondyield)
harvtest(modelCH, order.by= ~ EPI, data=bondyield)
harvtest(modelCH, order.by= ~ EXP, data=bondyield)
harvtest(modelCH, order.by= ~ RUS, data=bondyield)
## Rainbow
raintest(modelCH, order.by = "mahalanobis", data=bondyield)

## page 136, fit test statistics in Table 6.6 d)

### Chow 1966()
if(require(strucchange, quietly = TRUE)) {
sctest(modelYM, point=c(1965,4), data=bondyield, type="Chow")
}

### Fluctuation test
if(require(strucchange, quietly = TRUE)) {
sctest(modelYM, type="fluctuation", data=bondyield, rescale=FALSE)
}

### RESET
reset(modelYM, data=bondyield)
reset(modelYM, power=2, type="regressor", data=bondyield)
reset(modelYM, type="princomp", data=bondyield)

### Harvey-Collier
harvtest(modelYM, order.by = ~ MOOD, data=bondyield)
harvtest(modelYM, order.by = ~ Y, data=bondyield)
harvtest(modelYM, order.by = ~ K, data=bondyield)

### Rainbow
raintest(modelYM, order.by = "mahalanobis", data=bondyield)

---

### bptest

**Breusch-Pagan Test**

**Description**

Performs the Breusch-Pagan test against heteroskedasticity.

**Usage**

bptest(formula, varformula = NULL, studentize = TRUE, data = list())

**Arguments**

- **formula**: a symbolic description for the model to be tested (or a fitted "lm" object).
- **varformula**: a formula describing only the potential explanatory variables for the variance (no dependent variable needed). By default the same explanatory variables are taken as in the main regression model.
- **studentize**: logical. If set to TRUE Koenker's studentized version of the test statistic will be used.
- **data**: an optional data frame containing the variables in the model. By default the variables are taken from the environment which bptest is called from.
Details
The Breusch-Pagan test fits a linear regression model to the residuals of a linear regression model (by default the same explanatory variables are taken as in the main regression model) and rejects if too much of the variance is explained by the additional explanatory variables.

Under $H_0$ the test statistic of the Breusch-Pagan test follows a chi-squared distribution with parameter (the number of regressors without the constant in the model) degrees of freedom.

Examples can not only be found on this page, but also on the help pages of the data sets bondyield, currencysubstitution, growthofmoney, moneydemand, unemployment, wages.

Value
A list with class "htest" containing the following components:

- **statistic** the value of the test statistic.
- **p.value** the p-value of the test.
- **parameter** degrees of freedom.
- **method** a character string indicating what type of test was performed.
- **data.name** a character string giving the name(s) of the data.

References


See Also
- *lm*, *ncvTest*

Examples
```r
## generate a regressor
x <- rep(c(-1,1), 50)
## generate heteroskedastic and homoskedastic disturbances
err1 <- rnorm(100, sd=rep(c(1,2), 50))
err2 <- rnorm(100)
## generate a linear relationship
y1 <- 1 + x + err1
y2 <- 1 + x + err2
## perform Breusch-Pagan test
bptest(y1 ~ x)
bptest(y2 ~ x)
```
ChickEgg

Chickens, Eggs, and Causality

Description

US chicken population and egg production.

Usage

data(ChickEgg)

Format

An annual time series from 1930 to 1983 with 2 variables.

- **chicken**: number of chickens (December 1 population of all US chickens excluding commercial broilers),
- **egg**: number of eggs (US egg production in millions of dozens).

Source

The data set was provided by Walter Thurman and made available for R by Roger Koenker. Unfortunately, the data is slightly different than the data analyzed in Thurman & Fisher (1988).

References


Examples

```r
## Which came first: the chicken or the egg?
data(ChickEgg)
## chickens granger-cause eggs?
grangertest(egg ~ chicken, order = 3, data = ChickEgg)
## eggs granger-cause chickens?
grangertest(chicken ~ egg, order = 3, data = ChickEgg)

## To perform the same tests ‘by hand’, you can use dynlm() and waldtest():
if(require(dynlm)) {
## chickens granger-cause eggs?
em <- dynlm(egg ~ L(egg, 1) + L(egg, 2) + L(egg, 3), data = ChickEgg)
em2 <- update(em, . ~ . + L(chicken, 1) + L(chicken, 2) + L(chicken, 3))
waldtest(em, em2)

## eggs granger-cause chickens?
cm <- dynlm(chicken ~ L(chicken, 1) + L(chicken, 2) + L(chicken, 3), data = ChickEgg)
cm2 <- update(cm, . ~ . + L(egg, 1) + L(egg, 2) + L(egg, 3))
waldtest(cm, cm2)
}
```
Description

coeff test is a generic function for performing z and (quasi-)t tests of estimated coefficients.

Usage

coeff test(x, vcov. = NULL, df = NULL, ...)

Arguments

x               an object (for details see below).
vcov.           a specification of the covariance matrix of the estimated coefficients. This can be specified as a matrix or as a function yielding a matrix when applied to x.
df              the degrees of freedom to be used. If this is a finite positive number a t test with df degrees of freedom is performed. In all other cases, a z test (using a normal approximation) is performed. By default it tries to use x$df.residual and performs a z test if this is NULL.
...             further arguments passed to the methods.

Details

The generic function coeff test currently has a default method (which works in particular for "lm" and "g1m" objects) and a method for objects of class "breakpointsfull" (as computed by breakpoints.formula).

The default method assumes that a coef methods exists, such that coef(x) yields the estimated coefficients.

To specify a covariance matrix vcov. to be used, there are three possibilities: 1. It is pre-computed and supplied in argument vcov.. 2. A function for extracting the covariance matrix from x is supplied, e.g., vcovHC or vcovHAC from package sandwich. 3. vcov. is set to NULL, then it is assumed that a vcov method exists, such that vcov(x) yields a covariance matrix. For illustrations see below.

The degrees of freedom df determine whether a normal approximation is used or a t distribution with df degrees of freedoms is used. The default method uses df.residual(x) and if this is NULL a z test is performed.

Value

An object of class "coeff test" which is essentially a coefficient matrix with columns containing the estimates, associated standard errors, test statistics and p values.

See Also

lm, waldtest
Examples

```r
## load data and fit model
data(Mandible)
fm <- lm(length ~ age, data=Mandible, subset=(age <= 28))

## the following commands lead to the same tests:
summary(fm)
coeftest(fm)

## a z test (instead of a t test) can be performed by
coeftest(fm, df = Inf)

if(require(sandwich)) {
## a different covariance matrix can be also used:
## either supplied as a function
coeftest(fm, df = Inf, vcov = vcovHC)
## or as a matrix
coeftest(fm, df = Inf, vcov = vcovHC(fm, type = "HC0"))
}
```

---

**coxtest**

*Cox Test for Comparing Non-Nested Models*

**Description**

`coxtest` performs the Cox test for comparing two non-nested models.

**Usage**

```r
coxtest(formula1, formula2, data = list())
```

**Arguments**

- `formula1` either a symbolic description for the first model to be tested, or a fitted object of class "lm".
- `formula2` either a symbolic description for the second model to be tested, or a fitted object of class "lm".
- `data` an optional data frame containing the variables in the model. By default the variables are taken from the environment which `coxtest` is called from.

**Details**

The idea of the Cox test is the following: if the first model contains the correct set of regressors, then a fit of the regressors from the second model to the fitted values from first model should have no further explanatory value. But if it has, it can be concluded that model 1 does not contain the correct set of regressors.
Hence, to compare both models the fitted values of model 1 are regressed on model 2 and vice versa. A Cox test statistic is computed for each auxiliary model which is asymptotically standard normally distributed.

For further details, see the references.

**Value**

An object of class “anova” which contains the estimate plus corresponding standard error, z test statistic and p value for each auxiliary test.

**References**


**See Also**

*jtest, encomptest*

**Examples**

```r
## Fit two competing, non-nested models for aggregate
## consumption, as in Greene (1993), Examples 7.11 and 7.12

## load data and compute lags
data(USDistLag)
usdl <- na.contiguous(cbind(USDistLag, lag(USDistLag, k = 1)))
colnames(usdl) <- c("con", "gnp", "con1", "gnp1")

## C(t) = a0 + a1*Y(t) + a2*C(t-1) + u
fm1 <- lm(con ~ gnp + con1, data = usdl)

## C(t) = b0 + b1*Y(t) + b2*Y(t-1) + v
fm2 <- lm(con ~ gnp + gnp1, data = usdl)

## Cox test in both directions:
coxtest(fm1, fm2)

## ...and do the same for jtest() and encomptest().
## Notice that in this particular case they are coincident.
jtest(fm1, fm2)
encomptest(fm1, fm2)
```
Description

Currency Substitution Data.

Usage

data(currencysubstitution)

Format

A multivariate quarterly time series from 1960(4) to 1975(4) with variables

- \( \log\text{CUS} \) logarithm of the ratio of Canadian holdings of Canadian dollar balances and Canadian holdings of U.S. dollar balances,
- \( \text{Iu} \) yield on U.S. Treasury bills,
- \( \text{Ic} \) yield on Canadian Treasury bills,
- \( \log\text{Y} \) logarithm of Canadian real gross national product.

Source

The data was originally studied by Miles (1978), the data set is given in Krämer and Sonnberger (1986). Below we replicate a few examples from their book. Some of these results differ more or less seriously and are sometimes parameterized differently.

References


Examples

data(currencysubstitution)

## page 130, fit Miles OLS model and Bordo-Choudri OLS model
## third and last line in Table 6.3

```r
modelMiles <- logCUS ~ log(((1+Iu)/(I+Ic))
lm(modelMiles, data=currencysubstitution)
 dwtest(modelMiles, data=currencysubstitution)
```

```r
modelBordoChoudri <- logCUS ~ I(Iu-Ic) + Ic + logY
lm(modelBordoChoudri, data=currencysubstitution)
 dwtest(modelBordoChoudri, data=currencysubstitution)
```
dwtest  

**Description**  

Performs the Durbin-Watson test for autocorrelation of disturbances.
Usage

dwtest(formula, order.by = NULL, alternative = c("greater", "two.sided", "less"),
       iterations = 15, exact = NULL, tol = 1e-10, data = list())

Arguments

  formula  a symbolic description for the model to be tested (or a fitted "lm" object).
  order.by Either a vector z or a formula with a single explanatory variable like ~ z. The
           observations in the model are ordered by the size of z. If set to NULL (the default)
           the observations are assumed to be ordered (e.g., a time series).
  alternative a character string specifying the alternative hypothesis.
  iterations an integer specifying the number of iterations when calculating the p-value with
           the "pan" algorithm.
  exact     logical. If set to FALSE a normal approximation will be used to compute the p
           value, if TRUE the "pan" algorithm is used. The default is to use "pan" if the
           sample size is < 100.
  tol       tolerance. Eigenvalues computed have to be greater than tol to be treated as
           non-zero.
  data      an optional data frame containing the variables in the model. By default the
           variables are taken from the environment which dwtest is called from.

Details

The Durbin-Watson test has the null hypothesis that the autocorrelation of the disturbances is 0. It is
possible to test against the alternative that it is greater than, not equal to, or less than 0, respectively.
This can be specified by the alternative argument.

Under the assumption of normally distributed disturbances, the null distribution of the Durbin-
Watson statistic is the distribution of a linear combination of chi-squared variables. The p-value is
computed using the Fortran version of Applied Statistics Algorithm AS 153 by Farebrother (1980,
1984). This algorithm is called "pan" or "gradsol". For large sample sizes the algorithm might fail to
compute the p value; in that case a warning is printed and an approximate p value will be given; this
p value is computed using a normal approximation with mean and variance of the Durbin-Watson
test statistic.

Examples can not only be found on this page, but also on the help pages of the data sets bondyield,
currencysubstitution, growthofmoney, moneydemand, unemployment, wages.

For an overview on R and econometrics see Racine & Hyndman (2002).

Value

An object of class "htest" containing:

  statistic  the test statistic.
  p.value    the corresponding p-value.
  method     a character string with the method used.
  data.name  a character string with the data name.
References


See Also

lm

Examples

```r
## generate two AR(1) error terms with parameter
## rho = 0 (white noise) and rho = 0.9 respectively
err1 <- rnorm(100)

## generate regressor and dependent variable
x <- rep(c(-1), 50)
y1 <- 1 + x + err1

## perform Durbin-Watson test
dwtest(y1 ~ x)

err2 <- filter(err1, 0.9, method="recursive")
y2 <- 1 + x + err2
dwtest(y2 ~ x)
```

encomptest Encompassing Test for Comparing Non-Nested Models

Description

encomptest performs the encompassing test of Davidson & MacKinnon for comparing non-nested models.
Usage

encomptest(formula1, formula2, data = list(), vcov. = NULL, ...)

Arguments

formula1 either a symbolic description for the first model to be tested, or a fitted object of class "lm".
formula2 either a symbolic description for the second model to be tested, or a fitted object of class "lm".
data an optional data frame containing the variables in the model. By default the variables are taken from the environment which encomptest is called from.
vcov. a function for estimating the covariance matrix of the regression coefficients, e.g., vcovHC.
... further arguments passed to waldtest.

Details

To compare two non-nested models, the encompassing test fits an encompassing model which contains all regressors from both models such that the two models are nested within the encompassing model. A Wald test for comparing each of the models with the encompassing model is carried out by waldtest.

For further details, see the references.

Value

An object of class "anova" which contains the residual degrees of freedom in the encompassing model, the difference in degrees of freedom, Wald statistic (either "F" or "Chisq") and corresponding p value.

References


See Also
coxtest, jtest

Examples

## Fit two competing, non-nested models for aggregate consumption, as in Greene (1993), Examples 7.11 and 7.12
## load data and compute lags
data(USDistLag)
**Femal Temperature Data**

**Description**

Daily morning temperature of adult female (in degrees Celsius).

**Usage**

```r
data(ftemp)
```

**Format**

Univariate daily time series of 60 observations starting from 1990-07-11.

**Details**

The data gives the daily morning temperature of an adult woman measured in degrees Celsius at about 6.30am each morning.

At the start of the period the woman was sick, hence the high temperature. Then the usual monthly cycle can be seen. On the second cycle, the temperature doesn’t complete the downward part of the pattern due to a conception.
Source

The data set is taken from the Time Series Data Library at
maintained by Rob Hyndman and Muhammad Akram.

Examples

data(f temp)
plot(f temp)
y <- window(f temp, start = 8, end = 60)
if(require(strucchange)) {
  bp <- breakpoints(y ~ 1)
  plot(bp)
  fm.seg <- lm(y ~ 0 + breakfactor(bp))
  plot(y)
  lines(8:60, fitted(fm.seg), col = 4)
  lines(confint(bp))
}

---

**gqtest**  
*Goldfeld-Quandt Test*

Description

Goldfeld-Quandt test against heteroskedasticity.

Usage

gqtest(formula, point = 0.5, fraction = 0,
       alternative = c("greater", "two.sided", "less"),
       order.by = NULL, data = list())

Arguments

- **formula**: a symbolic description for the model to be tested (or a fitted "lm" object).
- **point**: numerical. If point is smaller than 1 it is interpreted as percentages of data, i.e. n*point is taken to be the (potential) breakpoint in the variances, if n is the number of observations in the model. If point is greater than 1 it is interpreted to be the index of the breakpoint.
- **fraction**: numerical. The number of central observations to be omitted. If fraction is smaller than 1, it is chosen to be fraction*n if n is the number of observations in the model.
- **alternative**: a character string specifying the alternative hypothesis. The default is to test for increasing variances.
order.by
Either a vector \( z \) or a formula with a single explanatory variable like \( \sim z \). The observations in the model are ordered by the size of \( z \). If set to NULL (the default) the observations are assumed to be ordered (e.g., a time series).

data
an optional data frame containing the variables in the model. By default the variables are taken from the environment which gqtest is called from.

Details
The Goldfeld-Quandt test compares the variances of two submodels divided by a specified break-point and rejects if the variances differ. Under \( H_0 \) the test statistic of the Goldfeld-Quandt test follows an F distribution with the degrees of freedom as given in parameter.

Examples can not only be found on this page, but also on the help pages of the data sets bondyield, currencysubstitution, growthofmoney, moneydemand, unemployment, wages.

Value
A list with class "htest" containing the following components:

- statistic: the value of the test statistic.
- p.value: the p-value of the test.
- parameter: degrees of freedom.
- method: a character string indicating what type of test was performed.
- data.name: a character string giving the name(s) of the data.

References


See Also

lm

Examples

```r
## generate a regressor
x <- rep(c(-1,1), 50)
## generate heteroskedastic and homoskedastic disturbances
err1 <- c(rnorm(50, sd=1), rnorm(50, sd=2))
err2 <- rnorm(100)
## generate a linear relationship
y1 <- 1 + x + err1
y2 <- 1 + x + err2
## perform Goldfeld-Quandt test
gqtest(y1 ~ x)
gqtest(y2 ~ x)
```
grangertest (Test for Granger Causality)

Description

grangertest is a generic function for performing a test for Granger causality.

Usage

```r
## Default S3 method:
grangertest(x, y, order = 1, na.action = na.omit, ...)
## S3 method for class 'formula'
grangertest(formula, data = list(), ...)
```

Arguments

- `x`: either a bivariate series (in which case `y` has to be missing) or a univariate series of observations.
- `y`: a univariate series of observations (if `x` is univariate, too).
- `order`: integer specifying the order of lags to include in the auxiliary regression.
- `na.action`: a function for eliminating NAs after aligning the series `x` and `y`.
- `...`: further arguments passed to `waldtest`.
- `formula`: a formula specification of a bivariate series like `y ~ x`.
- `data`: an optional data frame containing the variables in the model. By default the variables are taken from the environment which `grangertest` is called from.

Details

Currently, the methods for the generic function `grangertest` only perform tests for Granger causality in bivariate series. The test is simply a Wald test comparing the unrestricted model—in which `y` is explained by the lags (up to `order`) of `y` and `x`—and the restricted model—in which `y` is only explained by the lags of `y`.

Both methods are simply convenience interfaces to `waldtest`.

Value

An object of class "anova" which contains the residual degrees of freedom, the difference in degrees of freedom, Wald statistic and corresponding p value.

See Also

- `waldtest`, `ChickEgg`
growthofmoney

Examples

```r
## Which came first: the chicken or the egg?
data(ChickEgg) 
grangertest(egg ~ chicken, order = 3, data = ChickEgg) 
grangertest(chicken ~ egg, order = 3, data = ChickEgg)

## alternative ways of specifying the same test 
grangertest(ChickEgg, order = 3) 
grangertest(ChickEgg[, 1], ChickEgg[, 2], order = 3)
```

---

growthofmoney Growth of Money Supply

Description

Growth of Money Supply Data.

Usage

data(growthofmoney)

Format

A multivariate quarterly time series from 1970(2) to 1974(4) with variables

TG1.TG0 difference of current and preceding target for the growth rate of the money supply,
AG0.TG0 difference of actual growth rate and target growth rate for the preceding period.

Source

The data was originally studied by Hetzel (1981), the data set is given in Krämer and Sonnberger (1986). Below we replicate a few examples from their book. Some of these results differ more or less seriously and are sometimes parameterized differently.

References


Examples

```r
data(growthofmoney)

## page 137, fit Hetzel OLS model
## first/second line in Table 6.7
modelHetzel <- TG1.TG0 ~ AG0.TG0
```
### Harvey-Collier Test

**Description**

Harvey-Collier test for linearity.

**Usage**

```
harvtest(formula, order.by = NULL, data = list())
```
Arguments

formula  a symbolic description for the model to be tested (or a fitted "lm" object).
order.by Either a vector z or a formula with a single explanatory variable like ~ z. The observations in the model are ordered by the size of z. If set to NULL (the default) the observations are assumed to be ordered (e.g., a time series).
data an optional data frame containing the variables in the model. By default the variables are taken from the environment which harvtest is called from.

Details

The Harvey-Collier test performs a t-test (with parameter degrees of freedom) on the recursive residuals. If the true relationship is not linear but convex or concave the mean of the recursive residuals should differ from 0 significantly.

Examples can not only be found on this page, but also on the help pages of the data sets bondyield, currencysubstitution, growthofmoney, moneydemand, unemployment, wages.

Value

A list with class "htest" containing the following components:

- statistic the value of the test statistic.
- p.value the p-value of the test.
- parameter degrees of freedom.
- method a character string indicating what type of test was performed.
- data.name a character string giving the name(s) of the data.

References


See Also

lm

Examples

# generate a regressor and dependent variable
x <- 1:50
y1 <- 1 + x + rnorm(50)
y2 <- y1 + 0.3 * x * 2

## perform Harvey-Collier test
harv <- harvtest(y1 ~ x)
harv

## calculate critical value vor 0.05 level
qt(0.05, harv$parameter)
harvtest(y2 ~ x)
hmctest

Harrison-McCabe test for heteroskedasticity.

Usage

hmctest(formula, point = 0.5, order.by = NULL, simulate.p = TRUE, nsim = 1000, plot = FALSE, data = list())

Arguments

- formula: a symbolic description for the model to be tested (or a fitted "lm" object).
- point: numeric. If point is smaller than 1 it is interpreted as percentages of data, i.e. n*point is taken to be the (potential) breakpoint in the variances, if n is the number of observations in the model. If point is greater than 1 it is interpreted to be the index of the breakpoint.
- order.by: Either a vector z or a formula with a single explanatory variable like ~ z. The observations in the model are ordered by the size of z. If set to NULL (the default) the observations are assumed to be ordered (e.g., a time series).
- simulate.p: logical. If TRUE a p value will be assessed by simulation, otherwise the p value is NA.
- nsim: integer. Determines how many runs are used to simulate the p value.
- plot: logical. If TRUE the test statistic for all possible breakpoints is plotted.
- data: an optional data frame containing the variables in the model. By default the variables are taken from the environment which hmctest is called from.

Details

The Harrison-McCabe test statistic is the fraction of the residual sum of squares that relates to the fraction of the data before the breakpoint. Under $H_0$, the test statistic should be close to the size of this fraction, e.g. in the default case close to 0.5. The null hypothesis is reject if the statistic is too small.

Examples can not only be found on this page, but also on the help pages of the data sets bondyield, currency substitution, growth of money, money demand, unemployment, wages.

Value

A list with class "htest" containing the following components:

- statistic: the value of the test statistic.
- p.value: the simulated p-value of the test.
- method: a character string indicating what type of test was performed.
- data.name: a character string giving the name(s) of the data.
References


See Also

lm

Examples

```r
## generate a regressor
x <- rep(c(-1,1), 50)
## generate heteroskedastic and homoskedastic disturbances
err1 <- c(rnorm(50, sd=1), rnorm(50, sd=2))
err2 <- rnorm(100)
## generate a linear relationship
y1 <- 1 + x + err1
y2 <- 1 + x + err2
## perform Harrison-McCabe test
hmctest(y1 ~ x)
hmctest(y2 ~ x)
```

---

### jocci

*U.S. Macroeconomic Time Series*

Description

Several macroeconomic time series from the U.S.

Usage

```r
data(fyff)
data(gmdc)
data(ip)
data(jocci)
data(lhur)
data(pw561)
```

Format

All data sets are multivariate monthly time series from 1959(8) to 1993(12) (except 1993(10) for jocci) with variables

- **y** original time series,
- **dy** transformed times series (first differences or log first differences),
- **dy1** transformed series at lag 1,
\textbf{Details}

The description from Stock & Watson (1996) for the time series (with the transformation used):

- \texttt{fyff} interest rate (first differences),
- \texttt{gmdc} pce, implicit price deflator: pce (1987 = 100) (log first differences),
- \texttt{ip} index of industrial production (log first differences),
- \texttt{jocci} department of commerce commodity price index (log first differences),
- \texttt{lhur} unemployment rate: all workers, 16 years & over (\%, sa) (first differences),
- \texttt{pw561} producer price index: crude petroleum (82 = 100, nsa) (log first differences).

Stock & Watson (1996) fitted an AR(6) model to all transformed time series.

\textbf{Source}

Stock & Watson (1996) study the stability of 76 macroeconomic time series, which can be obtained from Mark W. Watson’s homepage \url{http://www.wws.princeton.edu/~mwatson/}.

\textbf{References}


\textbf{Examples}

\begin{verbatim}
data(jocci)
dwtest(dy ~ 1, data = jocci)
bptest(dy ~ 1, data = jocci)
ar6.model <- dy ~ dy1 + dy2 + dy3 + dy4 + dy5 + dy6
bptest(ar6.model, data = jocci)
var.model <- ~ I(dy1^2) + I(dy2^2) + I(dy3^2) + I(dy4^2) + I(dy5^2) + I(dy6^2)
bptest(ar6.model, var.model, data = jocci)
\end{verbatim}
Description

jtest performs the Davidson-MacKinnon J test for comparing non-nested models.

Usage

jtest(formula1, formula2, data = list(), vcov = NULL, ...)

Arguments

formula1 either a symbolic description for the first model to be tested, or a fitted object of class "lm".
formula2 either a symbolic description for the second model to be tested, or a fitted object of class "lm".
data an optional data frame containing the variables in the model. By default the variables are taken from the environment which jtest is called from.
v cov. a function for estimating the covariance matrix of the regression coefficients, e.g., vcovHC.
... further arguments passed to coeftest.

Details

The idea of the J test is the following: if the first model contains the correct set of regressors, then including the fitted values of the second model into the set of regressors should provide no significant improvement. But if it does, it can be concluded that model 1 does not contain the correct set of regressors.

Hence, to compare both models the fitted values of model 1 are included into model 2 and vice versa. The J test statistic is simply the marginal test of the fitted values in the augmented model. This is performed by coeftest.

For further details, see the references.

Value

An object of class "anova" which contains the coefficient estimate of the fitted values in the augmented regression plus corresponding standard error, test statistic and p value.

References

See Also

coxtest, encomptest

Examples

```r
## Fit two competing, non-nested models for aggregate
## consumption, as in Greene (1993), Examples 7.11 and 7.12

## load data and compute lags
data(USDistLag)
usdl <- na.contiguous(chbind(USDistLag, lag(USDistLag, k = -1)))
colnames(usdl) <- c("con", "gnp", "con1", "gnp1")

## C(t) = a0 + a1*Y(t) + a2*C(t-1) + u
fm1 <- lm(con ~ gnp + con1, data = usdl)

## C(t) = b0 + b1*Y(t) + b2*Y(t-1) + v
fm2 <- lm(con ~ gnp + gnp1, data = usdl)

## Cox test in both directions:
coxtest(fm1, fm2)

## ...and do the same for jtest() and encomptest().
## Notice that in this particular case they are coincident.
jtest(fm1, fm2)
encomptest(fm1, fm2)
```

### lrtest

**Likelihood Ratio Test of Nested Models**

**Description**

`lrtest` is a generic function for carrying out likelihood ratio tests. The default method can be employed for comparing nested (generalized) linear models (see details below).

**Usage**

```r
lrtest(object, ...)
```

## Default S3 method:
lrtest(object, ..., name = NULL)

## S3 method for class 'formula'
lrtest(object, ..., data = list())
**Arguments**

- **object**
  an object. See below for details.
- **...**
  further object specifications passed to methods. See below for details.
- **name**
  a function for extracting a suitable name/description from a fitted model object.
  By default the name is queried by calling `formula`.
- **data**
  a data frame containing the variables in the model.

**Details**

`lrtest` is intended to be a generic function for comparisons of models via asymptotic likelihood ratio tests. The default method consecutively compares the fitted model object `object` with the models passed in `...`. Instead of passing the fitted model objects in `...`, several other specifications are possible. The updating mechanism is the same as for `waldtest`: the models in `...` can be specified as integers, characters (both for terms that should be eliminated from the previous model), update formulas or fitted model objects. Except for the last case, the existence of an `update` method is assumed. See `waldtest` for details.

Subsequently, an asymptotic likelihood ratio test for each two consecutive models is carried out: Twice the difference in log-likelihoods (as derived by the `logLik` methods) is compared with a Chi-squared distribution.

The "formula" method fits a `lm` first and then calls the default method.

**Value**

An object of class "anova" which contains the log-likelihood, degrees of freedom, the difference in degrees of freedom, likelihood ratio Chi-squared statistic and corresponding p value.

**See Also**

`waldtest`

**Examples**

```r
## with data from Greene (1993):
## load data and compute lags
data("USDistLag")
usdl <- na.contiguous(cbind(USDistLag, lag(USDistLag, k = -1)))
colnames(usdl) <- c("con", "gnp", "con1", "gnp1")

fm1 <- lm(con ~ gnp + gnp1, data = usdl)
fm2 <- lm(con ~ gnp + con1 + gnp1, data = usdl)

## various equivalent specifications of the LR test
lrtest(fm2, fm1)
lrtest(fm2, 2)
lrtest(fm2, "con1")
lrtest(fm2, . ~ . - con1)
```
Money Demand Data.

Usage
data(moneydemand)

Description
Money Demand Data.

Usage
data(moneydemand)
Format
A multivariate yearly time series from 1879 to 1974 with variables

- \( \log M \) logarithm of quantity of money,
- \( \log Y_p \) logarithm of real permanent income,
- \( R_s \) short term interest rate,
- \( R_m \) rate of return on money,
- \( R_l \) not documented in the sources,
- \( \log S_{pp} \) logarithm of an operational measure of the variability of the rate of price changes.

Source
The data was originally studied by Allen (1982), the data set is given in Krämer and Sonnberger (1986). Below we replicate a few examples from the book. Some of these results differ more or less seriously and are sometimes parameterized differently.

References


Examples
```
data(moneydemand)
moneydemand <- window(moneydemand, start=1880, end=1972)

## page 125, fit Allen OLS model (and Durbin-Watson test),
## last line in Table 6.1
modelAllen <- logM ~ logYp + Rs + Rl + logSpp
lm(modelAllen, data = moneydemand)
dwtest(modelAllen, data = moneydemand)

## page 127, fit test statistics in Table 6.1 c)
#############################################################

## Breusch-Pagan
bptest(modelAllen, studentize = FALSE, data = moneydemand)
bptest(modelAllen, studentize = TRUE, data = moneydemand)

## RESET
reset(modelAllen, data = moneydemand)
reset(modelAllen, power = 2, type = "regressor", data = moneydemand)
reset(modelAllen, type = "princomp", data = moneydemand)

## Harvey-Collier tests (up to sign of the test statistic)
harvtest(modelAllen, order.by = ~logYp, data = moneydemand)
harvtest(modelAllen, order.by = ~Rs, data = moneydemand)
```
petest

**Description**

The PE test performs the MacKinnon-White-Davidson PE test for comparing linear vs. log-linear specifications in linear regressions.

**Usage**

```r
callpetest(formula1, formula2, data = list(), vcov = NULL, ...)
```

**Arguments**

- `formula1`: either a symbolic description for the first model to be tested, or a fitted object of class "lm".
- `formula2`: either a symbolic description for the second model to be tested, or a fitted object of class "lm".
- `data`: an optional data frame containing the variables in the model. By default the variables are taken from the environment which `petest` is called from.
- `vcov`: a function for estimating the covariance matrix of the regression coefficients, e.g., `vcovHC`.
- `...`: further arguments passed to `coeftest`.

**Details**

The PE test compares two non-nest models where one has a linear specification of type $y \sim x_1 + x_2$ and the other has a log-linear specification of type $\log(y) \sim z_1 + z_2$. Typically, the regressors in the latter model are logs of the regressors in the former, i.e., $z_1$ is $\log(x_1)$ etc.

The idea of the PE test is the following: If the linear specification is correct then adding an auxiliary regressor with the difference of the log-fitted values from both models should be non-significant. Conversely, if the log-linear specification is correct then adding an auxiliary regressor with the
difference of fitted values in levels should be non-significant. The PE test statistic is simply the marginal test of the auxiliary variable(s) in the augmented model(s). In petest this is performed by `coeftest`.

For further details, see the references.

**Value**

An object of class "anova" which contains the coefficient estimate of the auxiliary variables in the augmented regression plus corresponding standard error, test statistic and p value.

**References**


**See Also**

`jtest`, `coctest`, `encomptest`

**Examples**

```r
if(require("AER")) {
  ## Verbeek (2004), Section 3
data("HousePrices", package = "AER")

  ### Verbeek (2004), Table 3.3
  hp_lin <- lm(price ~ ., data = HousePrices)
summary(hp_lin)

  ### Verbeek (2004), Table 3.2
  hp_log <- update(hp_lin, log(price) ~ . - lotsize + log(lotsize))
summary(hp_log)

  ## PE test
  petest(hp_lin, hp_log)

  ## Greene (2003), Example 9.8
  data("USMacroG", package = "AER")

  ## Greene (2003), Table 9.2
  usm_lin <- lm(m1 ~ tbill + gdp, data = USMacroG)
  usm_log <- lm(log(m1) ~ log(tbill) + log(gdp), data = USMacroG)
petest(usm_lin, usm_log)
  ## matches results from Greene's errata
}
```
raintest  

Rainbow Test

Description
Rainbow test for linearity.

Usage
raintest(formula, fraction = 0.5, order.by = NULL, center = NULL, data=list())

Arguments

- **formula**
  a symbolic description for the model to be tested (or a fitted "lm" object).

- **fraction**
  numeric. The percentage of observations in the subset is determined by fraction*n if n is the number of observations in the model.

- **order.by**
  Either a vector z or a formula with a single explanatory variable like ~ z. The observations in the model are ordered by the size of z. If set to NULL (the default) the observations are assumed to be ordered (e.g., a time series). If set to "mahalanobis" then the observations are ordered by their Mahalanobis distances from the mean regressor.

- **center**
  numeric. If center is smaller than 1 it is interpreted as percentages of data, i.e. the subset is chosen that n*fraction observations are around observation number n*center. If center is greater than 1 it is interpreted to be the index of the center of the subset. By default center is 0.5.
  If the Mahalanobis distance is chosen center is taken to be the mean regressor, but can be specified to be a k-dimensional vector if k is the number of regressors and should be in the range of the respective regressors.

- **data**
  an optional data frame containing the variables in the model. By default the variables are taken from the environment which raintest is called from.

Details
The basic idea of the Rainbow test is that even if the true relationship is non-linear, a good linear fit can be achieved on a subsample in the "middle" of the data. The null hypothesis is rejected whenever the overall fit is significantly worse than the fit for the subsample. The test statistic under \( H_0 \) follows an F distribution with parameter degrees of freedom.

Examples can not only be found on this page, but also on the help pages of the data sets bondyield, currencysubstitution, growthofmoney, moneydemand, unemployment, wages.

Value
A list with class "htest" containing the following components:

- **statistic**
  the value of the test statistic.
resettest

p.value  the p-value of the test.
parameter  degrees of freedom.
method  a character string indicating what type of test was performed.
data.name  a character string giving the name(s) of the data.

References


See Also

lm

Examples

```r
x <- c(1:30)
y <- x^2 + rnorm(30,0,2)
rain <- rain<test(y ~ x)

## critical value
qf(0.95, rain$parameter[1], rain$parameter[2])
```

resettest  

*RESET Test*

Description

Ramsey’s RESET test for functional form.

Usage

```
resettest(formula, power = 2:3, type = c("fitted", "regressor", "princomp"), data = list())
```

Arguments

- **formula**: a symbolic description for the model to be tested (or a fitted "lm" object).
- **power**: integers. A vector of positive integers indicating the powers of the variables that should be included. By default, the test is for quadratic or cubic influence of the fitted response.
- **type**: a string indicating whether powers of the fitted response, the regressor variables (factors are left out), or the first principal component of the regressor matrix should be included in the extended model.
- **data**: an optional data frame containing the variables in the model. By default the variables are taken from the environment which resettest is called from.
Details

The RESET test is a popular diagnostic for correctness of functional form. The basic assumption is that under the alternative the model can be written in the form $y = X\beta + Z\gamma + u$. $Z$ is generated by taking powers either of the fitted response, the regressor variables, or the first principal component of $X$. A standard F-Test is then applied to determine whether these additional variables have significant influence. The test statistic under $H_0$ follows an $F$ distribution with parameter degrees of freedom.

This function was called `reset` in previous versions of the package. Please use `resettest` instead.

Examples can not only be found on this page, but also on the help pages of the data sets `bondyield`, `currencysubstitution`, `growthofmoney`, `moneydemand`, `unemployment`, `wages`.

Value

An object of class "htest" containing:

- `statistic` the test statistic.
- `p.value` the corresponding p-value.
- `parameter` degrees of freedom.
- `method` a character string with the method used.
- `data.name` a character string with the data name.

References


See Also

`lm`

Examples

```r
x <- c(1:30)
y1 <- 1 + x + x^2 + rnorm(30)
y2 <- 1 + x + rnorm(30)
resettest(y1 ~ x, power=2, type="regressor")
resettest(y2 ~ x, power=2, type="regressor")
```
**unemployment**

---

**Unemployment Data**

**Description**

Unemployment Data.

**Usage**

data(unemployment)

**Format**

A multivariate yearly time series from 1890 to 1979 with variables

- **UN** unemployment rate,
- **m** broad money supply,
- **p** implicit deflator of Gross National Product,
- **G** real purchases of goods and services,
- **x** real exports.

**Source**

The data was originally studied by Rea (1983), the data set is given in Krämer and Sonnberger (1986). Below we replicate a few examples from their book. Some of these results differ more or less seriously and are sometimes parameterized differently.

**References**


**Examples**

data(unemployment)

```r
## data transformation
myunemployment <- window(unemployment, start=1895, end=1956)
time <- 6:67

## page 144, fit Rea OLS model
## last line in Table 6.12

modelRea <- UN ~ log(m/p) + log(G) + log(x) + time
lm(modelRea, data = myunemployment)
## coefficients of logged variables differ by factor 100
```
## Description

US macroeconomic data for fitting a distributed lag model.

### Usage

data(USDistLag)

### Format

An annual time series from 1963 to 1982 with 2 variables.

- **consumption** real consumption,
- **gnp** gross national product (deflated by CPI).

### Source

Table 7.7 in Greene (1993)
References


Examples

```r
## Willam H. Greene, Econometric Analysis, 2nd Ed.
## Chapter 7
## load data set, p. 221, Table 7.7
data(USDistLag)

## fit distributed lag model, p.221, Example 7.8
usdl <- na.contiguous(cbind(USDistLag, lag(USDistLag, k = -1)))
colnames(usdl) <- c("con", "gnp", "con1", "gnp1")

## C(t) = b0 + b1*Y(t) + b2*C(t-1) + u
fm <- lm(con ~ gnp + con1, data = usdl)
summary(fm)
vcov(fm)
```

---

valueofstocks  
**Value of Stocks**

Description

Value of Stocks Data

Usage

data(valueofstocks)

Format

A multivariate quarterly time series from 1960(1) to 1977(3) with variables

- **VST** value of stocks,
- **MB** monetary base,
- **RTPD** dollar rent on producer durables,
- **RTPS** dollar rent on producer structures,
- **XBC** production capacity for business output.

Source

The data was originally studied by Woglom (1981), the data set is given in Krämer and Sonnberger (1986).
References


Examples

```r
data(woof stocks)
lm(log(VST) ~ , data=woof stocks)
```

<table>
<thead>
<tr>
<th>wages</th>
<th>Wages</th>
</tr>
</thead>
</table>

Description

Wages Data.

Usage

data(wages)

Format

A multivariate yearly time series from 1960 to 1979 with variables

- **w** wages,
- **CPI** consumer price index,
- **u** unemployment,
- **mw** minimum wage.

Source

The data was originally studied by Nicols (1983), the data set is given in Krämer and Sonnberger (1986). Below we replicate a few examples from their book. Some of these results differ more or less seriously and are sometimes parameterized differently.

References


**waldtest**

**waldtest**

**Wald Test of Nested Models**

**Description**

`waldtest` is a generic function for carrying out Wald tests. The default method can be employed for comparing nested (generalized) linear models (see details below).

**Usage**

`waldtest(object, ...)`

**Examples**

```r
data(wages)

## data transformation to include lagged series
mywages <- cbind(wages, lag(wages[,2], k = -1), lag(wages[,2], k = -2))
colnames(mywages) <- c(colnames(wages), "CPI2", "CPI3")
mywages <- window(mywages, start=1962, end=1979)

## page 142, fit Nichols OLS model
## equation (6.10)
modelNichols <- w ~ CPI + CPI2 + CPI3 + u + mw
lm(modelNichols, data = mywages)

## page 143, fit test statistics in table 6.11

if(require(strucchange, quietly = TRUE)) {
  ## Chow 1972
  sctest(modelNichols, point=c(1971,1), data=mywages, type="Chow")

  ## Breusch-Pagan
  bptest(modelNichols, data=mywages, studentize=FALSE)

  ## RESET (a)-(b)
  reset(modelNichols, data=mywages)

  ## Harvey-Collier
  harvtest(modelNichols, order.by = ~ CPI, data=mywages)
  harvtest(modelNichols, order.by = ~ CPI2, data=mywages)
  harvtest(modelNichols, order.by = ~ CPI3, data=mywages)
  harvtest(modelNichols, order.by = ~ u, data=mywages)

  ## Rainbow
  raintest(modelNichols, order.by = "mahalanobis", data=mywages)
}
```
### Default S3 method:
waldtest(object, ..., vcov = NULL,  
        test = c("Chisq", "F"), name = NULL)

### S3 method for class 'formula'
waldtest(object, ..., data = list())

### S3 method for class 'lm'
waldtest(object, ..., test = c("F", "Chisq"))

#### Arguments

object an object. See below for details.

... further object specifications passed to methods. See below for details.

vcov a function for estimating the covariance matrix of the regression coefficients,  
e.g., `vcovHC`. If only two models are compared it can also be the covariance  
matrix of the more general model.

test character specifying whether to compute the large sample Chi-squared statistic  
(with asymptotic Chi-squared distribution) or the finite sample F statistic (with  
approximate F distribution).

name a function for extracting a suitable name/description from a fitted model object.  
By default the name is queried by calling `formula`.

data a data frame containing the variables in the model.

#### Details

waldtest is intended to be a generic function for comparisons of models via Wald tests. The  
default method consecutively compares the fitted model object object with the models passed in  
... Instead of passing the fitted model objects in ..., several other specifications are possible. For  
all objects in list(object, ...) the function tries to consecutively compute fitted models using  
the following updating algorithm:

1. For each two consecutive objects, object1 and object2 say, try to turn object2 into a fitted  
   model that can be compared to (the already fitted model object) object1.

2. If object2 is numeric, the corresponding element of attr(terms(object1), "term.labels")  
is selected to be omitted.

3. If object2 is a character, the corresponding terms are included into an update formula like  
   . ~ . - term2a - term2b.

4. If object2 is a formula, then compute the fitted model via update(object1, object2).

Consequently, the models in ... can be specified as integers, characters (both for terms that should  
be eliminated from the previous model), update formulas or fitted model objects. Except for the last  
case, the existence of an `update` method is assumed. See also the examples for an illustration.

Subsequently, a Wald test for each two consecutive models is carried out. This is similar to `anova`  
(which typically performs likelihood-ratio tests), but with a few differences. If only one fitted  
model object is specified, it is compared to the trivial model (with only an intercept). The test can
be either the finite sample F statistic or the asymptotic Chi-squared statistic \(F = \frac{\text{Chisq}}{k}\) if \(k\) is the difference in degrees of freedom. The covariance matrix is always estimated on the more general of two subsequent models (and not only in the most general model overall). If `vcov` is specified, HC and HAC estimators can also be plugged into `waldtest`.

The default method is already very general and applicable to a broad range of fitted model objects, including `lm` and `glm` objects. It can be easily made applicable to other model classes as well by providing suitable methods to the standard generics `terms` (for determining the variables in the model along with their names), `update` (unless only fitted model objects are passed to `waldtest`, as mentioned above), `nobs` (or `residuals`, used for determining the number of observations), `df.residual` (needed only for the F statistic), `coef` (for extracting the coefficients; needs to be named matching the names in `terms`), `vcov` (can be user-supplied; needs to be named matching the names in `terms`). Furthermore, some means of determining a suitable name for a fitted model object can be specified (by default this is taken to be the result of a call to `formula`, if available).

The "formula" method fits a `lm` first and then calls the "lm" method. The "lm" method just calls the default method, but sets the default test to be the F test.

### Value

An object of class "anova" which contains the residual degrees of freedom, the difference in degrees of freedom, Wald statistic (either "Chisq" or "F") and corresponding p value.

### See Also

`coeftest`, `anova`, `linearHypothesis`

### Examples

```r
## fit two competing, non-nested models and their encompassing
## model for aggregate consumption, as in Greene (1993),
## Examples 7.11 and 7.12

## load data and compute lags
data(USDistLag)
usdl <- na.contiguous(chind(USDistLag, lag(USDistLag, k = -1)))
colnames(usdl) <- c("con", "gnp", "con1", "gnp1")

## C(t) = a0 + a1*Y(t) + a2*C(t-1) + u
fm1 <- lm(con ~ gnp + con1, data = usdl)

## C(t) = b0 + b1*Y(t) + b2*Y(t-1) + v
fm2 <- lm(con ~ gnp + gnp1, data = usdl)

## Encompassing model
fm3 <- lm(con ~ gnp + con1 + gnp1, data = usdl)

## a simple ANOVA for fm3 vs. fm2
waldtest(fm3, fm2)
anova(fm3, fm2)
## as df = 1, the test is equivalent to the corresponding t test in
coeftest(fm3)
```
### Various equivalent specifications of the two models

```r
waldtest(fm3, fm2)
waldtest(fm3, 2)
waldtest(fm3, "con1")
waldtest(fm3, . - . - con1)
```

### Comparing more than one model

```r
# (equivalent to the encompassing test)
waldtest(fm1, fm3, fm2)
encomptest(fm1, fm2)
```

### Using the asymptotic Chisq statistic

```r
# plugging in a HC estimator
if(require(sandwich)) waldtest(fm3, fm2, vcov = vcovHC)
```
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