

Package ‘mtarm’

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Type Package

Title Bayesian Estimation of Multivariate Threshold Autoregressive Models

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Description Estimation, inference and forecasting using the Bayesian approach for multivariate threshold autoregressive (TAR) models in which the distribution used to describe the noise process belongs to the class of Gaussian variance mixtures.

Imports methods, stats, utils, graphics, Formula, grDevices, GIGrvg, coda, mvtnorm, future.apply, progressr, future

BugReports <https://github.com/lhvanegasp/mtarm/issues>

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ars	<i>Auxiliary function to specify the number of regimes and lag orders</i>
-----	---

Description

This auxiliary function defines the regime structure of a multivariate TAR model by specifying the number of regimes and the corresponding lag orders for the endogenous, exogenous, and threshold series in each regime.

Usage

```
ars(nregim = 1, p = 1, q = 0, d = 0)
```

Arguments

nregim	A positive integer indicating the total number of regimes.
p	A list of positive integers specifying the autoregressive order of the output series within each regime.
q	A list of non-negative integers specifying the maximum lag of the exogenous series within each regime.
d	A list of non-negative integers specifying the maximum lag of the threshold series within each regime.

Value

A list containing the number of regimes and the regime-specific lag-order specifications.

as.mcmc.mtar

*Coercion of mtar objects to mcmc objects***Description**

This method converts an object of class `mtar` into a list of `mcmc` objects, each corresponding to a Markov chain produced during Bayesian estimation.

Usage

```
## S3 method for class 'mtar'
as.mcmc(x, ...)
```

Arguments

`x` an object of class `mtar` obtained from a call to `mtar()`.
`...` additional arguments passed to specific coercion methods.

Value

A list of `mcmc` objects containing the posterior simulation draws generated by the `mtar()` routine.

See Also

[as.mcmc](#)

Examples

```
##### Example 1: Returns of the closing prices of three financial indexes
data(returns)
fit1 <- mtar(~ COLCAP + BOVESPA | SP500, data=returns, row.names=Date,
            subset={Date<="2016-03-14"}, dist="Student-t",
            ars=ars(nregim=3,p=c(1,1,2)), n.burnin=2000, n.sim=3000,
            n.thin=2)
fit1.mcmc <- coda::as.mcmc(fit1)
summary(fit1.mcmc)

##### Example 2: Rainfall and two river flows in Colombia
data(riverflows)
fit2 <- mtar(~ Bedon + LaPlata | Rainfall, data=riverflows, row.names=Date,
            subset={Date<="2009-04-04"}, dist="Laplace",
            ars=ars(nregim=3,p=5), n.burnin=2000, n.sim=3000, n.thin=2)
fit2.mcmc <- coda::as.mcmc(fit2)
summary(fit2.mcmc)

##### Example 3: Temperature, precipitation, and two river flows in Iceland
data(iceland.rf)
fit3 <- mtar(~ Jokulsa + Vatnsdalsa | Temperature | Precipitation,
            data=iceland.rf, subset={Date<="1974-12-21"}, row.names=Date,
```

```

ars=ars(nregim=2,p=15,q=4,d=2), n.burnin=2000, n.sim=3000,
n.thin=2, dist="Slash")
fit3.mcmc <- coda::as.mcmc(fit3)
summary(fit3.mcmc)

```

coef.mtar	<i>coef method for objects of class mtar</i>
-----------	--

Description

coef method for objects of class mtar

Usage

```

## S3 method for class 'mtar'
coef(object, ..., FUN = mean)

```

Arguments

object	an object of class mtar obtained from a call to the mtar() function.
...	additional arguments passed to FUN.
FUN	a function to be applied to the MCMC chains associated with each model parameter. By default, FUN is set to mean.

Value

A list containing the summary statistics obtained by applying FUN to the MCMC chains of each model parameter.

DIC	<i>Deviance Information Criterion (DIC)</i>
-----	---

Description

Computes the Deviance Information Criterion (DIC), an adjusted within-sample measure of predictive accuracy, for models estimated using Bayesian methods.

Usage

```
DIC(...)
```

Arguments

...	one or more fitted model objects of the same class.
-----	---

Value

A numeric matrix containing the DIC values corresponding to each fitted object supplied in . . .

References

Spiegelhalter D.J., Best N.G., Carlin B.P. and Van Der Linde A. (2002) Bayesian Measures of Model Complexity and Fit. *Journal of the Royal Statistical Society Series B (Statistical Methodology)*, 64(4), 583–639.

Spiegelhalter D.J., Best N.G., Carlin B.P. and Van der Linde A. (2014). The deviance information criterion: 12 years on. *Journal of the Royal Statistical Society Series B (Statistical Methodology)*, 76(3), 485–493.

DIC.mtar

Deviance Information Criterion (DIC) for objects of class mtar

Description

This function computes the Deviance Information Criterion (DIC) for objects of class *mtar*.

Usage

```
## S3 method for class 'mtar'
DIC(...)
```

Arguments

. . . one or several objects of the class *mtar*.

Value

A numeric matrix containing the DIC values corresponding to each *mtar* object in the input.

See Also

[WAIC](#)

Examples

```
##### Example 1: Returns of the closing prices of three financial indexes
data(returns)
fit1a <- mtar(~ COLCAP + BOVESPA | SP500, data=returns, row.names=Date,
             subset={Date<="2016-03-14"}, dist="Student-t",
             ars=ars(nregim=3,p=c(1,1,2)), n.burnin=2000, n.sim=3000,
             n.thin=2)
fit1b <- update(fit1a,dist="Slash")
fit1c <- update(fit1a,dist="Laplace")
DIC(fit1a,fit1b,fit1c)
```

```
##### Example 2: Rainfall and two river flows in Colombia
data(riverflows)
fit2a <- mtar(~ Bedon + LaPlata | Rainfall, data=riverflows, row.names=Date,
             subset={Date<="2009-04-04"}, dist="Laplace",
             ars=ars(nregim=3,p=5), n.burnin=2000, n.sim=3000, n.thin=2)
fit2b <- update(fit2a,dist="Slash")
fit2c <- update(fit2a,dist="Student-t")
DIC(fit2a,fit2b,fit2c)

##### Example 3: Temperature, precipitation, and two river flows in Iceland
data(iceland.rf)
fit3a <- mtar(~ Jokulsa + Vatnsdalsa | Temperature | Precipitation,
             data=iceland.rf, subset={Date<="1974-12-21"}, row.names=Date,
             ars=ars(nregim=2,p=15,q=4,d=2), n.burnin=2000, n.sim=3000,
             n.thin=2, dist="Slash")
fit3b <- update(fit3a,dist="Laplace")
fit3c <- update(fit3a,dist="Student-t")
DIC(fit3a,fit3b,fit3c)
```

geweke.diagTAR

Geweke's convergence diagnostic for mtar objects

Description

This function computes Geweke's convergence diagnostic for Markov chain Monte Carlo (MCMC) output obtained from Bayesian estimation of multivariate TAR models. It is a wrapper around `geweke.diag()` that applies the diagnostic to the posterior chains returned by a call to `mtar()`.

Usage

```
geweke.diagTAR(x, frac1 = 0.1, frac2 = 0.5)
```

Arguments

<code>x</code>	An object of class <code>mtar</code> returned by the function <code>mtar()</code> .
<code>frac1</code>	A numeric value in $(0, 1)$ specifying the fraction of the initial part of each chain to be used in the diagnostic.
<code>frac2</code>	A numeric value in $(0, 1)$ specifying the fraction of the final part of each chain to be used in the diagnostic.

Value

A list containing the Geweke z-scores for the parameters of the `mtar` model.

See Also

[geweke.diag](#)

geweke.plotTAR	<i>Geweke-Brooks plot for objects of class mtar</i>
----------------	---

Description

This function is a wrapper around `geweke.plot()` that applies the Geweke-Brooks convergence diagnostic to the MCMC chains obtained from a fitted `mtar` model.

Usage

```
geweke.plotTAR(  
  x,  
  frac1 = 0.1,  
  frac2 = 0.5,  
  nbins = 20,  
  pvalue = 0.05,  
  auto.layout = TRUE,  
  ask,  
  ...  
)
```

Arguments

<code>x</code>	An object of class <code>mtar</code> returned by a call to <code>mtar()</code> .
<code>frac1</code>	fraction to use from beginning of chain
<code>frac2</code>	fraction to use from end of chain
<code>nbins</code>	Number of segments
<code>pvalue</code>	p-value used to plot confidence limits for the null hypothesis
<code>auto.layout</code>	If TRUE then, set up own layout for plots, otherwise use existing one
<code>ask</code>	If TRUE then prompt user before displaying each page of plots. Default is <code>dev.interactive()</code> .
<code>...</code>	Additional graphical parameters passed to the plotting routines.

See Also

[geweke.plot](#)

HPDinterval.mtar *Highest Posterior Density intervals for objects of class mtar*

Description

Highest Posterior Density intervals for objects of class mtar

Usage

```
## S3 method for class 'mtar'
HPDinterval(obj, prob = 0.95, ...)
```

Arguments

obj	an object of class mtar generated by a call to the function mtar().
prob	a numeric scalar in the interval (0, 1) giving the target probability content of the intervals. By default, prob is set to 0.95.
...	Optional additional arguments for methods. None are used at present.

See Also

[HPDinterval](#)

iceland.rf *Temperature, precipitation, and two river flows in Iceland*

Description

This data set contains two daily river-flow time series, measured in cubic meters per second, for rivers in Iceland from January 1, 1972, to December 12, 1974. Additionally, daily measurements of precipitation (in millimeters) and temperature (in degrees Celsius) were recorded at the Hveravellir meteorological station. The precipitation values correspond to the accumulated precipitation up to 9:00 A.M. relative to the same time on the previous day.

Usage

```
data(iceland.rf)
```

Format

A data frame with 1,096 rows and 5 variables:

Vatnsdalsa Numeric vector representing the daily flow of the Vatnsdalsá river.

Jokulsa Numeric vector representing the daily flow of the Jökulsá Eystrí river.

Precipitation Numeric vector of daily precipitation amounts (millimeters).

Temperature Numeric vector of daily temperature measurements (degrees Celsius).

Date Vector indicating the calendar date of each observation.

References

Tong, Howell (1990) Non-linear Time Series: A Dynamical System Approach. Oxford University Press. Oxford, UK.

Ruey S., Tsay (1998) Testing and Modeling Multivariate Threshold Models. Journal of the American Statistical Association, 93, 1188-1202.

Examples

```
data(iceland.rf)
dev.new()
plot(ts(as.matrix(iceland.rf[, -5])), main="Iceland")
```

mtar	<i>Bayesian estimation of a multivariate Threshold Autoregressive (TAR) model.</i>
------	--

Description

This function implements a Gibbs sampling algorithm to draw samples from the posterior distribution of the parameters of a multivariate Threshold Autoregressive (TAR) model and its special cases as SETAR and VAR models. The procedure accommodates a wide range of noise process distributions, including Gaussian, Student-*t*, Slash, Symmetric Hyperbolic, Contaminated normal, Laplace, Skew-normal, and Skew-Student-*t*.

Usage

```
mtar(
  formula,
  data,
  subset,
  Intercept = TRUE,
  trend = c("none", "linear", "quadratic"),
  nseason = NULL,
  ars = ars(),
  row.names,
  dist = c("Gaussian", "Student-t", "Hyperbolic", "Laplace", "Slash",
    "Contaminated normal", "Skew-Student-t", "Skew-normal"),
  prior = list(),
  n.sim = 500,
  n.burnin = 100,
  n.thin = 1,
  ssvs = FALSE,
  setar = NULL,
  progress = TRUE,
  ...
)
```

Arguments

formula	A three-part expression of class Formula describing the TAR model to be fitted. The first part specifies the variables in the multivariate output series, the second part defines the threshold series, and the third part specifies the variables in the multivariate exogenous series.
data	A data frame containing the variables in the model. If not found in data, the variables are taken from <code>environment(formula)</code> , typically the environment from which <code>mtar_grid()</code> is called.
subset	An optional vector specifying a subset of observations to be used in the fitting process.
Intercept	An optional logical indicating whether an intercept should be included within each regime.
trend	An optional character string specifying the degree of deterministic time trend to be included in each regime. Available options are "linear", "quadratic", and "none". By default, trend is set to "none".
nseason	An optional integer, greater than or equal to 2, specifying the number of seasonal periods. When provided, <code>nseason - 1</code> seasonal dummy variables are added to the regressors within each regime. By default, nseason is set to NULL, thereby indicating that the TAR model has no seasonal effects.
ars	A list defining the autoregressive structure of the model. It contains four components: the number of regimes (<code>nregim</code>), the autoregressive order within each regime (<code>p</code>), and the maximum lags for the exogenous (<code>q</code>) and threshold (<code>d</code>) series in each regime. The object can be validated using the helper function <code>ars()</code> .
row.names	An optional variable in data labelling the time points corresponding to each row of the data set.
dist	A character string specifying the multivariate distributions used to model the noise process. Available options are "Gaussian", "Student-t", "Slash", "Hyperbolic", "Laplace", "Contaminated normal", "Skew-normal", and "Skew-Student-t". By default, dist is set to "Gaussian".
prior	An optional list specifying the hyperparameter values that define the prior distribution. This list can be validated using the <code>priors()</code> function. By default, prior is set to an empty list, thereby indicating that the hyperparameter values should be set so that a non-informative prior distribution is obtained.
n.sim	An optional positive integer specifying the number of simulation iterations after the burn-in period. By default, n.sim is set to 500.
n.burnin	An optional positive integer specifying the number of burn-in iterations. By default, n.burnin is set to 100.
n.thin	An optional positive integer specifying the thinning interval. By default, n.thin is set to 1.
ssvs	An optional logical indicating whether the Stochastic Search Variable Selection (SSVS) procedure should be applied to identify relevant lags of the output, exogenous, and threshold series. By default, ssvs is set to FALSE.
setar	An optional positive integer indicating the component of the output series used as the threshold variable. By default, setar is set to NULL, indicating that the fitted model is not a SETAR model.

progress An optional logical indicating whether a progress bar should be displayed during execution. By default, progress is set to TRUE.

... further arguments passed to or from other methods.

Value

an object of class *mtar* in which the main results of the model fitted to the data are stored, i.e., a list with components including

chains list with several arrays, which store the values of each model parameter in each iteration of the simulation

n.sim number of iterations of the simulation after the burn-in period,

n.burnin number of burn-in iterations in the simulation,

n.thin thinning interval in the simulation,

ars list composed of four objects, namely: nregim, p, q and d, each of which corresponds to a vector of non

dist name of the multivariate distribution used to describe the behavior of the noise process,

threshold.series vector with the values of the threshold series,

output.series matrix with the values of the output series,

exogenous.series matrix with the values of the exogenous series,

Intercept If TRUE, then the model included an intercept term in each regime,

trend the degree of the deterministic time trend, if any,

nseason the number of seasonal periods, if any,

formula the formula,

call the original function call.

References

- Nieto, F.H. (2005) Modeling Bivariate Threshold Autoregressive Processes in the Presence of Missing Data. *Communications in Statistics - Theory and Methods*, 34, 905-930.
- Romero, L.V. and Calderon, S.A. (2021) Bayesian estimation of a multivariate TAR model when the noise process follows a Student-t distribution. *Communications in Statistics - Theory and Methods*, 50, 2508-2530.
- Calderon, S.A. and Nieto, F.H. (2017) Bayesian analysis of multivariate threshold autoregressive models with missing data. *Communications in Statistics - Theory and Methods*, 46, 296-318.

Vanegas, L.H. and Calderón, S.A. and Rondón, L.M. (2025) Bayesian estimation of a multivariate tar model when the noise process distribution belongs to the class of gaussian variance mixtures. *International Journal of Forecasting*.

See Also

[DIC, WAIC](#)

Examples

```
##### Example 1: Returns of the closing prices of three financial indexes
data(returns)
fit1 <- mtar(~ COLCAP + BOVESPA | SP500, data=returns, row.names=Date,
            subset={Date<="2016-03-14"}, dist="Student-t",
            ars=ars(nregim=3,p=c(1,1,2)), n.burnin=2000, n.sim=3000,
            n.thin=2, ssvs=TRUE)
summary(fit1)

##### Example 2: Rainfall and two river flows in Colombia
data(riverflows)
fit2 <- mtar(~ Bedon + LaPlata | Rainfall, data=riverflows, row.names=Date,
            subset={Date<="2009-04-04"}, dist="Laplace", ssvs=TRUE,
            ars=ars(nregim=3,p=5), n.burnin=2000, n.sim=3000, n.thin=2)
summary(fit2)

##### Example 3: Temperature, precipitation, and two river flows in Iceland
data(iceland.rf)
fit3 <- mtar(~ Jokulsa + Vatnsdalsa | Temperature | Precipitation,
            data=iceland.rf, subset={Date<="1974-12-21"}, row.names=Date,
            ars=ars(nregim=2,p=15,q=4,d=2), n.burnin=2000, n.sim=3000,
            n.thin=2, dist="Slash")
summary(fit3)
```

mtar_grid

Bayesian Estimation of Multivariate TAR Models

Description

This function is a wrapper that applies `mtar()` over a grid of model specifications defined by all combinations of the noise distribution (`dist`), the number of regimes (from `nregim.min` to `nregim.max`), the autoregressive order within each regime (from `p.min` to `p.max`), the maximum lag of the exogenous series within each regime (from `q.min` to `q.max`), and the maximum lag of the threshold series within each regime (from `d.min` to `d.max`). In all calls to `mtar()`, the same set of time points is used for model fitting. This is achieved by appropriately adjusting the `subset` argument of `mtar()` for each model specification, thereby ensuring comparability across models.

Usage

```

mtar_grid(
  formula,
  data,
  subset,
  Intercept = TRUE,
  trend = c("none", "linear", "quadratic"),
  nseason = NULL,
  nregim.min = 1,
  nregim.max = NULL,
  p.min = 1,
  p.max = NULL,
  q.min = 0,
  q.max = 0,
  d.min = 0,
  d.max = 0,
  row.names,
  dist = "Gaussian",
  prior = list(),
  n.sim = 500,
  n.burnin = 100,
  n.thin = 1,
  ssvs = FALSE,
  setar = NULL,
  plan_strategy = c("sequential", "multisession"),
  progress = TRUE
)

```

Arguments

formula	A three-part expression of class Formula describing the TAR model to be fitted. The first part specifies the variables in the multivariate output series, the second part defines the threshold series, and the third part specifies the variables in the multivariate exogenous series.
data	A data frame containing the variables in the model. If not found in data, the variables are taken from environment(formula), typically the environment from which mtar_grid() is called.
subset	An optional vector specifying a subset of observations to be used in the fitting process.
Intercept	An optional logical indicating whether an intercept should be included within each regime.
trend	An optional character string specifying the degree of deterministic time trend to be included in each regime. Available options are "linear", "quadratic", and "none". By default, trend is set to "none".
nseason	An optional integer, greater than or equal to 2, specifying the number of seasonal periods. When provided, nseason - 1 seasonal dummy variables are added to

	the regressors within each regime. By default, <code>nseason</code> is set to <code>NULL</code> , thereby indicating that the TAR model has no seasonal effects.
<code>nregim.min</code>	An optional integer specifying the minimum number of regimes. By default, <code>nregim.min</code> is set to 1.
<code>nregim.max</code>	An integer specifying the maximum number of regimes.
<code>p.min</code>	An optional integer specifying the minimum autoregressive order within each regime. By default, <code>p.min</code> is set to 1.
<code>p.max</code>	An integer specifying the maximum autoregressive order within each regime.
<code>q.min</code>	An optional integer specifying the minimum value of the maximum lag of the exogenous series within each regime. By default, <code>q.min</code> is set to 0.
<code>q.max</code>	An optional integer specifying the maximum value of the maximum lag of the exogenous series within each regime. By default, <code>q.max</code> is set to 0.
<code>d.min</code>	An optional integer specifying the minimum value of the maximum lag of the threshold series within each regime. By default, <code>d.min</code> is set to 0.
<code>d.max</code>	An optional integer specifying the maximum value of the maximum lag of the threshold series within each regime. By default, <code>d.max</code> is set to 0.
<code>row.names</code>	An optional variable in data labelling the time points corresponding to each row of the data set.
<code>dist</code>	A character vector specifying the multivariate distributions used to model the noise process. Available options are "Gaussian", "Student-t", "Slash", "Hyperbolic", "Laplace", "Contaminated normal", "Skew-normal", and "Skew-Student-t". By default, <code>dist</code> is set to "Gaussian".
<code>prior</code>	An optional list specifying the hyperparameter values that define the prior distribution. This list can be validated using the <code>priors()</code> function. By default, <code>prior</code> is set to an empty list, thereby indicating that the hyperparameter values should be set so that a non-informative prior distribution is obtained.
<code>n.sim</code>	An optional positive integer specifying the number of simulation iterations after the burn-in period. By default, <code>n.sim</code> is set to 500.
<code>n.burnin</code>	An optional positive integer specifying the number of burn-in iterations. By default, <code>n.burnin</code> is set to 100.
<code>n.thin</code>	An optional positive integer specifying the thinning interval. By default, <code>n.thin</code> is set to 1.
<code>ssvs</code>	An optional logical indicating whether the Stochastic Search Variable Selection (SSVS) procedure should be applied to identify relevant lags of the output, exogenous, and threshold series. By default, <code>ssvs</code> is set to <code>FALSE</code> .
<code>setar</code>	An optional positive integer indicating the component of the output series used as the threshold variable. By default, <code>setar</code> is set to <code>NULL</code> , indicating that the fitted model is not a SETAR model.
<code>plan_strategy</code>	An optional character string specifying the execution strategy for parallel computation. Available options are "sequential" and "multisession". By default, <code>plan_strategy</code> is set to "sequential".
<code>progress</code>	An optional logical indicating whether a progress bar should be displayed during execution. By default, <code>progress</code> is set to <code>TRUE</code> .

Value

A list whose elements are objects of class `mtar`, each corresponding to a distinct model specification considered in the grid.

See Also

`mtar`

<code>out.of.sample</code>	<i>Out-of-sample predictive accuracy measures</i>
----------------------------	---

Description

Computes out-of-sample predictive accuracy measures for one or more fitted models of the same class, based on their predictive distributions.

Usage

```
out.of.sample(..., newdata, n.ahead)
```

Arguments

<code>...</code>	one or more fitted model objects of the same class.
<code>newdata</code>	a data frame containing the future values of the output series required to evaluate predictive performance.
<code>n.ahead</code>	a positive integer specifying the number of forecast steps ahead to use in the predictive performance evaluation.

<code>predict.mtar</code>	<i>Forecasting for multivariate TAR models</i>
---------------------------	--

Description

Computes forecasts from a fitted multivariate Threshold Autoregressive (TAR) model.

Usage

```
## S3 method for class 'mtar'
predict(
  object,
  ...,
  newdata,
  n.ahead = 1,
  row.names,
  credible = 0.95,
  out.of.sample = FALSE
)
```

Arguments

object	An object of class <code>mtar</code> obtained from a call to <code>mtar()</code> .
...	Additional arguments that may affect the prediction method.
newdata	An optional <code>data.frame</code> containing future values of the threshold series (if included in the fitted model), the exogenous series (if included in the fitted model), and, when <code>out.of.sample = TRUE</code> , the realized values of the output series.
n.ahead	A positive integer specifying the number of steps ahead to forecast.
row.names	An optional variable in <code>newdata</code> specifying labels for the time
credible	An optional numeric value in $(0, 1)$ specifying the level of the required credible intervals. By default, <code>credible</code> is set to <code>0.95</code> .
out.of.sample	An optional logical indicator. If <code>TRUE</code> then the log-score, Absolute Error (AE), Absolute Percentage Error (APE) and Squared Error (SE) are computed as measures of predictive accuracy. In this case, <code>newdata</code> must include the observed values of the output series.

Value

A list containing the forecast summaries and, when requested, measures of predictive accuracy.

<code>ypred</code>	a matrix with the results of the forecasting,
<code>summary</code>	a matrix with the mean and credible intervals of the forecasting,

References

- Nieto, F.H. (2005) Modeling Bivariate Threshold Autoregressive Processes in the Presence of Missing Data. *Communications in Statistics - Theory and Methods*, 34, 905-930.
- Romero, L.V. and Calderon, S.A. (2021) Bayesian estimation of a multivariate TAR model when the noise process follows a Student-t distribution. *Communications in Statistics - Theory and Methods*, 50, 2508-2530.
- Calderon, S.A. and Nieto, F.H. (2017) Bayesian analysis of multivariate threshold autoregressive models with missing data. *Communications in Statistics - Theory and Methods*, 46, 296-318.
- Karlsson, S. (2013) Chapter 15-Forecasting with Bayesian Vector Autoregression. In Elliott, G. and Timmermann, A. *Handbook of Economic Forecasting*, Volume 2, 791–89, Elsevier.
- Vanegas, L.H. and Calderón, S.A. and Rondón, L.M. (2025) Bayesian estimation of a multivariate tar model when the noise process distribution belongs to the class of gaussian variance mixtures. *International Journal of Forecasting*.

Examples

```
##### Example 1: Returns of the closing prices of three financial indexes
data(returns)
fit1 <- mtar(~ COLCAP + BOVESPA | SP500, data=returns, row.names=Date,
            subset={Date<="2016-03-14"}, dist="Student-t",
            ars=ars(nregim=3,p=c(1,1,2)), n.burnin=2000, n.sim=3000,
```

```

n.thin=2, ssvs=TRUE)
out1 <- predict(fit1, newdata=subset(returns,Date>"2016-03-14"), n.ahead=10)
out1$summary

##### Example 2: Rainfall and two river flows in Colombia
data(riverflows)
fit2 <- mtar(~ Bedon + LaPlata | Rainfall, data=riverflows, row.names=Date,
             subset={Date<="2009-04-04"}, dist="Laplace",
             ars=ars(nregim=3,p=5), n.burnin=2000, n.sim=3000, n.thin=2)
out2 <- predict(fit2, newdata=subset(riverflows,Date>"2009-04-04"), n.ahead=10)
out2$summary

##### Example 3: Temperature, precipitation, and two river flows in Iceland
data(iceland.rf)
fit3 <- mtar(~ Jokulsa + Vatnsdalsa | Temperature | Precipitation,
             data=iceland.rf, subset={Date<="1974-12-21"}, row.names=Date,
             ars=ars(nregim=2,p=15,q=4,d=2), n.burnin=2000, n.sim=3000,
             n.thin=2)
out3 <- predict(fit3, newdata=subset(iceland.rf,Date>"1974-12-21"), n.ahead=10)
out3$summary

```

priors

Auxiliary function for setting hyperparameter values

Description

This function constructs and validates the list of hyperparameter values used to define the prior distributions of the model parameters. Hyperparameters not explicitly provided by the user are assigned their default values, which define non-informative prior distributions.

Usage

```
priors(prior, regim, k, dist, setar, ssvs)
```

Arguments

prior	A list specifying user-defined values for the hyperparameters. Any hyperparameters not included in this list are set to their default values.
regim	A positive integer indicating the number of regimes in the model.
k	A positive integer indicating the dimension of the multivariate output series.
dist	A character string specifying the distribution chosen to model the noise process.
setar	A positive integer indicating the component of the output series that acts as the threshold variable in a SETAR specification. If NULL is specified then the model is not a SETAR.
ssvs	A logical indicating whether the Stochastic Search Variable Selection (SSVS) procedure should be applied.

Value

A list containing the hyperparameter values defining the prior distributions of all model parameters.

returns

Returns of the closing prices of three financial indexes

Description

This dataset contains daily returns computed from the closing prices of the COLCAP, BOVESPA, and S&P 500 stock market indexes over the period from February 10, 2010, to March 31, 2016, comprising 1,505 observations. The COLCAP index reflects the price dynamics of the 20 most liquid stocks traded on the Colombian stock market. The BOVESPA index represents the Brazilian stock market, the largest and most important exchange in Latin America and among the largest worldwide. The Standard & Poor's 500 (S&P 500) index tracks the performance of 500 large-cap companies listed in the United States.

Usage

```
data(returns)
```

Format

A data frame with 1,505 rows and 4 variables:

Date A vector indicating the date of each observation.

COLCAP A numeric vector containing the returns of the COLCAP index.

SP500 A numeric vector containing the returns of the S&P 500 index.

BOVESPA A numeric vector containing the returns of the BOVESPA index.

References

Romero, L.V. and Calderon, S.A. (2021) Bayesian estimation of a multivariate TAR model when the noise process follows a Student-t distribution. *Communications in Statistics - Theory and Methods*, 50, 2508-2530.

Examples

```
data(returns)
dev.new()
plot(ts(as.matrix(returns[,-1])), main="Returns")
```

riverflows

Rainfall and two river flows in Colombia

Description

This dataset contains daily observations of rainfall (in millimeters) and river flows (in m^3/s) for two rivers in southern Colombia. Rainfall was recorded at a meteorological station located at an altitude of 2400 meters above sea level. River flows were measured at two hydrological stations: El Trébol station, which monitors the Bedón River at an altitude of 1720 meters, and Villalosada station, which monitors the La Plata River at an altitude of 1300 meters. The stations are located near the equator, a geographic feature that helps reduce seasonal distortions and facilitates the analysis of the dynamic relationship between rainfall and river flows. The sample period spans from January 1, 2006, to April 14, 2009.

Usage

```
data(riverflows)
```

Format

A data frame with 1200 rows and 4 variables:

Date A vector indicating the date of each observation.

Bedon A numeric vector giving the daily flow of the Bedón River.

LaPlata A numeric vector giving the daily flow of the La Plata River.

Rainfall A numeric vector indicating daily rainfall amounts.

References

Calderon, S.A. and Nieto, F.H. (2017) Bayesian analysis of multivariate threshold autoregressive models with missing data. *Communications in Statistics - Theory and Methods*, 46, 296-318.

Examples

```
data(riverflows)
dev.new()
plot(ts(as.matrix(riverflows[,-1])), main="Rainfall and river flows")
```

 simtar

Simulation of multivariate time series from a TAR model

Description

This function simulates multivariate time series generated by a user-specified Threshold Autoregressive (TAR) model.

Usage

```
simtar(
  n,
  k = 2,
  ars = ars(),
  Intercept = TRUE,
  trend = c("none", "linear", "quadratic"),
  nseason = NULL,
  parms,
  delay = 0,
  thresholds = NULL,
  t.series = NULL,
  ex.series = NULL,
  dist = c("Gaussian", "Student-t", "Hyperbolic", "Laplace", "Slash",
    "Contaminated normal", "Skew-Student-t", "Skew-normal"),
  skewness = NULL,
  extra = NULL,
  setar = NULL,
  Verbose = TRUE
)
```

Arguments

n	A positive integer specifying the length of the simulated output series.
k	A positive integer specifying the dimension of the multivariate output series.
ars	A list defining the TAR model structure, composed of four elements: the number of regimes (<code>nregim</code>), the autoregressive order (<code>p</code>), and the maximum lags of the exogenous (<code>q</code>) and threshold (<code>d</code>) series within each regime. This object can be validated using the <code>ars()</code> function.
Intercept	An optional logical indicating whether an intercept term is included in each regime.
trend	An optional character string specifying the degree of deterministic time trend to be included in each regime. Available options are a linear trend ("linear"), a quadratic trend ("quadratic"), or no trend ("none"). By default, trend is set to "none".

nseason	An optional integer, greater than or equal to 2, specifying the number of seasonal periods. When provided, nseason - 1 seasonal dummy variables are added to the regressors within each regime. By default, nseason is set to NULL, thereby indicating that the TAR model has no seasonal effects.
parms	A list with one sublist per regime. Each sublist contains two matrices: the first matrix corresponds to the location parameters, and the second matrix corresponds to the scale parameters of the model.
delay	An optional non-negative integer specifying the delay parameter of the threshold series. By default, delay is set to 0.
thresholds	A numeric vector of length nregim-1 containing the threshold values, sorted in ascending order.
t.series	A matrix containing the values of the threshold series.
ex.series	A matrix containing the values of the multivariate exogenous series.
dist	An optional character string specifying the multivariate distribution chosen to model the noise process. Supported options include Gaussian ("Gaussian"), Student- <i>t</i> ("Student-t"), Slash ("Slash"), Symmetric Hyperbolic ("Hyperbolic"), Laplace ("Laplace"), and Contaminated Normal ("Contaminated normal"). By default, dist is set to "Gaussian".
skewness	An optional numeric vector specifying the skewness parameters of the noise distribution, when applicable.
extra	An optional value specifying the extra parameter of the noise distribution, when required.
setar	An optional positive integer indicating which component of the output series is used as the threshold variable. By default, setar is set to NULL, indicating that the model is not of SETAR type.
Verbose	An optional logical indicating whether a description of the simulated TAR model should be printed. By default, Verbose is set to TRUE.

Value

A data.frame containing the simulated multivariate output series, and, if specified, the threshold series and multivariate exogenous series.

References

Vanegas, L.H. and Calderón, S.A. and Rondón, L.M. (2025) Bayesian estimation of a multivariate tar model when the noise process distribution belongs to the class of gaussian variance mixtures. International Journal of Forecasting.

Examples

```
##### Simulation of a trivariate TAR model with two regimes
n <- 2000
k <- 3
myars <- ars(nregim=2,p=c(1,2))
Z <- as.matrix(arima.sim(n=n+max(myars$p),list(ar=c(0.5))))
```

```

probs <- sort((0.6 + runif(myars$nregim-1)*0.8)*c(1:(myars$nregim-1))/myars$nregim)
dist <- "Student-t"; extra <- 6
parms <- list()
for(j in 1:myars$nregim){
  np <- 1 + myars$p[j]*k
  parms[[j]] <- list()
  parms[[j]]$location <- c(ifelse(runif(np*k)<=0.5,1,-1)*rbeta(np*k,shape1=4,shape2=16))
  parms[[j]]$location <- matrix(parms[[j]]$location,np,k)
  parms[[j]]$scale <- rgamma(k,shape=1,scale=1)*diag(k)
}
thresholds <- quantile(Z,probs=probs)
out1 <- simtar(n=n, k=k, ars=myars, parms=parms, thresholds=thresholds,
              t.series=Z, dist=dist, extra=extra)
str(out1)

fit1 <- mtar(~ Y1 + Y2 + Y3 | Z, data=out1, ars=myars, dist=dist,
             n.burn=2000, n.sim=3000, n.thin=2)
summary(fit1)

##### Simulation of a trivariate VAR model
n <- 2000
k <- 3
myars <- ars(nregim=1,p=2)
dist <- "Slash"; extra <- 2
parms <- list()
for(j in 1:myars$nregim){
  np <- 1 + myars$p[j]*k
  parms[[j]] <- list()
  parms[[j]]$location <- c(ifelse(runif(np*k)<=0.5,1,-1)*rbeta(np*k,shape1=4,shape2=16))
  parms[[j]]$location <- matrix(parms[[j]]$location,np,k)
  parms[[j]]$scale <- rgamma(k,shape=1,scale=1)*diag(k)
}
out2 <- simtar(n=n, k=k, ars=myars, parms=parms, dist=dist, extra=extra)
str(out2)

fit2 <- mtar(~ Y1 + Y2 + Y3, data=out2, ars=myars, dist=dist,
             n.burn=2000, n.sim=3000, n.thin=2)
summary(fit2)

n <- 5000
k <- 3
myars <- ars(nregim=2,p=c(1,2))
dist <- "Laplace"
parms <- list()
for(j in 1:myars$nregim){
  np <- 1 + myars$p[j]*k
  parms[[j]] <- list()
  parms[[j]]$location <- c(ifelse(runif(np*k)<=0.5,1,-1)*rbeta(np*k,shape1=4,shape2=16))
  parms[[j]]$location <- matrix(parms[[j]]$location,np,k)
  parms[[j]]$scale <- rgamma(k,shape=1,scale=1)*diag(k)
}
out3 <- simtar(n=n, k=k, ars=myars, parms=parms, delay=2,
              thresholds=-1, dist=dist, setar=2)

```

```
str(out3)

fit3 <- mtar(~ Y1 + Y2 + Y3, data=out3, ars=myars, dist=dist,
            n.burn=2000, n.sim=3000, n.thin=2, setar=2)
summary(fit3)
```

US.returns

U.S. Stock Returns

Description

The dataset comprises observations of both continuously compounded and simple returns derived from the S&P 500 index, along with the first difference of the Chicago Board Options Exchange Market Volatility Index (VIX). The sample period spans from January 5, 1990, to March 30, 2012.

Usage

```
data(US.returns)
```

Format

A data frame with 5606 rows and 4 variables:

Date A vector indicating the date of each observation.

CCR A numeric vector giving the continuously compounded returns.

SR A numeric vector giving the simple returns.

dVIX A numeric vector giving (the first difference of) the Chicago Board Options Exchange Market Volatility Index (VIX).

References

Massacci, D. (2014) A two-regime threshold model with conditional skewed student-t distributions for stock returns. *Economic Modelling*, 43, 9-20.

Examples

```
data(US.returns)
dev.new()
plot(ts(as.matrix(US.returns[,-1])), main="Returns and (the first difference of) VIX")
```

vcov.mtar	<i>vcov method for objects of class mtar</i>
-----------	--

Description

Computes estimates of the variance–covariance matrices for the scale parameters of a fitted multivariate TAR model.

Usage

```
## S3 method for class 'mtar'
vcov(object, ..., FUN = mean)
```

Arguments

object	an object of class <code>mtar</code> , typically obtained from a call to <code>mtar()</code> .
...	additional arguments passed to <code>FUN</code> .
FUN	a function to be applied to the MCMC chains of the scale parameters in order to obtain point estimates. By default, <code>FUN</code> is set to <code>mean()</code> .

Value

A list containing the variance–covariance estimates obtained by applying `FUN` to the MCMC chains associated with the scale parameters.

WAIC	<i>Watanabe-Akaike or Widely Available Information Criterion (WAIC)</i>
------	---

Description

Computes Watanabe-Akaike or Widely Available Information Criterion (WAIC), an adjusted within-sample measure of predictive accuracy, for models estimated using Bayesian methods.

Usage

```
WAIC(...)
```

Arguments

...	one or more fitted model objects of the same class.
-----	---

Value

A numeric matrix containing the WAIC values corresponding to each fitted object supplied in ...

References

Watanabe S. (2010). Asymptotic Equivalence of Bayes Cross Validation and Widely Applicable Information Criterion in Singular Learning Theory. *The Journal of Machine Learning Research*, 11, 3571–3594.

WAIC.mtar	<i>Watanabe-Akaike or Widely Available Information Criterion (WAIC) for objects of class mtar</i>
-----------	---

Description

This function computes the Watanabe-Akaike or Widely Available Information Criterion (WAIC), for objects of class `mtar`.

Usage

```
## S3 method for class 'mtar'
WAIC(...)
```

Arguments

... one or several objects of the class `mtar`.

Value

A numeric matrix containing the WAIC values corresponding to each `mtar` object in the input.

See Also

[DIC](#)

Examples

```
##### Example 1: Returns of the closing prices of three financial indexes
data(returns)
fit1a <- mtar(~ COLCAP + BOVESPA | SP500, data=returns, row.names=Date,
             subset={Date<="2016-03-14"}, dist="Student-t",
             ars=ars(nregim=3,p=c(1,1,2)), n.burnin=2000, n.sim=3000,
             n.thin=2)
fit1b <- update(fit1a,dist="Slash")
fit1c <- update(fit1a,dist="Laplace")
WAIC(fit1a,fit1b,fit1c)

##### Example 2: Rainfall and two river flows in Colombia
data(riverflows)
fit2a <- mtar(~ Bedon + LaPlata | Rainfall, data=riverflows, row.names=Date,
             subset={Date<="2009-04-04"}, dist="Laplace",
             ars=ars(nregim=3,p=5), n.burnin=2000, n.sim=3000, n.thin=2)
fit2b <- update(fit2a,dist="Slash")
```

```
fit2c <- update(fit2a,dist="Student-t")
WAIC(fit2a,fit2b,fit2c)

##### Example 3: Temperature, precipitation, and two river flows in Iceland
data(iceland.rf)
fit3a <- mtar(~ Jokulsa + Vatnsdalsa | Temperature | Precipitation,
             data=iceland.rf, subset={Date<="1974-12-21"}, row.names=Date,
             ars=ars(nregim=2,p=15,q=4,d=2), n.burnin=2000, n.sim=3000,
             n.thin=2, dist="Slash")
fit3b <- update(fit3a,dist="Laplace")
fit3c <- update(fit3a,dist="Student-t")
WAIC(fit3a,fit3b,fit3c)
```

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