

# 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](https://doi.org/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](https://doi.org/10.1016/S0304-405X(01)00055-1)>).

**License** GPL

**Encoding** UTF-8

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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**

Terasvirta T. and Yang Y. (2014), Specification, Estimation and Evaluation of Vector Smooth Transition Autoregressive Models with Applications. *CREATES Research Paper 2014-8*

**Examples**

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

---

logLik.VLSTAR	<i>Log-Likelihood method</i>
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---

**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:

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

**Value**

An object with class attribute logLik.

**Author(s)**

Andrea Bucci

**See Also**

[VLSTAR](#)

---

lrvarbart	<i>Long-run variance using Bartlett kernel</i>
-----------	--

---

**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**

```
lrvarbart(x)
```

**Arguments**

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

**Value**

lrv	long-run variance
return	bandwidth size of the window

**Author(s)**

Andrea Bucci

**References**

Hamilton J. D. (1994), Time Series Analysis. *Princeton University Press*; Tsay R.S. (2005), Analysis of Financial Time Series. *John Wiley & SONS*

**Examples**

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

---

multiCUMSUM	<i>Multivariate CUMSUM test</i>
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---

**Description**

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

**Usage**

```
multiCUMSUM(data, conf.level = 0.95, max.breaks = 7)
```

**Arguments**

data	a (T x 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**

Aue A., Hormann S., Horvath L. and Reimherr M. (2009), Break detection in the covariance structure of multivariate time series models. *The Annals of Statistics*. 37: 4046-4087  
 Bai J., Lumsdaine R. L. and Stock J. H. (1998), Testing For and Dating Common Breaks in Multivariate Time Series. *Review of Economic Studies*. 65: 395-432  
 Barassi M., Horvath L. and Yuqian Z. (2018), Change-Point Detection in the Conditional Correlation Structure of Multivariate Volatility Models. *Journal of Business & Economic Statistics*

**Examples**

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

---

 plot.VLSTAR

---

*Plot methods for a VLSTAR object*


---

**Description**

Plot method for objects with class attribute VLSTAR.

**Usage**

```
## 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.

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.
oma	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](#)

---

plot.vlstarpred	<i>Plot methods for a vlstarpred object</i>
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---

**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.



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

```
## 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**

Granger C.W.J. and Terasvirta T. (1993), Modelling Non-Linear Economic Relationships. *Oxford University Press*;

Lundbergh S. and Terasvirta T. (2007), Forecasting with Smooth Transition Autoregressive Models. *John Wiley and Sons*;

Terasvirta T. and Yang Y. (2014), Specification, Estimation and Evaluation of Vector Smooth Transition Autoregressive Models with Applications. *CREATES Research Paper 2014-8*

**See Also**

[VLSTAR](#) for log-likelihood and nonlinear least squares estimation of the VLSTAR model.

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print.VLSTAR

*Print method for objects of class 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**

Terasvirta T. and Yang Y. (2014), Specification, Estimation and Evaluation of Vector Smooth Transition Autoregressive Models with Applications. *CREATES Research Paper 2014-8*

**See Also**

[VLSTAR](#)

---

rcov *Realized Covariance*

---

### Description

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

### Usage

```
rcov(
  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

Andersen T.G., Bollerslev T., Diebold F.X. and Labys P. (2003), Modeling and Forecasting Realized Volatility. *Econometrica*. 71: 579-625

Barndorff-Nielsen O.E. and Shephard N. (2002), Econometric analysis of realised volatility and its use in estimating stochastic volatility models *Journal of the Royal Statistical Society*. 64(2): 253-280

**Examples**

```
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**

```
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	<i>Ten simulated prices series for 19 trading days in January 2010.</i>
----------------	---

---

**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	<i>Starting parameters for a VLSTAR model</i>
----------------	---

---

**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 (Txn)
exo	(optional) data.frame or matrix of exogenous variables of dimension (Txk)
p	lag order
m	number of regimes
st	single transition variable for all the equation of dimension (Tx1)
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**

Anderson H.M. and Vahid F. (1998), Testing multiple equation systems for common nonlinear components. *Journal of Econometrics*. 84: 1-36

Bacon D.W. and Watts D.G. (1971), Estimating the transition between two intersecting straight lines. *Biometrika*. 58: 525-534

Terasvirta T. and Yang Y. (2014), Specification, Estimation and Evaluation of Vector Smooth Transition Autoregressive Models with Applications. *CREATES Research Paper 2014-8*

**See Also**

[VLSTAR](#)

**Examples**

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

```
st <- st[-length(st)]
starting <- startingVLSTAR(y, p = 1, n.combi = 3,
                           singlegamma = FALSE, st = st,
                           ncores = 1)
```

---

summary.VLSTAR

*Summary method for objects of class VLSTAR*

---

## Description

'summary' methods for class 'VLSTAR'.

## Usage

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

## 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

Terasvirta T. and Yang Y. (2014), Specification, Estimation and Evaluation of Vector Smooth Transition Autoregressive Models with Applications. *CREATES Research Paper 2014-8*

## See Also

[VLSTAR](#)



---

techprices	<i>Daily closing prices of 3 tech stocks.</i>
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---

**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

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VLSTAR	<i>VLSTAR- Estimation</i>
--------	---------------------------

---

**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

<code>y</code>	data.frame or matrix of dependent variables of dimension (Txn)
<code>exo</code>	(optional) data.frame or matrix of exogenous variables of dimension (Txk)
<code>p</code>	lag order
<code>m</code>	number of regimes
<code>st</code>	single transition variable for all the equation of dimension (Tx1)
<code>constant</code>	TRUE or FALSE to include or not the constant
<code>starting</code>	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.
<code>method</code>	Fitting method: maximum likelihood or nonlinear least squares.
<code>n.iter</code>	number of iteration of the algorithm until forced convergence
<code>singlecgamma</code>	TRUE or FALSE to use single gamma and c
<code>epsilon</code>	convergence check measure
<code>ncores</code>	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

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

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  $j = 1, 2, \dots, p$ ,  $A_0$  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

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

Each diagonal element  $G_{i,t}^r$  is specified as a logistic cumulative density functions, i.e.

$$G_{i,t}^r(s_{i,t}^r; \gamma_i^r, c_i^r) = [1 + \exp\{-\gamma_i^r(s_{i,t}^r - c_i^r)\}]^{-1}$$

for *latex* and  $r = 0, 1, \dots, m - 1$ , 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

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

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 created 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

- Anderson H.M. and Vahid F. (1998), Testing multiple equation systems for common nonlinear components. *Journal of Econometrics*. 84: 1-36
- Bacon D.W. and Watts D.G. (1971), Estimating the transition between two intersecting straight lines. *Biometrika*. 58: 525-534
- Terasvirta T. and Yang Y. (2014), Specification, Estimation and Evaluation of Vector Smooth Transition Autoregressive Models with Applications. *CREATES Research Paper 2014-8*

## Examples

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

```

st <- Realized[-nrow(Realized),1]
st <- st[-length(st)]
stvalues <- startingVLSTAR(y, p = 1, n.combi = 3,
  singlecgamma = FALSE, st = st, ncores = 1)
fit.VLSTAR <- VLSTAR(y, p = 1, singlecgamma = FALSE, starting = stvalues,
  n.iter = 1, st = st, method = 'NLS', ncores = 1)
# a few methods for VLSTAR
print(fit.VLSTAR)
summary(fit.VLSTAR)
plot(fit.VLSTAR)
predict(fit.VLSTAR, st.num = 1, n.ahead = 1)
logLik(fit.VLSTAR, type = 'Univariate')
coef(fit.VLSTAR)

```

---

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

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

### Details

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

Assuming a 2-state VLSTAR model, such that

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

Where the null  $H_0 : \gamma_j = 0, j = 1, \dots, \tilde{n}$ , 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  $c_j$  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

$$\begin{aligned} G(s_t; \gamma_j, c_j) &= (1/2) + (1/4)\gamma_j(s_t - c_j) + r_{jt} \\ &= a_j s_t + b_j + r_{jt} \end{aligned}$$

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

$$\begin{aligned} G_t &= \text{diag}\{a_1 s_t + b_1 + r_{1t}, \dots, a_n s_t + b_n + r_{nt}\} \\ &= A s_t + B + R_t \end{aligned}$$

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

$$\begin{aligned} y_t &= B_1 z_t + (A s_t + B + R_t) B_2 z_t + \varepsilon_t \\ &= (B_1 + B B_2) z_t + A B_2 z_t s_t + R_t B_2 z_t + \varepsilon_t \\ &= \Theta_0 z_t + \Theta_1 z_t s_t + \varepsilon_t^* \end{aligned}$$

where  $\Theta_0 = B_1 + B_2' B$ ,  $\Theta_1 = B_2' A$  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

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

where

$$S = z_1' s_1 : z_t' s_t$$

and where  $\tilde{B}_1$  and  $\tilde{\Omega}$  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

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

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)

Andrea Bucci

## References

- Luukkonen R., Saikkonen P. and Terasvirta T. (1988), Testing Linearity Against Smooth Transition Autoregressive Models. *Biometrika*, 75: 491-499
- Terasvirta T. and Yang Y. (2015), Linearity and Misspecification Tests for Vector Smooth Transition Regression Models. *CREATES Research Paper 2014-4*

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