Package ‘starvars’

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Type Package

Title Vector Logistic Smooth Transition Models / Realized Covariances Construction

Version 1.1.1

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 (>= 3.5.0)

Imports MASS, ks, zoo, data.table, methods, matrixcalc, vars, maxLik, rlist, fGarch, lubridate, xts, lessR, quantmod

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

NeedsCompilation no

Author Andrea Bucci [aut, cre, cph],
Giulio Palomba [aut],
Eduardo Rossi [aut],
Andrea Faragalli [ctb]

Maintainer Andrea Bucci <andrea.bucci@unich.it>

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R topics documented:

`coef` *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.

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

Examples

```
##
##See 'VLSTAR' examples
##
```

`logLik` *Log-Likelihood method*

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)

The code was written by 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

Examples

```
##
##See 'VLSTAR' examples
##
```

`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

```
lrvarbart(x)
```

Arguments

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

Value

`lrv`	long-run variance
`bandwidth`	size of the window

Author(s)

The code was written by 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 *Multivariate CUMSUM test*

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)
## S3 method for class 'multiCUMSUM'
print(x, ...)
```

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.
`x`	object of class '`multiCUMSUM`'
`...`	further arguments to be passed to and from other methods

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)

The code was written by 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)
testCS
```

---

plot *Plot methods for a VLSTAR object*

Description

Plot method for objects with class attribute `VLSTAR` and `vlstarpred`.

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,...)



## 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

`adj.mtext`	Adjustment for `mtext()`.
`col.ci`	Character vector, colors for the interval forecast when an object of class '`vlstarpred`' is used.
`col.fit`	Character vector, colors for diagram of fit.
`col.logi`	Character vector, colors for logistic function plot.

`col.mtext`	Character, color for `mtext()`, only applicable.
`col.obs`	Character vector, colors for the observed values when an object of class ‘`vlstarpred`’ is used.
`col.pred`	Character vector, colors for the predicted values when an object of class ‘`vlstarpred`’ is used.
`col.resid`	Character vector, colors for residual plot.
`col.vline`	Character vector, colors for the vertical line when an object of class ‘`vlstarpred`’ is used.
`lag.acf`	Integer, lag.max for ACF of residuals.
`lag.pacf`	Integer, lag.max for PACF of residuals.
`lty.ci`	Vector, lty for the interval forecast when an object of class ‘`vlstarpred`’ is used.
`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.
`lty.obs`	Vector, lty for the plot of the observed values when an object of class ‘`vlstarpred`’ is used.
`lty.pred`	Vector, lty for the plot of the predicted values when an object of class ‘`vlstarpred`’ is used.
`lty.vline`	Vector, lty for the vertical line when an object of class ‘`vlstarpred`’ is used.
`lwd.ci`	Vector, lwd for the interval forecast when an object of class ‘`vlstarpred`’ is used.
`lwd.fit`	Vector, lwd for diagram of fit.
`lwd.logi`	Vector, lwd for the plot of the logistic function.
`lwd.obs`	Vector, lwd for the plot of the observed values when an object of class ‘`vlstarpred`’ is used.
`lwd.pred`	Vector, lwd for the plot of the predicted values when an object of class ‘`vlstarpred`’ is used.
`lwd.resid`	Vector, lwd for residual plot.
`lwd.vline`	Vector, lwd for the vertical line when an object of class ‘`vlstarpred`’ is used.
`main`	Character vector, the titles of the plot.
`main.acf`	Character vector, main for residuals’ ACF.
`main.fit`	Character vector, main for diagram of fit.
`main.pacf`	Character vector, main for residuals’ PACF.
`main.logi`	Character vector, main for the plot of the logistic function.
`mar`	Setting of margins.
`names`	Character vector, the variables names to be plotted. If left `NULL`, all variables are plotted.
`oma`	Setting of outer margins.
`padj.mtext`	Adjustment for `mtext()`.

type	Character, if `multiple` all plots are drawn in a single device, otherwise the plots are shown consecutively.
x	An object of class 'VLSTAR' or 'vlstarpred'.
xlab	Character vector signifying the labels for the x-axis.
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.
ylab	Character vector signifying the labels for the y-axis.
ylab.acf	Character, ylab for ACF.
ylab.fit	Character vector, ylab for diagram of fit.
ylab.pacf	Character, ylab for PACF
ylab.resid	Character vector, ylab for residual plot.
ylab.logi	Character vector, ylab for the plot of the logistic function.
ylim	Vector, the limits of the y-axis.
ylim.fit	Vector, ylim for diagram of fit.
ylim.resid	Vector, ylim for residual plot.
...	Passed to internal plot function.

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.

Author(s)

Andrea Bucci

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`, `predict.VLSTAR`

Examples

```
##
##See 'VLSTAR' examples
##
```

predict — *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
`method`	A character identifying which multi-step ahead method should be used among `naive`, `Monte Carlo` and `bootstrap`
`newdata`	`data.frame` or `matrix` of new data for the exogenous variables

Value

A `list` containing:

`forecasts`	`data.frame` of predictions for each dependent variable and the (1-α) prediction intervals
`y`	a matrix of values for y

Author(s)

The code was written by 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-likehood and nonlinear least squares estimation of the VLSTAR model.

Examples

```
##
##See 'VLSTAR' examples
##
```

---

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 $M \times N$ matrix of returns, when `make.ret = TRUE`

Author(s)

The code was written by 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)
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` *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

summary *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 'VLSTAR'
print.summary(x, ...)
```

Arguments

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

Value

A data frame of predictions for each dependent variable and the (1-α) prediction intervals.

Author(s)

The code was written by 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

Examples

```
##
##See 'VLSTAR' examples
##
```

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

Description

This data set contains the series of daily prices of Google, Microsof 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, n.combi = NULL,
       method = c('ML', 'NLS'), n.iter = 500, epsilon = 10^(-3))
## S3 method for class 'VLSTAR'
print(x, ...)
```

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
`starting`	(optional) set of intial 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.
`n.combi`	Number of combination for the searching grid of Gamma and C
`method`	Fitting method: maximum likelihood or nonlinear least squares.
`n.iter`	number of iteration of the algorithm until forced convergence
`epsilon`	convergence check measure
`x`	An object of class '`VLSTAR`' obtained through `VLSTAR()` to be printed.
`...`	further arguments to be passed to and from other methods

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 μ_0 and μ_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 ε_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 $G^r_{i,t}$ is specified as a logistic cumulative density functions, i.e.

$$G^r_{i,t}(s^r_{i,t};\gamma^r_i,c^r_i) = \left[1 + \exp\left\{-\gamma^r_i(s^r_{i,t} - c^r_i)\right\}\right]^{-1}$$

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 θ is obtained by solving the optimization problem

$$\hat{\theta}_{ML} = arg \max_{\theta} logL(\theta)$$

where $logL(\theta)$ is the log-likelihood function of VLSTAR model, given by

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

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 θ is crucial. If there is no clear indication on the initial set of parameters, θ, this can be done by implementing a grid search. Thus, a discrete grid in the parameter space of Γ and C is create to obtain the estimates of B conditionally on each point in the grid. The initial pair of Γ 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 Γ and C, computing Ψ for each poin in the grid
2. Estimation of $\hat{B}$ in each equation, calculating the residual sum of squares, Q_t
3. Finding the pair of Γ 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 Γ 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)

The code was written by 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

`VLSTARjoint` to test the presence of a unique transition variable among equations and `predict.VLSTAR` for details on predictions produced for this model; `summary`, `coef`, `plot`, `logLik`

Examples

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

```
st <- Realized[-nrow(Realized),1]
st <- st[-length(st)]
fit.VLSTAR <- VLSTAR(y, p = 1, n.combi = 3,
n.iter = 3, st = st, method ='NLS')

# a few methods for VLSTAR
summary(fit.VLSTAR)
plot(fit.VLSTAR)
predict(fit.VLSTAR, newdata = Realized[nrow(Realized),1:10])
logLik(fit.VLSTAR)
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, st, st.choice = FALSE, alpha = 0.05)
## S3 method for class 'VLSTARjoint'
print(x, ...)
```

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`	a vector with single transition variable for all the equation of dimension `(Tx1)` or a matrix with `R` potential variables of dimension `(TxR)`
`st.choice`	boolean identifying whether the transition variable should be selected from a matrix of `R` potential variables of dimension `(TxR)`
`alpha`	Confidence level
`x`	'VLSTARjoint' object
`...`	further arguments to be passed to and from other methods

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

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

Where the null $H_0 : \gamma_j = 0$, $j = 1, \ldots, \widetilde{n}$, is such that $G_t \equiv (1/2)/\widetilde{n}$ 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

$$\begin{aligned} G_t &= diag\big\{a_1 s_t + b_1 + r_{1t}, \ldots, a_{\widetilde{n}} s_t + b_{\widetilde{n}} + r_{\widetilde{n}t}\big\} \\ &= A s_t + B + R_t \end{aligned}$$

where $A = diag(a_1, \ldots, a_{\widetilde{n}})$, $B = diag(b_1, \ldots, b_{\widetilde{n}})$ e $R_t = diag(r_{1t}, \ldots, r_{\widetilde{n}t})$, 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

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

where

$$S = z_1' s_1 \vdots z_t' s_t$$

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

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

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

Value

An object of class VLSTARjoint.

Author(s)

The code was written by 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*

See Also

VLSTAR for log-likehood and for NLS estimation of the VLSTAR model.

Examples

```
data(Realized)
VLSTARjoint(Realized[-1,1:10], Realized[-1,11:16], st=Realized[1:(nrow(Realized)-1),1])
```

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