Package ‘starvars’

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Type Package

Title Vector Logistic Smooth Transition Models Estimation and Prediction

Version 1.1.10

Description Allows the user to estimate a vector logistic smooth transition autoregressive model via maximum log-likelihood or nonlinear least squares. It further permits to test for linearity in the multivariate framework against a vector logistic smooth transition autoregressive model with a single transition variable. The estimation method is discussed in Terasvirta and Yang (2014, <doi:10.1108/S0731-9053(2013)0000031008>). Also, realized covariances can be constructed from stock market prices or returns, as explained in Andersen et al. (2001, <doi:10.1016/S0304-405X(01)00055-1>).

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LazyData true

Depends R (>= 4.0)

Imports MASS, ks, zoo, doSNOW, foreach, methods, matrixcalc, optimParallel, parallel, vars, xts, lessR, quantmod

URL https://github.com/andbucci/starvars

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NeedsCompilation no

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coef.VLSTAR

Coefficient method for objects of class VLSTAR

Description

Returns the coefficients of a VLSTAR model for objects generated by VLSTAR().

Usage

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

Arguments

- object: An object of class ‘VLSTAR’: generated by VLSTAR().
- ...: Currently not used.

Value

Estimated coefficients of the VLSTAR model

Author(s)

Andrea Bucci
References

Examples
```
mean(1:3)
```

---

**Description**
Returns the log-Likelihood of a VLSTAR object.

**Usage**
```
# S3 method for class 'VLSTAR'
logLik(object, type = c('Univariate', 'Multivariate'), ...)
```

**Arguments**
- `object`: An object of class ‘VLSTAR’ obtained through `VLSTAR()`.
- `type`: Type of Log-Likelihood to be showed (univariate or multivariate).
- `...`: further arguments to be passed to and from other methods

**Details**
The log-likelihood of a VLSTAR model is defined as:

\[
\log l(y_t|I_t; \theta) = -\frac{T}{2} \ln(2\pi) - \frac{T}{2} \ln|\Omega| - \frac{1}{2} \sum_{t=1}^{T} (y_t - \hat{G}_t B z_t)' \Omega^{-1} (y_t - \hat{G}_t B z_t)
\]

**Value**
An object with class attribute `logLik`.

**Author(s)**
Andrea Bucci

**See Also**
`VLSTAR`
lrvarbart

*Long-run variance using Bartlett kernel*

**Description**

Function returns the long-run variance of a time series, relying on the Bartlett kernel. The window size of the kernel is the cube root of the sample size.

**Usage**

\[ \text{lrvarbart}(x) \]

**Arguments**

- \( x \) a \((T \times 1)\) vector containing the time series over period \( T \)

**Value**

- \( \text{lrv} \) long-run variance
- \( \text{return} \) bandwidth size of the window

**Author(s)**

Andrea Bucci

**References**


**Examples**

```r
data(Realized)
lrvarbart(Realized[,1])
```

---

multiCUMSUM

*Multivariate CUMSUM test*

**Description**

Function returns the test statistics for the presence of co-breaks in a set of multivariate time series.

**Usage**

\[ \text{multiCUMSUM}(\text{data}, \text{conf.level} = 0.95, \text{max.breaks} = 7) \]

---
Arguments

- `data` a \((T \times N)\) matrix or `data.frame` containing the \(N\) time series over period \(T\)
- `conf.level` Confidence level. By default set to 0.95
- `max.breaks` Integer, determines the highest number of common breaks from 1 to 7.

Value

- **Lambda Test statistics**
  - a matrix of test statistics on the presence of a number of co-break equal to `max.breaks` in the conditional mean

- **Omega Test statistics**
  - a matrix of test statistics on the presence of a number of co-break equal to `max.breaks` in the conditional variance

- **Break location**
  - the index and the Date where the common breaks are located

Author(s)

Andrea Bucci and Giulio Palomba

References


Examples

```r
data(Realized)
testCS <- multiCUMSUM(Realized[,1:10], conf.level = 0.95)
print(testCS)
```

Description

Plot method for objects with class attribute `VLSTAR`. 
Usage

```r
## S3 method for class 'VLSTAR'
plot(
  x,
  names = NULL,
  main.fit = NULL,
  main.acf = NULL,
  main.pacf = NULL,
  main.logi = NULL,
  ylim.fit = NULL,
  ylim.resid = NULL,
  lty.fit = NULL,
  lty.resid = NULL,
  lty.logi = NULL,
  lwd.fit = NULL,
  lwd.resid = NULL,
  lwd.logi = NULL,
  lag.acf = NULL,
  lag.pacf = NULL,
  col.fit = NULL,
  col.resid = NULL,
  col.logi = NULL,
  ylab.fit = NULL,
  ylab.resid = NULL,
  ylab.acf = NULL,
  ylab.pacf = NULL,
  ylab.logi = NULL,
  xlab.fit = NULL,
  xlab.resid = NULL,
  xlab.logi = NULL,
  mar = par("mar"),
  oma = par("oma"),
  adj.mtext = NA,
  padj.mtext = NA,
  col.mtext = NA,
  ...
)
```

Arguments

- `x`: An object of class ‘VLSTAR’.
- `names`: Character vector, the variables names to be plotted. If left NULL, all variables are plotted.
- `main.fit`: Character vector, main for diagram of fit.
- `main.acf`: Character vector, main for residuals’ ACF.
- `main.pacf`: Character vector, main for residuals’ PACF.
- `main.logi`: Character vector, main for the plot of the logistic function.
plot.VLSTAR

ylim.fit Vector, ylim for diagram of fit.
ylim.resid Vector, ylim for residual plot.
lty.fit Vector, lty for diagram of fit.
lty.resid Vector, lty for residual plot.
lty.logi Vector, lty for the plot of the logistic function.
lwd.fit Vector, lwd for diagram of fit.
lwd.resid Vector, lwd for residual plot.
lwd.logi Vector, lwd for the plot of the logistic function.
lag.acf Integer, lag.max for ACF of residuals.
lag.pacf Integer, lag.max for PACF of residuals.
col.fit Character vector, colors for diagram of fit.
col.resid Character vector, colors for residual plot.
col.logi Character vector, colors for logistic function plot.
ylab.fit Character vector, ylab for diagram of fit.
ylab.resid Character vector, ylab for residual plot.
ylab.acf Character, ylab for ACF.
ylab.pacf Character, ylab for PACF
ylab.logi Character vector, ylab for the plot of the logistic function.
xlab.fit Character vector, xlab for diagram of fit.
xlab.resid Character vector, xlab for residual plot.
xlab.logi Character vector, xlab for the plot of the logistic function.
mar Setting of margins.
ona Setting of outer margins.
adj.mtext Adjustment for mtext().
padj.mtext Adjustment for mtext().
col.mtext Character, color for mtext(), only applicable.
... Passed to internal plot function.
main Character vector, the titles of the plot.
xlab Character vector signifying the labels for the x-axis.
ylab Character vector signifying the labels for the y-axis.
ylim Vector, the limits of the y-axis.

Details
When the plot function is applied to a VLSTAR object, the values of the logistic function, given the estimated values of gamma and c through VLSTAR, are reported.

Value
Plot of VLSTAR fitted values, residuals, ACF, PACF and logistic function
Author(s)
Andrea Bucci

See Also
VLSTAR

Description
Plot method for objects with class attribute vlstarpred.

Usage
## S3 method for class 'vlstarpred'
plot(
  x,
  type = c("single", "multiple"),
  names = NULL,
  main = NULL,
  xlab = NULL,
  ylab = NULL,
  lty.obs = 2,
  lty.pred = 1,
  lty.ci = 3,
  lty.vline = 1,
  lwd.obs = 1,
  lwd.pred = 1,
  lwd.ci = 1,
  lwd.vline = 1,
  col.obs = NULL,
  col.pred = NULL,
  col.ci = NULL,
  col.vline = NULL,
  ylim = NULL,
  mar = par("mar"),
  oma = par("oma"),
  ...
)

Arguments

x An object of class 'vlstarpred'.
type Character, if multiple all plots are drawn in a single device, otherwise the plots are shown consecutively.
### plot.vlstarpred

- **names**: Character vector, the variables names to be plotted. If left NULL, all variables are plotted.
- **main**: Character vector, the titles of the plot.
- **xlab**: Character vector signifying the labels for the x-axis.
- **ylab**: Character vector signifying the labels for the y-axis.
- **lty.obs**: Vector, lty for the plot of the observed values.
- **lty.pred**: Vector, lty for the plot of the predicted values.
- **lty.ci**: Vector, lty for the interval forecast.
- **lty.vline**: Vector, lty for the vertical line.
- **lwd.obs**: Vector, lwd for the plot of the observed values.
- **lwd.pred**: Vector, lwd for the plot of the predicted values.
- **lwd.ci**: Vector, lwd for the interval forecast.
- **lwd.vline**: Vector, lwd for the vertical line.
- **col.obs**: Character vector, colors for the observed values.
- **col.pred**: Character vector, colors for the predicted values.
- **col.ci**: Character vector, colors for the interval forecast.
- **col.vline**: Character vector, colors for the vertical line.
- **ylim**: Vector, the limits of the y-axis.
- **mar**: Setting of margins.
- **oma**: Setting of outer margins.
- **...**: Passed to internal plot function.

### Value

Plot of predictions from VLSTAR with their prediction interval

### Author(s)

Andrea Bucci

### See Also

- [predict.VLSTAR](#)
predict.VLSTAR  

VLSTAR Prediction

Description

One-step or multi-step ahead forecasts, with interval forecast, of a VLSTAR object.

Usage

```r
## S3 method for class 'VLSTAR'
predict(
  object,
  ..., 
  n.ahead = 1,
  conf.lev = 0.95,
  st.new = NULL,
  M = 5000,
  B = 1000,
  st.num = NULL,
  newdata = NULL,
  method = c("naive", "Monte Carlo", "bootstrap")
)
```

Arguments

- `object`: An object of class `'VLSTAR'` obtained through `VLSTAR()`
- `...`: further arguments to be passed to and from other methods
- `n.ahead`: An integer specifying the number of ahead predictions
- `conf.lev`: Confidence level of the interval forecast
- `st.new`: Vector of new data for the transition variable
- `M`: An integer with the number of errors sampled for the Monte Carlo method
- `B`: An integer with the number of errors sampled for the bootstrap method
- `st.num`: An integer with the index of dependent variable if `st.new` is `NULL` and the transition variable is a lag of one of the dependent variables
- `newdata`: data.frame or matrix of new data for the exogenous variables
- `method`: A character identifying which multi-step ahead method should be used among naive, Monte Carlo and bootstrap

Value

A list containing:

- `forecasts`: data.frame of predictions for each dependent variable and the \((1 - \alpha)\) prediction intervals
- `y`: a matrix of values for \(y\)
Author(s)
Andrea Bucci and Eduardo Rossi

References

See Also
VLSTAR for log-likehood and nonlinear least squares estimation of the VLSTAR model.

print.VLSTAR

Description
‘print’ methods for class ‘VLSTAR’.

Usage
## S3 method for class 'VLSTAR'
print(x, ...)

Arguments
x An object of class ‘VLSTAR’ obtained through VLSTAR().
... further arguments to be passed to and from other methods

Value
Print of VLSTAR results

Author(s)
Andrea Bucci

References

See Also
VLSTAR
Description

Function returns the vectorization of the lowest triangular of the Realized Covariance matrices for different frequencies.

Usage

```r
ccov(
data,  
freq = c("daily", "monthly", "quarterly", "yearly"),  
make.ret = TRUE,  
cholesky = FALSE)
```

Arguments

data a (T x N) xts object containing the N price/return series over period T
freq a string defining the desired frequency for the Realized Covariance matrices between "daily", "monthly", "quarterly" or "yearly"
make.ret boolean, in case it is TRUE the data are converted in returns, FALSE otherwise
cholesky boolean, in case it is TRUE the Cholesky factors of the Realized Covariance matrices are calculated, FALSE by default

Value

- Realized Covariances
  a $M \times N(N+1)/2$ matrix of realized covariances, where $M$ is the number of lower frequency data
- Cholesky Factors (optional)
  a $M \times N(N+1)/2$ matrix of Cholesky factors of the realized covariance matrices, where $M$ is the number of lower frequency data
- returns (optional)
  a $T \times N$ matrix of returns, when make.ret = TRUE

Author(s)

Andrea Bucci

References


**Realized**

**Examples**

```r
data(Sample5minutes)
rc <- rcov(Sample5minutes, freq = 'daily', cholesky = TRUE, make.ret = TRUE)
print(rc)
```

---

**Realized**

*Monthly time series used to test VLSTAR models.*

---

**Description**

This data set contains the series of realized covariances in 4 stock market indices, i.e. SP-500, Nikkei, DAX, and FTSE, Dividend Yield and Earning Price growth rate, inflation growth rates for U.S., U.K., Japan and Germany, from August 1990 to June 2018.

**Usage**

```r
data(Realized)
```

**Format**

A zoo data frame with 334 monthly observations, ranging from 1990:M8 until 2018:M6.

- **SP**: Monthly realized variances of S&P 500 index.
- **SP-NIKKEI**: Monthly realized covariances between S&P 500 and Nikkei.
- **SP-FTSE**: Monthly realized covariances between S&P 500 and FTSE.
- **SP-DAX**: Monthly realized covariances between S&P 500 and DAX.
- **NIKKEI**: Monthly realized variances of Nikkei index.
- **NIKKEI-FTSE**: Monthly realized covariances between Nikkei and FTSE.
- **NIKKEI-DAX**: Monthly realized covariances between Nikkei and DAX.
- **FTSE**: Monthly realized variances of FTSE index.
- **FTSE-DAX**: Monthly realized covariances between FTSE and DAX.
- **DAX**: Monthly realized variances of DAX index.
- **DP**: Monthly Dividends growth rate over the past year relative to current market prices; S&P 500 index.
- **EP**: Monthly Earnings growth rate over the past year relative to current market prices; S&P500 index.
- **Inf_US**: US monthly Industrial Production growth.
- **Inf_UK**: UK monthly Industrial Production growth.
- **Inf_JPN**: Japan monthly Industrial Production growth.
- **Inf_GER**: Germany monthly Industrial Production growth.

**Author(s)**

Andrea Bucci
See Also

rcov to build realized covariances from stock prices or returns.

---

Sample5minutes  

Ten simulated prices series for 19 trading days in January 2010.

Description

Ten hypothetical price series were simulated according to the factor diffusion process discussed in Barndorff-Nielsen et al.

Usage

data("Sample5minutes")

Format

xts object

Author(s)

Andrea Bucci

---

startingVLSTAR  

Starting parameters for a VLSTAR model

Description

This function allows the user to obtain the set of starting values of Gamma and C for the convergence algorithm via searching grid.

Usage

startingVLSTAR(
  y,
  exo = NULL,
  p = 1,
  m = 2,
  st = NULL,
  constant = TRUE,
  n.combi = NULL,
  ncores = 2,
  singlecgamma = FALSE
)
Arguments

- **y**: data.frame or matrix of dependent variables of dimension \((T \times n)\)
- **exo**: (optional) data.frame or matrix of exogenous variables of dimension \((T \times k)\)
- **p**: lag order
- **m**: number of regimes
- **st**: single transition variable for all the equation of dimension \((T \times 1)\)
- **constant**: TRUE or FALSE to include or not the constant
- **n.combi**: Number of combination for the searching grid of Gamma and C
- **ncores**: Number of cores used for parallel computation. Set to 2 by default
- **singlecgamma**: TRUE or FALSE to use single gamma and c

Details

The searching grid algorithm allows for the optimal choice of the parameters \(\gamma\) and \(c\) by minimizing the sum of the Squared residuals for each possible combination.

The parameter \(c\) is initialized by using the mean of the dependent(s) variable, while \(\gamma\) is sampled between 0 and 100.

Value

An object of class `startingVLSTAR`.

Author(s)

Andrea Bucci

References


See Also

- `VLSTAR`

Examples

```r
data(Realized)
y <- Realized[-1,1:10]
y <- y[-nrow(y),1]
st <- Realized[-nrow(Realized),1]
```
st <- st[-length(st)]
starting <- startingVLSTAR(y, p = 1, n.combi = 3,
    singlecgamma = FALSE, st = st,
    ncores = 1)

summary.VLSTAR

---

Summary method for objects of class `VLSTAR`

**Description**

‘s`summary` methods for class ‘`VLSTAR`’.

**Usage**

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

```r
## S3 method for class 'summary.VLSTAR'
print(x, ...)
```

**Arguments**

- `object` An object of class ‘`VLSTAR`’ obtained through `VLSTAR()`.
- `...` further arguments to be passed to and from other methods
- `x` A summary object of class ‘`VLSTAR`’ obtained through `summary()`.

**Value**

An object of class `summary.VLSTAR` containing a list of summary information from `VLSTAR` estimates. When `print` is applied to this object, summary information are printed.

**Functions**

- `print.summary.VLSTAR`: Print of the summary

**Author(s)**

Andrea Bucci

**References**


**See Also**

`VLSTAR`
techprices  Daily closing prices of 3 tech stocks.

Description
This data set contains the series of daily prices of Google, Microsoft and Amazon stocks from January 3, 2005 to June 16, 2020, gathered from Yahoo.

Usage
data("techprices")

Format
An xts object with 3890 daily observations, ranging from from January 3, 2005 to June 16, 2020.

- Google  daily closing prices of Google (GOOG) stock.
- Microsoft daily closing prices of Microsoft (MSFT) stock.
- Amazon  daily closing stock prices of Amazon (AMZN) stock.

Author(s)
Andrea Bucci

VLSTAR  VLSTAR- Estimation

Description
This function allows the user to estimate the coefficients of a VLSTAR model with $m$ regimes through maximum likelihood or nonlinear least squares. The set of starting values of Gamma and C for the convergence algorithm can be either passed or obtained via searching grid.

Usage
VLSTAR(
y,
exo = NULL,
p = 1,
m = 2,
st = NULL,
constant = TRUE,
starting = NULL,
method = c("ML", "NLS"),
n.iter = 500,
singlecgamma = FALSE,
epsilon = 10^(-3),
ncores = NULL
)

Arguments

y data.frame or matrix of dependent variables of dimension (T\times n)
exo (optional) data.frame or matrix of exogenous variables of dimension (T\times k)
p lag order
m number of regimes
st single transition variable for all the equation of dimension (T\times 1)
constant TRUE or FALSE to include or not the constant
starting set of initial values for Gamma and C, inserted as a list of length m-1. Each
element of the list should contain a data.frame with 2 columns (one for Gamma
and one for c), and n rows.
method Fitting method: maximum likelihood or nonlinear least squares.
n.iter number of iteration of the algorithm until forced convergence
singlecgamma TRUE or FALSE to use single gamma and c
epsilon convergence check measure
ncores Number of cores used for parallel computation. Set to NULL by default and
automatically calculated.

Details

The multivariate smooth transition model is an extension of the smooth transition regression model
introduced by Bacon and Watts (1971) (see also Anderson and Vahid, 1998). The general model is

\[ y_t = \mu_0 + \sum_{j=1}^p \Phi_{0,j} y_{t-j} + A_0 x_t^\prime \cdot G_t(s_t; \gamma, c)[\mu_1 + \sum_{j=1}^p \Phi_{1,j} y_{t-j} + A_1 x_t] + \varepsilon_t \]

where \( \mu_0 \) and \( \mu_1 \) are the \( \tilde{n} \times 1 \) vectors of intercepts, \( \Phi_{0,j} \) and \( \Phi_{1,j} \) are square \( \tilde{n} \times \tilde{n} \) matrices of
parameters for lags \( j = 1, 2, \ldots, p \), \( A_0 \) and \( A_1 \) are \( \tilde{n} \times k \) matrices of parameters, \( x_t \) is the \( k \times 1 \)
vector of exogenous variables and \( \varepsilon_t \) is the innovation. Finally, \( G_t(s_t; \gamma, c) \) is a \( \tilde{n} \times \tilde{n} \) diagonal
matrix of transition function at time \( t \), such that

\[ G_t(s_t; \gamma, c) = \{ G_{1,t}(s_{1,t}; \gamma_1, c_1), G_{2,t}(s_{2,t}; \gamma_2, c_2), \ldots, G_{\tilde{n},t}(s_{\tilde{n},t}; \gamma_{\tilde{n}}, c_{\tilde{n}}) \}. \]

Each diagonal element \( G_{r,t}^t(s_{r,t}^t; \gamma_r, c_r) \) is specified as a logistic cumulative density functions, i.e.

\[ G_{r,t}^t(s_{r,t}^t; \gamma_r, c_r) = \left[ 1 + \exp \left\{ - \gamma_r^t (s_{r,t}^t - c_r^t) \right\} \right]^{-1} \]

for \( latex \) and \( r = 0, 1, \ldots, m - 1 \), so that the first model is a Vector Logistic Smooth Transition
AutoRegressive (VLSTAR) model. The ML estimator of \( \theta \) is obtained by solving the optimization
problem

\[ \hat{\theta}_{ML} = \arg \max_{\theta} \log L(\theta) \]
where $\log L(\theta)$ is the log-likelihood function of VLSTAR model, given by

$$l_l(y_t|I_t; \theta) = -\frac{Tn}{2} \ln(2\pi) - \frac{T}{2} \ln |\Omega| - \frac{1}{2} \sum_{t=1}^{T} (y_t - \tilde{G}_t B z_t)'\Omega^{-1}(y_t - \tilde{G}_t B z_t)$$

The NLS estimators of the VLSTAR model are obtained by solving the optimization problem

$$\hat{\theta}_{NLS} = \arg \min_{\theta} \sum_{t=1}^{T} (y_t - \Psi'_t B' x_t)'(y_t - \Psi'_t B' x_t).$$

Generally, the optimization algorithm may converge to some local minimum. For this reason, providing valid starting values of $\theta$ is crucial. If there is no clear indication on the initial set of parameters, $\theta$, this can be done by implementing a grid search. Thus, a discrete grid in the parameter space of $\Gamma$ and $C$ is create to obtain the estimates of $B$ conditionally on each point in the grid. The initial pair of $\Gamma$ and $C$ producing the smallest sum of squared residuals is chosen as initial values, then the model is linear in parameters. The algorithm is the following:

1. Construction of the grid for $\Gamma$ and $C$, computing $\Psi$ for each point in the grid
2. Estimation of $\hat{B}$ in each equation, calculating the residual sum of squares, $Q_t$
3. Finding the pair of $\Gamma$ and $C$ providing the smallest $Q_t$
4. Once obtained the starting-values, estimation of parameters, $B$, via nonlinear least squares (NLS)
5. Estimation of $\Gamma$ and $C$ given the parameters found in step 4
6. Repeat step 4 and 5 until convergence.

Value

An object of class VLSTAR, with standard methods.

Author(s)

Andrea Bucci

References


Examples

data(Realized)
y <- Realized[-1,1:10]
y <- y[-nrow(y),]
VLSTARjoint

Joint linearity test

Description

This function allows the user to test linearity against a Vector Smooth Transition Autoregressive Model with a single transition variable.

Usage

VLSTARjoint(y, exo = NULL, st, st.choice = FALSE, alpha = 0.05)

Arguments

y  
data.frame or matrix of dependent variables of dimension (Txn)
exo  
(optional) data.frame or matrix of exogenous variables of dimension (Txk)
st  
single transition variable for all the equation of dimension (Tx1)
st.choice  
boolean identifying whether the transition variable should be selected from a matrix of R potential variables of dimension (TxR)
alpha  
Confidence level

Details

Given a VLSTAR model with a unique transition variable, $s_{1t} = s_{2t} = \ldots = s_{\tilde{n}t} = s_t$, a generalization of the linearity test presented in Luukkonen, Saikkonen and Terasvirta (1988) may be implemented.

Assuming a 2-state VLSTAR model, such that

$$y_t = B_1 z_t + G_t B_2 z_t + \epsilon_t.$$  

Where the null $H_0 : \gamma_j = 0, j = 1, \ldots, \tilde{n}$, is such that $G_t \equiv (1/2)/\tilde{n}$ and the previous Equation is linear. When the null cannot be rejected, an identification problem of the parameter $\epsilon_j$ in the
transition function emerges, that can be solved through a first-order Taylor expansion around \( \gamma_j = 0 \).

The approximation of the logistic function with a first-order Taylor expansion is given by

\[
G(s_t; \gamma_j, c_j) = \frac{1}{2} + \frac{1}{4} \gamma_j(s_t - c_j) + r_{jt}
\]

\[
= a_j s_t + b_j + r_{jt}
\]

where \( a_j = \gamma_j/4 \), \( b_j = 1/2 - a_j c_j \) and \( r_j \) is the error of the approximation. If \( G_t \) is specified as follows

\[
G_t = \text{diag}\{a_1 s_t + b_1, \ldots, a_n s_t + b_n, r_{1t}, \ldots, r_{nt}\}
\]

\[
= As_t + B + R_t
\]

where \( A = \text{diag}(a_1, \ldots, a_n) \), \( B = \text{diag}(b_1, \ldots, b_n) \) e \( R_t = \text{diag}(r_{1t}, \ldots, r_{nt}) \), \( y_t \) can be written as

\[
y_t = B_1 z_t + (A s_t + B + R_t) B_2 z_t + \varepsilon_t
\]

\[
= (B_1 + B B_2) z_t + AB_2 s_t z_t + R_t B_2 z_t + \varepsilon_t
\]

\[
= \Theta_0 z_t + \Theta_1 z_t s_t + \varepsilon_t^*
\]

where \( \Theta_0 = B_1 + B_2^T B \), \( \Theta_1 = B_2' A \) and \( \varepsilon_t^* = R_t B_2 + \varepsilon_t \). Under the null, \( \Theta_0 = B_1 \) and \( \Theta_1 = 0 \), while the previous model is linear, with \( \varepsilon_t^* = \varepsilon_t \). It follows that the Lagrange multiplier test, under the null, is derived from the score

\[
\frac{\partial \log L(\hat{\theta})}{\partial \Theta_1} = \sum_{t=1}^T z_t s_t (y_t - B_1 z_t)' \hat{\Omega}^{-1} = S(Y - Z\hat{B}_1)' \hat{\Omega}^{-1},
\]

where

\[
S = z_1' s_1; z_t' s_t
\]

and where \( \hat{\Omega} \) and \( \hat{B}_1 \) are estimated from the model in \( H_0 \). If \( P_Z = Z(Z' Z)^{-1} Z' \) is the projection matrix of \( Z \), the LM test is specified as follows

\[
LM = tr\{\hat{\Omega}^{-1}(Y - Z\hat{B}_1)' S' [S' (I_t - P_Z) S]^{-1} S' (Y - Z\hat{B}_1) \}.
\]

Under the null, the test statistics is distributed as a \( \chi^2 \) with \( \tilde{n}(p \cdot \tilde{n} + k) \) degrees of freedom.

**Value**

An object of class `VLSTARjoint`.

**Author(s)**

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