Package 'GAS'

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Type Package

Title Generalized Autoregressive Score Models

Version 0.1.4

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Description Simulate, estimate and forecast using univariate and multivariate GAS models.

License GPL-3

LazyData TRUE

Imports Rcpp (>= 0.12.2)

LinkingTo Rcpp, RcppArmadillo

Depends R (>= 2.10), Rsolnp, methods, MASS, xts, numDeriv, zoo

NeedsCompilation yes

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R topics documented:

`GAS-package` *Generalized Autoregressive Score models in R*

Description

The GAS package allows us to simulate, estimate and forecast using univariate and multivariate Generalized Autoregressive Score (GAS) models (also known as Dynamic Conditional Score (DCS) models), see e.g., Creal et. al. (2013) and Harvey (2013) and the website `www.gasmodel.com`. A detailed implementation of the package functionalities are reported in Ardia et. al. (2016).

Details

Package:	GAS
Type:	Package
Version:	0.1.4
Date:	2016-07-09
License:	GPL (>= 2)

The authors acknowledge Google for financial support via the Google Summer of Code 2016 project "GAS"; see https://summerofcode.withgoogle.com/projects/#4717600793690112.

Current limitations:

- The multivariate GAS model for N>4 does not report the exact update for the correlation parameters since the Jacobian of the hyperspherical coordinates transformation needs to be coded for the case N>4. The Jacobian for N>4 is replaced by the identity matrix.

Author(s)

Leopoldo Catania [aut,cre], Kris Boudt [ctb], David Ardia [ctb]

Maintainer: Leopoldo Catania <leopoldo.catania@uniroma2.it>

References

Ardia D, Boudt K and Catania L (2016). "Generalized Autoregressive Score Models in R: The GAS Package." Available at SSRN: http://ssrn.com/abstract=2825380.

Creal D, Koopman SJ, Lucas A (2013). "Generalized Autoregressive Score Models with Applications." Journal of Applied Econometrics, 28(5), 777-795. doi: 10.1002/jae.1279.

Harvey AC (2013). Dynamic Models for Volatility and Heavy Tails: With Applications to Financial and Economic Time Series. Cambridge University Press.

`BacktestDensity` *Backtest a series of one-step ahead density predictions.*

Description

The `BacktestDensity()` function accepts an object of the class uGASRoll, and returns a `list` with two elements: (i) the averages Negative Log Score (NLS) and weighted Continuous Ranked Probability Score (wCRPS) introduced by Gneiting and Ranjan (2012), and (ii) their values at each point in time. The wCRPS is evaluated using 5 weight functions, see Details.

Usage

```
BacktestDensity(Roll, lower, upper, K = 1000, a = 0.0, b = 1.0)
```

Arguments

`Roll`	an object of the class uGASRoll.
`lower`	`numeric` the lower bound used to approximate the wCRSP by Monte Carlo integration as detailed in Gneiting and Ranjan (2012). This coincides with y_l in Equation 16 of Gneiting and Ranjan (2012).

upper	numeric the upper bound used to approximate the wCRSP by Monte Carlo integration as detailed in Gneiting and Ranjan (2012). This coincides with y_u in Equation 16 of Gneiting and Ranjan (2012).
K	numeric integer representing the number of points used to discretize the wCRPS integral. This is I in Equation 16 of Gneiting and Ranjan (2012). By default K = 1000.
a	numeric. mean of the normal distribution used in the weight function. By default a = 0.0.
b	numeric. standard deviation of the normal distribution used in the weight function. By default b = 1.0.

Details

The average Negative Log Score (NLS) is computed as the negative of the average of the log scores evaluated during the out-of-sample period. The average weighted Continuous Ranked Probability Score (wCRPS) is computed as the average of the wCRPS evaluated during the out-of-sample period, see Gneiting and Ranjan (2012).

The wCRPS is evaluated using Equation 16 of Gneiting and Ranjan (2012). The weights functions implemented are:

- $w(z) = 1$: Uniform,
- $w(z) = \phi_{a,b}(z)$: Center,
- $w(z) = 1 - \phi_{a,b}(z)$: Tails,
- $w(z) = \Phi_{a,b}(z)$: Right tail,
- $w(z) = 1 - \Phi_{a,b}(z)$: Left tail,

where $\phi_{a,b}(z)$ and $\Phi_{a,b}(z)$ are the pdf and cdf of a Gaussian distribution with mean a and standard deviation b, respectively. The label "Uniform" represents the case where equal emphasis is given to all the parts of the distribution.

Value

A list with elements: average, series. The element "average" is a named vector with the averages NLS and wCRSP. The element "series" is a list: the fist element, LS, contains the out-of-sample Log Score (not with the negative sign), the second element, WCRPS, contains a matrix with the wCRPS series. The columns of this matrix are named: "uniform", "center", "tails", "tail_r", "tail_l", which are associated with the wCRSP with emphasis on: Uniform, Center, Tails, Right tail and Left tail, respectively.

Author(s)

Leopoldo Catania

References

Gneiting T, Ranjan R (2011). "Comparing Density Forecasts using Threshold -and Quantile-Weighted Scoring Rules." Journal of Business & Economic Statistics, 29(3), 411-422, doi: 10.1198/jbes.2010.08110.

Examples

```
data("cpichg")

GASSpec = UniGASSpec(Dist = "std", ScalingType = "Identity",
                     GASPar = list(location = TRUE, scale = TRUE,
                                   shape = FALSE))

Roll = UniGASRoll(cpichg, GASSpec, ForecastLength = 50,
                  RefitEvery = 10, RefitWindow = c("moving"))

BackTest = BacktestDensity(Roll, lower = -100, upper = 100)

BackTest$average
```

BacktestVaR *Backtest Value at Risk (VaR)*

Description

This function implements several backtesting procedures for the Value at Risk (VaR). These are: (i) The statistical tests of Kupiec (1995), Christoffesen (1998) and Engle and Manganelli (2004), (ii) The tick loss function detailed in Gonzalez-Rivera et al. (2004), the mean and max absolute loss used by McAleer and Da Veiga (2008) and the actual over expected exceedance ratio.

Usage

```
BacktestVaR(data, VaR, tau, alphaTest = 0.95, Lags = 4)
```

Arguments

`data`	`numeric` Vector of observations.
`VaR`	`numeric` Vector containing the VaR series.
`tau`	`numeric` The VaR confidence level.
`alphaTest`	`numeric` Confidence level used in the statistical tests.
`Lags`	`numeric` Lags used in the Dynamic Quantile test of Engle and Manganelli (2004).

Details

This function implements several backtesting procedure for the Value at Risk. The implemented statistical tests are:

- `LRuc` The unconditional coverage test of Kupiec (1995).
- `LRcc` The conditional coverage test of Christoffesen (1998).
- `DQ` The Dynamic Quantile test of Engle and Manganelli (2004).

The implemented VaR backtesting quantities are:

- `AD` mean and maximum absolute deviation between the observations and the quantiles as in McAleer and Da Veiga (2008).
- `Loss` Average quantile loss and quantile loss series as in Gonzalez-Rivera et al. (2004).
- `AE` Actual over Expected exceedance ratio.

Value

A `list` with elements: `LRuc`, `LRcc`, `DQ`, `AD`, `AE`.

Author(s)

Leopoldo Catania

References

Christoffersen PF (1998). "Evaluating interval forecasts." International Economic Review, 39(4), 841-862, doi: 10.2307/2527341.

Engle RF and Manganelli S. (2004). "CAViaR: Conditional Autoregressive Value at Risk by Regression Quantiles." Journal of Business & Economic Statistics, 22(4), 367-381, doi: 10.1198/073500104000000370.

Gonzalez-Rivera G, Lee TH, and Mishra, S (2004). "Forecasting Volatility: A Reality Check Based on Option Pricing, Utility Function, Value-at-Risk, and Predictive Likelihood." International Journal of Forecasting, 20(4), 629-645, doi: 10.1016/j.ijforecast.2003.10.003.

Kupiec PH (1995). "Techniques for Verifying the Accuracy of Risk Measurement Models." The Journal of Derivatives, 3(2), 73-84, doi: 10.3905/jod.1995.407942

McAleer M and Da Veiga B (2008). "Forecasting Value-at-Risk with a Parsimonious Portfolio Spillover GARCH (PS-GARCH) Model." Journal of Forecasting, 27(1), 1-19, doi: 10.1002/for.1049.

Examples

```
data("StockIndices")

GASSpec = UniGASSpec(Dist = "std", ScalingType = "Identity",
                     GASPar = list(location = FALSE, scale = TRUE,
                                   shape = FALSE))

FTSEMIB = StockIndices[, "FTSEMIB"]

InSampleData  = FTSEMIB[1:1500]
OutSampleData = FTSEMIB[1501:2404]

Fit = UniGASFit(GASSpec, InSampleData)
```

```
Forecast = UniGASFor(Fit, Roll = TRUE, out = OutSampleData)

tau = 0.05

VaR = quantile(Forecast, tau)

BackTest = BacktestVaR(OutSampleData, VaR, tau)
```

`ConfidenceBands` *Build confidence bands for the filtered parameters*

Description

Build confidence bands for the filtered parameters sampling the coefficients from the asymptotic distribution as in Blasques et al. (2016).

Usage

```
ConfidenceBands(object, B = 10000, probs = c(0.01,0.1,0.9,0.99), ...)
```

Arguments

`object`	An object of the class uGASFit or mGASFit
`B`	`numeric` Number of draws from the asymptotic distributions.
`probs`	`numeric` Quantiles to returns.
`...`	Additional arguments.

Details

This function implements the "In-Sample Simulation-Based Bands" Sec 3.3 of Blasques et al. (2016).

Value

An object of the class `array` of dimension T+1 x B x K, where T is the length of the time series, K is the number of parameters and B the number of draws. The first slice reports the estimated filtered parameters. Also the one step ahead prediction is reported, this why T + 1.

Author(s)

Leopoldo Catania

References

Blasques F, Koopman SJ, Lasak K, and Lucas, A (2016). "In-sample Confidence Bands and Out-of-Sample Forecast Bands for Time-Varying Parameters in Observation-Driven Models." International Journal of Forecasting, 32(3), 875-887. doi: 10.1016/j.ijforecast.2016.04.002.

Examples

```
## Not run:
# show the information of all the supported distributions
library("GAS")

data("cpichg")

GASSpec = UniGASSpec(Dist = "std", ScalingType = "Identity",
                     GASPar = list(location = TRUE, scale = TRUE,
                                   shape = FALSE))

Fit = UniGASFit(GASSpec, cpichg)

Bands = ConfidenceBands(Fit)


## End(Not run)
```

`cpichg` *Data: Quarterly logarithmic change in percentage points of the Consumer Price Index for All Urban Consumers: All Items (CPIAUCSL) from 1947-04-01 to 2016-05-01*

Description

Quarterly logarithmic change in percentage points of the Consumer Price Index for All Urban Consumers: All Items (CPIAUCSL) from 1947-04-01 to 2016-05-01 available at https://fred.stlouisfed.org/series/CPIAUCSL.

Usage

```
data("cpichg")
```

Format

A xts object containing 276 observations from 1947-04-01 to 2016-05-01.

References

US. Bureau of Labor Statistics, Consumer Price Index for All Urban Consumers: All Items [CPIAUCSL], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/CPIAUCSL, June 24, 2016.

DistInfo *Information for the supported distributions*

Description

Print the information regarding distributions supported in the GAS package.

Usage

```
DistInfo(DistLabel = NULL, N = 2, FULL = TRUE)
```

Arguments

DistLabel	character indicating the label of the conditional distribution. if DistLabel = NULL all the supported distributions are printed. Default DistLabel = NULL. Run DistLabels() to see the labels of the currently implemented distributions.
N	numeric Indicating the number of asset if DistLabel link to a multivariate distribution. Default N = 2.
FULL	logical If TRUE the function prints all the the information. Default FULL = TRUE

Details

The information are printed in the console.

Author(s)

Leopoldo Catania

Examples

```
# show the information of all the supported distributions
library("GAS")

DistInfo()
```

distributions *Distributions of the GAS package*

Description

Density, distribution function, quantile function, random generator, moments, scores and information matrix of univariate and multivariate distributions of the GAS package.

Usage

```
ddist_Uni(y, Theta, Dist, log = FALSE)
pdist_Uni(q, Theta, Dist)
qdist_Uni(p, Theta, Dist)
rdist_Uni(Theta, Dist)
mdist_Uni(Theta, Dist)
Score_Uni(y, Theta, Dist)
IM_Uni(Theta, Dist)

ddist_Multi(y, Theta, Dist, log = FALSE)
rdist_Multi(Theta, N, Dist)
Score_Multi(y, Theta, Dist)
```

Arguments

y, q	numeric Scalar quantile. For Score_Multi and ddist_Multi, y is a numeric vector.
p	numeric Scalar probability.
Theta	numeric Vector of distribution parameters. The order of the parameters is generally: location, scale, skewness, shape, shape2. When the distribution defined by Dist does not have, say, the shape parameter, this should be simply omitted. See also DistInfo for specific distributions.
Dist	character Label of the conditional distribution, see DistInfo.
log	logical If TRUE, the density value $p(y)$ is given as $log(p(y))$. Dy Default log = FALSE.
N	numeric Integer. cross-sectional dimension for the multivariate case.

Details

The function mdist_Uni returns a vector with four elements: mean, variance, skewness and kurtosis coefficients. The functions Score_Uni and IM_Uni returns the score and the Fisher information matrix for univariate distributions. The function Score_Multi returns the score for multivariate distributions. See DistInfo for the lists of supported distributions. These functions are not vectorized. ddist_Uni and ddist_Multi give the density, pdist_Uni gives the distribution function, qdist_Uni gives the quantile function, and rdist_Uni and rdist_Multi generate random deviates.

Value

1. numeric scalar for: ddist_Uni, pdist_Uni, qdist_Uni, rdist_Uni,
2. numeric vector for: Score_Uni, Score_Multi and rdist_Multi,
3. matrix for IM_Uni.

Author(s)

Leopoldo Catania

Examples

```
# Skew Student-t distribution

# log density
Theta = c("location" = 0, "scales" = 1, "skewness" = 1.2, "shape" = 7)

ddist_Uni(y = 0.5, Theta, "sstd", TRUE)

# probability
pdist_Uni(q = -1.69, Theta, "sstd")

#quantile
qdist_Uni(p = 0.05, Theta, "sstd")

#random generator
rdist_Uni(Theta, "sstd")

#moments
mdist_Uni(Theta, "sstd")
```

`dji30ret` *data: Dow Jones 30 Constituents Closing Value Log Return*

Description

This dataset is taken from the `rugarch` package of Ghalanos (2015).

Dow Jones 30 Constituents closing value log returns from 1987-03-16 to 2009-02-03 from Yahoo Finance. Note that AIG was replaced by KFT (Kraft Foods) on September 22, 2008. This is not reflected in this data set as that would bring the starting date of the data to 2001.

Usage

```
data("dji30ret")
```

Format

A data.frame containing 5,521x30 observations.

Source

Yahoo Finance

References

Ghalanos A (2015). "rugarch: Univariate GARCH models." R package version 1.3-6, https://cran.r-project.org/package=rugarch.

mGASFit *Class for the Multivariate GAS fitted object*

Description

Class for the multivariate GAS fitted object.

Objects from the Class

A virtual Class: No objects may be created from it.

Slots

`Data`: Object of class `list`. Contains the user's data.

`Estimates`: Object of class `list`. Contains: `lParList` list of estimated parameters, `optimiser` object delivered from the optimization function, `StaticFit` ML estimates for the constant model, `Inference` inferential results for the estimated parameters.

`GASDyn`: Object of class `list`. Contains: the series of filtered dynamic (`GASDyn$mTheta`) for the time–varying parameters, the series of scaled scores (`GASDyn$mInnovation`), the series of unrestricted filtered parameters (`GASDyn$mTheta_tilde`), the series of log densities (`GASDyn$vLLK`), the log likelihood evaluated at its optimum value (`GASDyn$dLLK`)

`ModelInfo`: Object of class `list`. Contains information about the GAS specification:

- `Spec` Object of the class uGASSpec containing the GAS specification.
- `iT` `numeric` Number of observation.
- `elapsedTime` `Numeric` elapsed time in seconds.

Methods

- show `signature(object = "mGASFit")`: Show summary.
- plot `signature(x='mGASFit',y='missing')`: Plot filtered dynamic and other estimated quantities.
- getFilteredParameters `signature(object = "mGASFit")`: Extract filtered parameters.
- getObs `signature(object = "mGASFit")`: Extract original observations.
- coef `signature(object = "mGASFit")`: Extract estimated coefficients.
- getMoments `signature(object = "mGASFit")`: Extract conditional moments.

Author(s)

Leopoldo Catania

mGASFor *Class for the Multivariate GAS Forecast object*

Description

Class for the multivariate GAS forecast object.

Objects from the Class

A virtual Class: No objects may be created from it.

Slots

`Forecast`: Object of class `list`. Contains forecasts:

- `PointForecast`: `matrix` with parameters forecasts.
- `Moments`: `list` with centered moments forecasts. The first element contains a `matrix` with the predicted conditional means. The second element contains an `array` with the predicted conditional covariances.
- `vLS`: `numeric` Log Score (Predictive Log Likelihood).

`Bands`: `array` with confidence bands parameters forecasts. Available only if `Roll = TRUE`.

`Draws`: If `ReturnsDraws = TRUE` it is a iH x iB `matrix` of draws from the predictive distribution.

`Info`: `list` with forecast information.

`Data`: `list` with original data.

Methods

- `show signature(object = "uGASFor")`: Show summary.
- `plot signature(x='uGASFor',y='missing')`: Plot forecasted quantities.
- `getForecast signature(object = "uGASFor")`: Extract parameters forecast.
- `getObs signature(object = "uGASFor")`: Extract original observations.
- `getMoments signature(object = "uGASFor")`: Extract moments forecasts.
- `LogScore signature(object = "uGASFor")`: Extract Log Scores.

Author(s)

Leopoldo Catania

mGASRoll *Class for the Multivariate GAS Rolling object*

Description

Class for the multivariate GAS rolling object.

Objects from the Class

A virtual Class: No objects may be created from it.

Slots

`Forecast`: Object of class `list`. Contains forecasts:

- `PointForecast`: `matrix` with parameters forecasts.
- `Moments`: `list` with centered moments forecasts. The first element contains a `matrix` with the predicted conditional means. The second element contains an `array` with the predicted conditional covariances.
- `vLS`: `numeric` Log Score (Predictive Log Likelihood).

`Info`: `list` with forecast information.

`Data`: `list` with original data.

Methods

- `show` `signature(object = 'uGASFor')`: Show summary.
- `plot` `signature(x = 'uGASFor',y = 'missing')`: Plot forecasted quantities.
- `getForecast` `signature(object = 'uGASFor')`: Extract parameters forecast.
- `getObs` `signature(object = 'uGASFor')`: Extract original observations.
- `getMoments` `signature(object = 'uGASFor')`: Extract moments forecasts.
- `LogScore` `signature(object = 'uGASFor')`: Extract Log Scores.

Author(s)

Leopoldo Catania

mGASSim *Class for Multivariate GAS Simulation*

Description

Class for multivariate GAS model simulation.

Objects from the Class

A virtual Class: No objects may be created from it.

Slots

`ModelInfo`: Object of class `list`. Contains information about the multivariate GAS specification:

- iT: `numeric` Time length of simulated observations.
- iN: `numeric` Cross sectional dimension.
- iK : `numeric` number of (possibly) time–varying parameters implied by the distributional assumption.
- vKappa `numeric` vector of unconditional level for the reparametrized vector of parameters.
- mA `matrix` of coefficients of dimension iK x iK that premultiply the conditional score in the GAS updating recursion.
- mB `matrix` of autoregressive coefficients of dimension iK x iK.
- Dist `character` label of the conditional distribution, see DistInfo
- ScalingType `character` representing the scaling mechanism for the conditional score, see DistInfo

`GASDyn`: Object of class `list`. Contains: the series of simulated parameters (`GASDyn$mTheta`), the series of scaled scores (`GASDyn$mInnovation`), the series of unrestricted simulated parameters (`GASDyn$mTheta_tilde`), the series of log densities (`GASDyn$vLLK`), the log likelihood evaluated at its optimum value (`GASDyn$dLLK`)

`Data`: Object of class `matrix`. Matrix of dimension iN x iT of simulated data

Methods

- `show signature(object = 'mGASSim')`: Show summary.
- `plot signature(x = 'mGASSim',y = 'missing')`: Plot simulated data and parameters.
- `getFilteredParameters signature(object = 'mGASSim')`: Extract simulated parameters.
- `getObs signature(object = 'mGASSim')`: Extract simulated observations
- `coef signature(object = 'mGASSim')`: Extract delivered coefficients
- `getMoments signature(object = 'uGASFor')`: Extract simulated moments.

Author(s)

Leopoldo Catania

mGASSpec *Class for the Multivariate GAS model specification*

Description

Class for the Multivariate GAS model specification.

Objects from the Class

A virtual Class: No objects may be created from it.

Slots

`Spec`: Object of class `list`. Contains information abount the multivariate GAS specification:

- `Dist`: `character` Containing the conditional distribution assumption.
- `ScalingType`: `character` indicating the scaling mechanism for the conditional score.
- `GASPar`: `list` with elements: location, scale, correlation, shape.
- `ScalarParameters`: `logical` indicates if the parameters of the locations, scales and correlations dynamic have to be scalars or a diagonal matrices.

Methods

- show `signature(object = 'mGASSpec')`: Show summary.

Author(s)

Leopoldo Catania

MultiGASFit *Estimate multivariate GAS models*

Description

Estimate multivariate GAS models by Maximum Likelihood.

Usage

```
MultiGASFit(GASSpec, data)
```

Arguments

`GASSpec`	An object of the class mGASSpec created using the function MultiGASSpec
`data`	`matrix` (or something coercible to that using `as.matrix()`) of dimension TxN containing the multivariate time series of observations. It can also be an object of the class `ts`, `xts` or `zoo`.

Details

Maximum Likelihood estimation of GAS models is an on-going research topic. General results are reported by Blasques et al. (2014b), Blasques et al. (2014a) and Harvey (2013), while results for specific models have been derived by Blasques et al. (2014c) and Andres (2014).

The optimizer used is the General Nonlinear Augmented Lagrange Multiplier method of Ye (1988) available in the R package Rsolnp (Ghalanos and Theussl 2016).

Starting values for the optimizer are chosen in the following way: (i) estimate the static version of the model (i.e., with A = 0 and B = 0) and set the initial value of the intercept parameter accordingly, and (ii) perform a grid search for the coefficients contained in A and B. Further technical details are presented in Section 3.2 of Ardia et. al. (2016).

The function prints some information during the estimation procedure.

Value

An object of the class mGASFit.

Author(s)

Leopoldo Catania

References

Ardia D, Boudt K and Catania L (2016). "Generalized Autoregressive Score Models in R: The GAS Package." Available at SSRN: http://ssrn.com/abstract=2825380.

Blasques F, Koopman SJ, Lucas A (2014a). "Maximum Likelihood Estimation for Correctly Specified Generalized Autoregressive Score Models: Feedback Effects, Contraction Conditions and Asymptotic Properties. techreport TI 14-074/III, Tinbergen Institute. URL http://www.tinbergen.nl/discussionpaper/?paper=2332.

Blasques F, Koopman SJ, Lucas A (2014b). "Maximum Likelihood Estimation for Generalized Autoregressive Score Models." techreport TI 2014-029/III, Tinbergen Institute. URL http://www.tinbergen.nl/discussionpaper/?paper=2286.

Blasques F, Koopman SJ, Lucas A, Schaumburg J (2014c). "Spillover Dynamics for Systemic Risk Measurement using Spatial Financial Time Series Models." techreport TI 2014-103/III, Tinbergen Institute. URL http://www.tinbergen.nl/discussionpaper/?paper=2369.

Creal D, Koopman SJ, Lucas A (2013). "Generalized Autoregressive Score Models with Applications." Journal of Applied Econometrics, 28(5), 777-795. doi: 10.1002/jae.1279.

Ghalanos A, Theussl S (2016). Rsolnp: General Non-Linear Optimization using Augmented Lagrange Multiplier Method. R package version 1.16, URL https://cran.r-project.org/

package=Rsolnp.

Harvey AC (2013). Dynamic Models for Volatility and Heavy Tails: With Applications to Financial and Economic Time Series. Cambridge University Press.

Ye Y (1988). Interior Algorithms for Linear, Quadratic, and Linearly Constrained Convex Programming. Ph.D. thesis, Stanford University.

Examples

```
## Not run:
# Specify an GAS model with multivariate Student-t
# conditional distribution and time-varying scales and correlations

library("GAS")

data("StockIndices")

GASSpec = MultiGASSpec(Dist = "mvt", ScalingType = "Identity",
                       GASPar = list(scale = TRUE, correlation = TRUE))

Fit = MultiGASFit(GASSpec, StockIndices)

Fit


## End(Not run)
```

`MultiGASFor` *Forecast with multivariate GAS models*

Description

Forecast with multivariate GAS models. One-step ahead prediction of the conditional density is available in closed form. Multistep ahead prediction are performed by simulation as detailed in Blasques et al. (2016).

Usage

```
MultiGASFor(mGASFit, H, Roll = FALSE, out = NULL, B = 10000,
                       Bands = c(0.1, 0.15, 0.85, 0.9), ReturnDraws = FALSE)
```

Arguments

`mGASFit`	An object of the class mGASFit created using the function MultiGASFit
`H`	`numeric` Forecast horizon. Ignored if `Roll = TRUE`
`Roll`	`boolean` Forecast should be made using a rolling procedure ? Note that if `Roll = TRUE`, then `out` has to be specified.

out	matrix of out of sample observation of dimension H x N for rolling forecast. N refers to the cross sectional dimension.
B	numeric Number of draws from the iH-step ahead distribution if Roll = TRUE.
Bands	numeric Vector of probabilities representing the confidence band levels for multistep ahead parameters forecasts. Only if Roll = TRUE.
ReturnDraws	boolean Return the draws from the multistep ahead predictive distribution when Roll = TRUE ?

Value

An object of the class mGASFor

Author(s)

Leopoldo Catania

References

Blasques F, Koopman SJ, Lasak K, and Lucas, A (2016). "In-sample Confidence Bands and Out-of-Sample Forecast Bands for Time-Varying Parameters in Observation-Driven Models." International Journal of Forecasting, 32(3), 875-887. doi: 10.1016/j.ijforecast.2016.04.002.

Examples

```
## Not run:
# Specify a GAS model with multivatiate  Student-t conditional
# distribution and time-varying scales and correlations.

# Stock returns forecast

set.seed(123)

data("StockIndices")

mY = StockIndices[, 1:2]

# Specification mvt
GASSpec = MultiGASSpec(Dist = "mvt", ScalingType = "Identity",
                       GASPar = list(location = FALSE, scale = TRUE,
                                     correlation = TRUE, shape = FALSE))

# Perform H-step ahead forecast with confidence bands

# Estimation
Fit = MultiGASFit(GASSpec, mY)

# Forecast
Forecast  = MultiGASFor(Fit, H = 50)

Forecast
```

```
# Perform 1-Step ahead rolling forecast

InSampleData  = mY[1:1000, ]
OutSampleData = mY[1001:2404, ]

# Estimation
Fit = MultiGASFit(GASSpec, InSampleData)

Forecast  = MultiGASFor(Fit, Roll = TRUE, out = OutSampleData)

Forecast

## End(Not run)
```

`MultiGASRoll` *Rolling forecast with multivariate GAS models*

Description

One-step ahead rolling forecasts with model re-estimation. The function also reports several quantity for backtesting for point and density forecasts.

Usage

```
MultiGASRoll(data, GASSpec, ForecastLength = 500, Nstart = NULL,
             RefitEvery = 23, RefitWindow = c("moving", "recursive"),
             cluster = NULL)
```

Arguments

`data`	`matrix` of dimension (T + ForecastLength) x N containing the time series of observations.
`GASSpec`	An object of the class mGASSpec created using the function MultiGASSpec
`ForecastLength`	`numeric` Length of the out of sample
`Nstart`	`numeric` Period when perform the first forecast. Ignored if `ForecastLength` is supplied.
`RefitEvery`	`numeric` Number of periods before model coefficients re-estimation.
`RefitWindow`	`character` Type of window. If `RefitWindow = "recursive"` all the observations are used when the model is re-estimated. If `RefitWindow = "moving"` old observations are eliminated.
`cluster`	A `cluster` object created calling using the `paralell` package. If supplied parallel processing is used to speed up the computations.

Value

An object of the class mGASRoll

Author(s)

Leopoldo Catania

Examples

```
## Not run:
# Specify a GAS model with Multivariate Student-t conditional
# distribution and time-varying scale and correlation parameters

# stock returns Forecast

data("StockIndices")

mY = StockIndices[, 1:2]

# Specification mvt
GASSpec = MultiGASSpec(Dist = "mvt", ScalingType = "Identity",
                       GASPar = list(location = FALSE, scale = TRUE,
                                     correlation = TRUE, shape = FALSE))

# Perform 1-step ahead rolling forecast with refit
library(parallel)

Roll = MultiGASRoll(mY, GASSpec, ForecastLength = 250,
                       RefitEvery = 100, RefitWindow = c("moving"))

Roll


## End(Not run)
```

`MultiGASSim` *Simulate multivariate GAS processes*

Description

Simulate multivariate GAS processes.

Usage

```
MultiGASSim(T.sim, N, kappa, A, B, Dist, ScalingType)
```

Arguments

`T.sim`	`numeric` Length of the simulated time series.
`N`	`numeric` Cross sectional dimension (Only N<5 supported for now).
`kappa`	`numeric` vector of unconditional level for the reparametrized vector of parameters.

A	matrix of coefficients of dimension K x K that premultiply the conditional score in the GAS updating recursion, see Details.
B	matrix of autoregressive coefficients of dimension K x K, see Details.
Dist	character Label of the conditional distribution, see DistInfo.
ScalingType	character indicating the scaling mechanism for the conditional score. Only ScalingType = "Identity" is supported for multivariate distributions, see the function DistInfo.

Details

All the information regarding the supported multivariate conditional distributions can be investigated using the DistInfo function. The model is specified as:

$$y_t \sim p(y|\theta_t)$$

where θ_t is the vector of parameters for the density $p(y|.)$. Note that, θ_t includes also those parameters that are not time-varying. The GAS recursion for θ_t is:

$$\theta_t = \Lambda(\tilde{\theta}_t)$$

$$\tilde{\theta}_t = \kappa + A * s_{t-1} + B * \tilde{\theta}_{t-1}$$

where $h(.)$ is the mapping function (see MultiMapParameters) and $\tilde{\theta}_t$ is the vector of reparametrised parameters. The process is initialized at $\theta_1 = (I - B)^{-1}\kappa$, where κ is the Kappa vector. The vector s_t is the scaled score of $p(y|.)$ with respect to $\tilde{\theta}_t$. See Ardia et. al. (2016) for further details.

Value

An object of the class mGASSim

Author(s)

Leopoldo Catania

References

Ardia D, Boudt K and Catania L (2016). "Generalized Autoregressive Score Models in R: The GAS Package." Available at SSRN: http://ssrn.com/abstract=2825380.

Creal D, Koopman SJ, Lucas A (2013). "Generalized Autoregressive Score Models with Applications." Journal of Applied Econometrics, 28(5), 777-795. doi: 10.1002/jae.1279.

Harvey AC (2013). Dynamic Models for Volatility and Heavy Tails: With Applications to Financial and Economic Time Series. Cambridge University Press.

Examples

```
# Simulate from a GAS process with Multivariate Student-t conditional
# distribution, time-varying locations, scales, correlations
# and fixed shape parameter.
library("GAS")

set.seed(786)

T.sim = 1000 # Number of observations to simulate.
N = 3        # Trivariate series.
Dist = "mvt" # Conditional Multivariate Studen-t distribution.

# Build unconditional vector of reparametrised parameters.

Mu = c(0.1, 0.2, 0.3)  # Vector of location parameters (this is not transformed).
Phi = c(1.0, 1.2, 0.3) # Vector of scale parameters for the firs, second and third variables.

Rho = c(0.1, 0.2, 0.3) # This represents vec(R), where R is the correlation matrix.
                       # Note that is up to the user to ensure that vec(R) implies a
                       # proper correlation matrix.

Theta = c(Mu, Phi, Rho, 7) # Vector of parameters such that the degrees of freedom are 7.

kappa = MultiUnmapParameters(Theta, Dist, N)

A = matrix(0, length(kappa), length(kappa))

# Update scales and correlations, do not update locations and shape parameters.
diag(A) = c(0, 0, 0, 0.05, 0.01, 0.09, 0.01, 0.04, 0.07, 0)

B = matrix(0, length(kappa), length(kappa))

# Update scales and correlations, do not update locations and shape parameters.
diag(B) = c(0, 0, 0, 0.7, 0.7, 0.5, 0.94, 0.97, 0.92, 0)

Sim = MultiGASSim(T.sim, N, kappa, A, B, Dist, ScalingType = "Identity")

Sim
```

MultiGASSpec *Multivariate GAS specification*

Description

Specify the conditional distribution, scaling mechanism and time-varying parameters for multivariate GAS models.

Usage

```
MultiGASSpec(Dist = "mvnorm", ScalingType = "Identity",
             GASPar = list(location = FALSE, scale = TRUE,
                           correlation = FALSE, shape = FALSE),
             ScalarParameters = TRUE)
```

Arguments

`Dist`	`character` indicating the label of the conditional distribution. Available distribution can be displayed using the function DistInfo. Default value `Dist = "mvnorm"`.
`ScalingType`	`character` indicating the scaling mechanism for the conditional score. Only `ScalingType = "Identity"` is supported for multivariate distributions.
`GASPar`	`list` containing information about which parameters of the conditional distribution have to be time-varying. `location = TRUE` refers to the location parameters, `scale = TRUE` refers to the scale parameters, `shape = TRUE` refers to the shape parameter (e.g., the degree of freedom of the multivariate Student-t distribution), `correlation = TRUE` refers to the correlations. If the distribution specified in the `Dist` argument does not have, say, a shape parameter, the condition `shape = TRUE` is ignored.
`ScalarParameters`	`logical` indicating if the parameters of the locations, scales and correlations dynamic have to be scalars or a diagonal matrices. By default `ScalarParameters = TRUE`.

Details

All the information regarding the supported multivariate conditional distributions can be investigated using the DistInfo function.

Value

An object of the class mGASSpec

Author(s)

Leopoldo Catania

References

Creal D, Koopman SJ, Lucas A (2011). "A Dynamic Multivariate Heavy-Tailed Model for Time-Varying Volatilities and Correlations." Journal of Business & Economic Statistics, 29(4), 552-563. doi: 10.1198/jbes.2011.10070.

Creal D, Koopman SJ, Lucas A (2013). "Generalized Autoregressive Score Models with Applications." Journal of Applied Econometrics, 28(5), 777-795. doi: 10.1002/jae.1279.

Harvey AC (2013). Dynamic Models for Volatility and Heavy Tails: With Applications to Financial and Economic Time Series. Cambridge University Press.

Examples

```
# Specify a GAS model with multivariate Student-t
# conditional distribution and time-varying locations,
# scales and correlations  parameters but constant shape parameter.

library("GAS")

GASSpec = MultiGASSpec(Dist = "mvt", ScalingType = "Identity",
                       GASPar = list(location = TRUE, scale = TRUE,
                                     correlation = TRUE, shape = FALSE))

GASSpec
```

`MultiMapParameters` *Mapping function for univariate distributions*

Description

Map unrestricted vector of parameters into the proper space. This function transforms the parameters updated using the GAS recursion into their proper space.

Usage

```
MultiMapParameters(Theta_tilde, Dist, N)
```

Arguments

`Theta_tilde`	`numeric` Vector of reparametrised parameters, see Details.
`Dist`	`character` Label of the conditional distribution, see DistInfo.
`N`	`numeric` Cross sectional dimension. Note that only `iN<5` is supported.

Details

The order of the parameters is generally: locations, scales, correlations, shape. When the distribution defined by `Dist` does not have, say, the shape parameter, this should be simply omitted. See also DistInfo for specific distributions.

Value

A `numeric` vector of parameters.

Author(s)

Leopoldo Catania

Examples

```
# Map unrestricted parameters for the Multivariate Student-t distribution with N=3
library("GAS")

N = 3

Dist = "mvt"

# Vector of location parameters (this is not transformed).
Mu_tilde  = c(0.1,0.2,0.3)

# Vector of unrestricted scales parameters such that
# the scales will be equal to 1.0, 1.2 and 0.3, for the first, second and
# third variables, respectively.
Phi_tilde = c(log(1.0), log(1.2), log(0.3))

# The vector c(0.1,0.2,0.3) represents vec(R),
# where R is the correlation matrix.
# Note that is up to the user to ensure that
# vec(R) implies a proper correlation matrix
# The function UnMapR_C transforms vec(R) in a vector of unrestricted parameters. It is
# the inverse of the hyperspherical coordinates transformration.

Rho_tilde = UnMapR_C(c(0.1,0.2,0.3), N)

# Vector of unconditional reparametrised parameters such that the
# degrees of freedom are 7.
#
# LowerNu() prints the lower bound numerical parameter for the degree
# of freedom, see help(LowerNu)
#

Theta_tilde = c(Mu_tilde, Phi_tilde , Rho_tilde, log(7 - LowerNu()))

Theta = MultiMapParameters(Theta_tilde, Dist, N)

Theta
```

MultiUnmapParameters *Inverse of MultiMapParameters*

Description

Transform distribution parameters into the unrestricted parameters. The unrestricted vector of parameters is updated using the GAS recursion.

Usage

```
MultiUnmapParameters(Theta, Dist, N)
```

Arguments

Theta	numeric Vector parameters, see Details.
Dist	character Label of the conditional distribution, see DistInfo.
N	numeric Cross sectional dimension. Note that only iN<5 is supported.

Details

The order of the parameters is generally: locations, scales, correlations, shape. When the distribution defined by Dist does not have, say, the shape parameter, this should be simply omitted. See also DistInfo for specific distributions.

Value

A numeric vector of parameters.

Author(s)

Leopoldo Catania

Examples

```
# Unmap parameters for the Multivariate Student-t distribution with N=3
library(GAS)

N = 3

Dist = "mvt"

# Vector of location parameters (this is not transformed).
Mu  = c(0.1,0.2,0.3)

# Vector of scales parameters for the firs, second and third variables.
Phi = c(1.0, 1.2, 0.3)

# This represents vec(R), where R is the correlation matrix.
# Note that is up to the user to ensure that vec(R) implies a proper correlation matrix
Rho = c(0.1,0.2,0.3)

# Vector of parameters such that the degrees of freedom are 7.
Theta = c(Mu, Phi, Rho, 7)

Theta_tilde = MultiUnmapParameters(Theta, Dist, N)

Theta_tilde

# It works
all(abs(MultiMapParameters(Theta_tilde, Dist, N) - Theta) < 1e-16)
```

NumericalBounds *Numerical bounds imposed in parameters transformation.*

Description

Prints the numerical bounds.

Usage

```
UpperNu()
LowerNu()
UpperA()
LowerA()
UpperB()
LowerB()
```

Details

`UpperNu()` and `LowerNu()` print the numerical upper and lower bounds for the degree of freedom parameter of the Student–t distribution, `std`. (including also `sstd` and `mvt`).

`UpperA()` and `LowerA()` print the numerical upper and lower bounds for the score parameter in the GAS recursion. These bounds are applied to each diagonal element of the matrix `A` that premultiplies the scaled score.

`UpperB()` and `LowerB()` print the numerical upper and lower bounds for the autoregressive parameter in the GAS recursion. These bounds are applied to each diagonal element of the matrix `B` that premultiplies the past value of the parameters.

Value

Prints the numerical bounds.

Author(s)

Leopoldo Catania

Examples

```
UpperNu()
LowerNu()
UpperA()
LowerA()
UpperB()
LowerB()
```

PIT_test *Goodness of fit for conditional densities*

Description

This function implements density goodness of fit procedure of Diebold et al. (1998).

Usage

```
PIT_test(U, G = 20, alpha = 0.05, plot = FALSE)
```

Arguments

U	numeric Vector of Probability Integral Transformation (PIT).
G	numeric Number of bins of the empirical cumulative density function of the PIT.
alpha	numeric Test confidence level.
plot	boolean Indicates whether the istogram of the PIT has to be displaied. By defauld plot = FALSE.

Details

This function implements density goodness of fit procedure of Diebold et al. (1998). The test relays on the result that, if the series of estimated conditional distributions is the true one, then the PIT series evaluated accordingly are iid Unif(0, 1) distributed. The test of the iid Uniform(0, 1) assumption consists of two parts. The first part concerns the independent assumption, and it tests if all the conditional moments of the data, up to the fourth one, have been accounted for by the model, while the second part checks if the conditional distribution assumption is reliable by testing if the PITs are Uniform over the interval (0, 1). See also Jondeau and Rockinger (2006) and Vlaar and Palm (1993).

Value

A list with elements: (i) Hist and (ii) IID. The fist element Hist concerns the test of the unconditional assumption of uniformity of the PIT, it is a list with elements:

- test Statistic test.
- crit The critical value of the test.
- pvalue The pvalue of the test.
- hist The histogram, evaluated using the hist function.
- confidence Approximated asymptotic confidence level.

The second element IID concerns the iid assumption, it is a list with elements:

- test A named numeric vector with elements: test1, test2, test3, test4 representing the Lagrange Multiplier test for the first four conditional moments of the PITs.

- `crit` The critical value of the test.
- `pvalue` A named `numeric` vector with elements: `pvalue1`, `pvalue2`, `pvalue3`, `pvalue4` representing the pvalues of the Lagrange Multiplier test for the first four conditional moments of the PITs.

Author(s)

Leopoldo Catania

References

Diebold FX, Gunther TA and Tay AS (1998). "Evaluating Density Forecasts with Applications to Financial Risk Management." International Economic Review, 39(4), 863-883, doi: 10.2307/2527342.

Jondeau E and Rockinger M (2006). "The Copula-Garch Model of Conditional Dependencies: An International Stock Market Application." Journal of International Money and Finance, 25(5), 827-853, doi: 10.1016/j.jimonfin.2006.04.007.

Vlaar PJ and Palm FC (1993). "The Message in Weekly Exchange Rates in the European Monetary System: Mean Reversion, Conditional Heteroscedasticity, and Jumps." Journal of Business & Economic Statistics, 11(3), 351-360, doi: 10.1080/07350015.1993.10509963.

Examples

```
data("StockIndices")

GASSpec = UniGASSpec(Dist = "std", ScalingType = "Identity",
                     GASPar = list(location = FALSE, scale = TRUE,
                                   shape = FALSE))

FTSEMIB = StockIndices[, "FTSEMIB"]

Fit = UniGASFit(GASSpec, FTSEMIB)

U = pit(Fit)

Test = PIT_test(U, G=20, alpha=0.05, plot=TRUE)
```

---

sp500ret *Data: Daily logarithmic returns in percentage points of the S&P500 index from 1950-01-04 to 2016-06-24*

Description

Daily logarithmic returns in percentage points of the S&P500 index from 1950-01-04 to 2016-06-24 obtained from yahoo finance http://finance.yahoo.com/quote/%5EGSPC?ltr=1.

Usage

```
data("sp500ret")
```

Format

A xts object of dimension 16,727 x 1 containing the daily logarithmic returns in percentage points from 1950-01-04 to 2016-06-24.

Source

Yahoo Finance

---

sp500rv — *Data: SP500 Daily 5 minutes Realized Volatility from 2000-01-03 to 2000-01-10*

Description

Oxford-Man Institute Daily 5 minutes Realized Volatility from 2000-01-03 to 2000-01-10 for the SP500 Index available at http://realized.oxford-man.ox.ac.uk/data.

Usage

```
data("sp500rv")
```

Format

A xts object containing 4,310 observations from 2000-01-03 to 2000-01-10.

References

http://realized.oxford-man.ox.ac.uk/data

StockIndices — *Data: Daily logarithmic returns in percentage points of the DAX, FTSEMIB and CAC40 from 2007-01-03 to 2016-06-24*

Description

Daily logarithmic returns in percentage points of the DAX, FTSEMIB and CAC40 from 2007-01-03 to 2016-06-24 obtained at https://finance.yahoo.com/.

Usage

```
data("StockIndices")
```

Format

A matrix object of dimension 2,445 x 3 containing the daily logarithmic returns in percentage points from 2007-01-03 to 2016-06-24. Missing values are simply removed.

References

https://finance.yahoo.com/

Examples

```
## Not run:
library("quantmod")

Ticker = c( "^GDAXI", "FTSEMIB.MI", "^FCHI" )

From = "2007-01-01"
To = "2016-06-24"

StockEnv = new.env(has = TRUE)

getSymbols(Ticker, from = From, to = To, env = StockEnv)

mPrices = do.call(cbind, eapply(StockEnv, Ad ))

mRet = diff( log( mPrices ) )

colnames(mRet) = c( "DAX", "FTSEMIB", "CAC40" )

StockIndices = mRet[-1, ]

## End(Not run)
```

---

tqdata *Data from Bien et al (2011).*

Description

From the readme.bnp.txt file in the JAE Data Archive available at http://qed.econ.queensu.ca/jae/datasets/bien001/:

The high-frequency data used in the paper come from the Trades and Quotation (TAQ) database. The data contains time-stamped quotations of Citicorp stock traded at the NYSE over the period from 20th February to 23rd February 2001.

In the study, 30-second bid and ask quote changes are constructed from the irregularly-spaced quote data. The study covers observations recorded from 9:35 EST until 16:00 EST.

The data contains 3080 rows and eight columns - in order:

1. year 2. month 3. day 4. time in number of seconds after the 9:35 EST 5. best ask quote 6. best bid quote 7. 30-second change of the ask quote in number of ticks 8. 30-second change of the bid quote in number of ticks.

Usage

```
data("tqdata")
```

Format

A data.frame object containing 3,080 observat. ions.

References

Bien K, Nolte, I, Pohlmeier W (2011). "An Inflated Multivariate Integer Count Hurdle Model: An Application to Bid and Ask Quote Dynamics", Journal of Applied Econometrics, 26(4), 669-707. doi: 10.1002/jae.1122

---

uGASFit *Class for the univariate GAS fitted object*

Description

Class for the univariate GAS fitted object.

Objects from the Class

A virtual Class: No objects may be created from it.

Slots

`ModelInfo`**:** Object of class `list`. Contains information about the GAS specification:

- `Spec`: object of the class uGASSpec containing the GAS specification.
- `iT`: `numeric` number of observation.
- `elapsedTime`: `numeric` elapsed Time in seconds.

`GASDyn`**:** Object of class `list`. Contains: the series of filtered dynamic (`GASDyn$mTheta`) for the time–varying parameters, the series of scaled scores (`GASDyn$mInnovation`), the series of unrestricted filtered parameters (`GASDyn$mTheta_tilde`), the series of log densities (`GASDyn$vLLK`), the log likelihood evaluated at its optimum value (`GASDyn$dLLK`).

`Estimates`**:** Object of class `list`. Contains: `lParList` list of estimated parameters, `optimiser` object delivered from the optimization function, `StaticFit` ML estimates for the constant model, `Inference` inferential results for the estimated parameters.

`Data`**:** The user's data.

`Testing`**:** Statistical tests results.

Methods

- show `signature(object = 'uGASFit')`: Show summary.
- `plot signature(x = 'uGASFit',y = 'missing')`: Plot filtered dynamic and other estimated quantities.
- `getFilteredParameters signature(object = 'uGASFit')`: Extract filtered parameters.
- `getObs signature(object = 'uGASFit')`: Extract original observations.
- `coef signature(object = 'uGASFit')`: Extract estimated coefficients.
- `pit signature(object = 'uGASFit')`: Extract Probability Integral Transformation.
- `getMoments signature(object = 'uGASFor')`: Extract conditional moments.

Author(s)

Leopoldo Catania

`uGASFor` *Class for the univariate GAS forecast object*

Description

Class for the univariate GAS forecast object.

Objects from the Class

A virtual Class: No objects may be created from it.

Slots

`Forecast`: Object of class `list`. Contains forecasts:

- `PointForecast`: `matrix` with parameters forecasts.
- `Moments`: `matrix` with centered moments forecasts.
- `vLS`: `numeric` Log Score (Predictive Log Likelihood).
- `vU`: `numeric` Out-of-sample Probability Integral Transformation (PIT).

`Bands`: `array` with confidence bands parameters forecasts. Available only if `Roll = TRUE`.

`Draws`: If `ReturnsDraws = TRUE` it is a iH x iB `matrix` of draws from the predictive distribution.

`Info`: `list` with forecast information.

`Data`: `list` with original data.

Methods

- show `signature(object = 'uGASFor')`: Show summary.
- plot `signature(x = 'uGASFor', y = 'missing')`: Plot forecasted quantities.
- getForecast `signature(object = 'uGASFor')`: Extract parameters forecast.
- getObs `signature(object = 'uGASFor')`: Extract original observations.
- pit `signature(object = 'uGASFor')`: Extract Probability Integral Transformation, only if `Roll = TRUE`.
- quantile `signature(object = 'uGASFor')`: Extract quantile forecasts. It accepts the additional argument `probs` representing the vector of probabilities.
- getMoments `signature(object = 'uGASFor')`: Extract moments forecasts.
- LogScore `signature(object = 'uGASFor')`: Extract Log Scores.

Author(s)

Leopoldo Catania

---

uGASRoll *Class for the univariate GAS rolling object*

Description

Class for the univariate GAS rolling object.

Objects from the Class

A virtual Class: No objects may be created from it.

Slots

`Forecast`: Object of class `list`. Contains forecasts:

- `PointForecast`: `matrix` with parameters forecasts.
- `Moments`: `matrix` with centered moments forecasts.
- `vLS`: `numeric` Log Score (Predictive Log Likelihood).
- `vU`: `numeric` Out-of-sample Probability Integral Transformation (PIT).

`Info`: `list` with forecast information.

`Data`: `list` with original data.

`Testing`: Statistical tests results.

Methods

- show `signature(object = 'uGASFor')`: Show summary.
- plot `signature(x = 'uGASFor', y = 'missing')`: Plot forecasted quantities.
- getForecast `signature(object = 'uGASFor')`: Extract parameters forecast.
- getObs `signature(object = 'uGASFor')`: Extract original observations.
- pit `signature(object = 'uGASFor')`: Extract Probability Integral Transformation, only if `Roll = TRUE`
- quantile `signature(object = 'uGASFor')`: Extract quantile forecasts. It accepts the addional argument `probs` representing the vector of probabilities.
- getMoments `signature(object = 'uGASFor')`: Extract moments forecasts.
- LogScore `signature(object = 'uGASFor')`: Extract Log Scores.

Author(s)

Leopoldo Catania

---

uGASSim *Class for Univariate GAS Simulation*

Description

Class for Univariate GAS model Simulation.

Objects from the Class

A virtual Class: No objects may be created from it.

Slots

`ModelInfo`**:** Object of class `list`. Contains information about the univariate GAS specification:

- `iT` `numeric` Time length of simulated observations.
- `iK` `numeric` Number of (possibly) time-varying parameters implied by the distributional assumption.
- `vKappa` `numeric` Vector of unconditional level for the reparametrised vector of parameters.
- `mA` `matrix` Of coefficients of dimension iK x iK that premultiply the conditional score in the GAS updating recursion.
- `mB` `matrix` Of autoregressive coefficients of dimension iK x iK.
- `Dist` `character` Label of the conditional distribution, see DistInfo
- `ScalingType` `character` Representing the scaling mechanism for the conditional score, see DistInfo.

`GASDyn`**:** Object of class `list`. Contains: the series of simulated parameters (`GASDyn$mTheta`), the series of scaled scores (`GASDyn$mInnovation`), the series of unrestricted simulated parameters (`GASDyn$mTheta_tilde`), the series of log densities (`GASDyn$vLLK`), the log likelihood evaluated at its optimum value (`GASDyn$dLLK`).

`Data`**:** Object of class `numeric`. Vector of length `iT` of simulated data.

Methods

- show `signature(object = 'uGASSim')`: Show summary.
- plot `signature(x = 'uGASSim', y = 'missing')`: Plot simulated data and parameters.
- getFilteredParameters `signature(object = 'uGASSim')`: Extract simulated parameters.
- getObs `signature(object = 'uGASSim')`: Extract simulated observations.
- coef `signature(object = 'uGASSim')`: Extract delivered coefficients.

Author(s)

Leopoldo Catania

---

uGASSpec *Class for the univariate GAS model specification*

Description

Class for the univariate GAS model specification.

Objects from the Class

A virtual Class: No objects may be created from it.

Slots

`Spec`: Object of class `list`. Contains information about the univariate GAS specification:

- `Dist`: `character` containing the conditional distribution assumption.
- `ScalingType`: `character` indicating the scaling mechanism for the conditional score.
- `iK`: `numeric` representing the number of (possibly) time-varying parameters implied by the distributional assumption.
- `GASPar` `list` with elements: `location`, `scale`, `skewness`, `shape`, `shape2`.

Methods

- show `signature(object = 'uGASSpec')`: Show summary.

Author(s)

Leopoldo Catania

UniGASFit *Estimate univariate GAS models*

Description

Estimate univariate GAS models by Maximum Likelihood.

Usage

```
UniGASFit(GASSpec, data)
```

Arguments

GASSpec	An object of the class uGASSpec created using the function UniGASSpec.
data	numeric vector of length Tx1 containing the time series of observations. It can also be an object of the class ts, xts or zoo.

Details

Maximum Likelihood estimation of GAS models is an on-going research topic. General results are reported by Blasques et al. (2014b), Blasques et al. (2014a) and Harvey (2013), while results for specific models have been derived by Blasques et al. (2014c) and Andres (2014).

The optimizer used is the General Nonlinear Augmented Lagrange Multiplier method of Ye (1988) available in the R package Rsolnp (Ghalanos and Theussl 2016).

Starting values for the optimizer are chosen in the following way: (i) estimate the static version of the model (i.e., with A = 0 and B = 0) and set the initial value of the intercept parameter accordingly, and (ii) perform a grid search for the coefficients contained in A and B. Further technical details are presented in Section 3.2 of Ardia et. al. (2016).

The function prints some information during the estimation procedure.

Value

An object of the class uGASFit

Author(s)

Leopoldo Catania

References

Ardia D, Boudt K and Catania L (2016). "Generalized Autoregressive Score Models in R: The GAS Package." Available at SSRN: http://ssrn.com/abstract=2825380.

Blasques F, Koopman SJ, Lucas A (2014a). "Maximum Likelihood Estimation for Correctly Specified Generalized Autoregressive Score Models: Feedback Effects, Contraction Conditions and Asymptotic Properties. techreport TI 14-074/III, Tinbergen Institute. URL http://www.tinbergen.nl/discussionpaper/?paper=2332.

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Blasques F, Koopman SJ, Lucas A, Schaumburg J (2014c). "Spillover Dynamics for Systemic Risk Measurement using Spatial Financial Time Series Models." techreport TI 2014-103/III, Tinbergen Institute. URL http://www.tinbergen.nl/discussionpaper/?paper=2369.

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Harvey AC (2013). Dynamic Models for Volatility and Heavy Tails: With Applications to Financial and Economic Time Series. Cambridge University Press.

Ye Y (1988). Interior Algorithms for Linear, Quadratic, and Linearly Constrained Convex Programming. Ph.D. thesis, Stanford University.

Examples

```
## Not run:
# Specify an univariate GAS model with Student-t
# conditional distribution and time-varying scale.
library("GAS")

data("sp500ret")

GASSpec = UniGASSpec(Dist = "std", ScalingType = "Identity",
                     GASPar = list(location = FALSE, scale = TRUE,
                                   shape = FALSE))

Fit = UniGASFit(GASSpec, sp500ret)

Fit


## End(Not run)
```

UniGASFor *Forecast with univariate GAS models*

Description

Forecast with univariate GAS models. The one-step ahead prediction of the conditional density is available in closed form. The multi-step ahead prediction is performed by simulation as detailed in Blasques et al. (2016).

Usage

```
UniGASFor(uGASFit, H, Roll = FALSE, out = NULL, B = 10000,
                    Bands = c(0.1, 0.15, 0.85, 0.9), ReturnDraws = FALSE)
```

Arguments

uGASFit	An object of the class uGASFit created using the function UniGASFit.
H	numeric Forecast horizon. Ignored if Roll = TRUE.
Roll	boolean Forecast should be made using a rolling procedure ? Note that, if Roll = TRUE, then out has to be specified.
out	numeric Vector of out-of-sample observation for rolling forecast.
B	numeric Number of draws from the H-step ahead distribution if Roll = TRUE.
Bands	numeric Vector of probabilities representing the confidence band levels for multi-step ahead parameters forecasts. Only if Roll = TRUE.
ReturnDraws	boolean Return the draws from the multi-step ahead predictive distribution when Roll = TRUE ?

Value

An object of the class uGASFor.

Author(s)

Leopoldo Catania

References

Blasques F, Koopman SJ, Lasak K, and Lucas, A (2016). "In-sample Confidence Bands and Out-of-Sample Forecast Bands for Time-Varying Parameters in Observation-Driven Models." International Journal of Forecasting, 32(3), 875-887. doi: 10.1016/j.ijforecast.2016.04.002.

Examples

```
# Specify an univariate GAS model with Student-t
# conditional distribution and time-varying location, scale and shape parameter

# Inflation Forecast

set.seed(123)

data("cpichg")

GASSpec = UniGASSpec(Dist = "std", ScalingType = "Identity",
                     GASPar = list(location = TRUE, scale = TRUE, shape = FALSE))

# Perform H-step ahead forecast with confidence bands

Fit = UniGASFit(GASSpec, cpichg)
Forecast = UniGASFor(Fit, H = 12)

Forecast

# Perform 1-Step ahead rolling forecast

InsampleData = cpichg[1:250]
OutSampleData = cpichg[251:276]

Fit = UniGASFit(GASSpec, InsampleData)

Forecast = UniGASFor(Fit, Roll = TRUE, out = OutSampleData)

Forecast
```

UniGASRoll *Rolling forecast with univariate GAS models*

Description

One-step ahead rolling forecasts with model re-estimation. The function also reports several quantity for backtesting for point and density forecasts.

Usage

```
UniGASRoll(data, GASSpec, ForecastLength = 500, Nstart = NULL,
           RefitEvery = 23, RefitWindow = c("moving", "recursive"),
           cluster=NULL)
```

Arguments

data	numeric vector containing the time series of observations.
GASSpec	An object of the class uGASSpec created using the function UniGASSpec.
ForecastLength	numeric Length of the out-of-sample.
Nstart	numeric Period when perform the first forecast. Ignored if ForecastLength is supplied.
RefitEvery	numeric Number of periods before model coefficients re-estimation.
RefitWindow	character Type of window. If RefitWindow = "recursive" all the observations are used when the model is re-estimated. If RefitWindow = "moving" old observations are eliminated.
cluster	A cluster object created calling using the paralell package. If supplied parallel processing is used to speed up the computations.

Value

An object of the class uGASRoll.

Author(s)

Leopoldo Catania

Examples

```
# Specify an univariate GAS model with Student-t
# conditional distribution and time-varying location, scale and shape parameter

# Inflation Forecast

data("cpichg")
help(cpichg)

GASSpec = UniGASSpec(Dist = "std", ScalingType = "Identity",
                     GASPar = list(location = TRUE, scale = TRUE, shape = FALSE))

# Perform 1-step ahead rolling forecast with refit
library("parallel")

Roll = UniGASRoll(cpichg, GASSpec, ForecastLength = 50,
                  RefitEvery = 10, RefitWindow = c("moving"))


Roll
```

UniGASSim *Simulate Univariate GAS processes*

Description

Simulate Univariate GAS processes.

Usage

```
UniGASSim(T.sim, kappa, A, B, Dist, ScalingType)
```

Arguments

T.sim	numeric Length of the simulated time series.
kappa	numeric Vector of unconditional level for the reparametrised vector of parameters.
A	matrix Of coefficients of dimension K x K that premultiply the conditional score in the GAS updating recursion, see Details.
B	matrix Of autoregressive coefficients of dimension K x K, see Details.
Dist	character Label of the conditional distribution, see DistInfo.
ScalingType	character Indicating the scaling mechanism for the conditional score. Possible choices are "Identity", "Inv", "InvSqrt". Note that, for some distribution only ScalingType = "Identity" is supported, see the function DistInfo. When ScalingType = "InvSqrt" the inverse of the Cholesky decomposition of the information matrix is used. Default value ScalingType = "Identity".

Details

All the information regarding the supported univariate conditional distributions can be investigated using the DistInfo function. The model is specified as

$$y_t \sim p(y|\theta_t)$$

, where θ_t is the vector of parameters for the density $p(y|.)$. Note that, θ_t includes also those parameters that are not time-varying. The GAS recursion for θ_t is

$$\theta_t = \Lambda(\tilde{\theta}_t)$$

,

$$\tilde{\theta}_t = \kappa + A * s_{t-1} + B * \tilde{\theta}_{t-1}$$

, where $\Lambda(.)$ is the mapping function (see UniMapParameters) and $\tilde{\theta}_t$ is the vector of reparametrised parameters. The process is initialized at $\theta_1 = (I - B)^{-1}\kappa$, where κ is the vKappa vector. The vector s_t is the scaled score of $p(y|.)$ with respect to $\tilde{\theta}_t$. See Ardia et. al. (2016) for further details.

Value

An object of the class uGASSim.

Author(s)

Leopoldo Catania

References

Ardia D, Boudt K and Catania L (2016). "Generalized Autoregressive Score Models in R: The GAS Package." Available at SSRN: http://ssrn.com/abstract=2825380.

Creal D, Koopman SJ, Lucas A (2013). "Generalized Autoregressive Score Models with Applications." Journal of Applied Econometrics, 28(5), 777-795. doi: 10.1002/jae.1279.

Harvey AC (2013). Dynamic Models for Volatility and Heavy Tails: With Applications to Financial and Economic Time Series. Cambridge University Press.

Examples

```
# Simulate from a GAS process with Student-t conditional
# distribution, time-varying location, scale and fixed shape parameter.

library(GAS)

set.seed(786)

T.sim  = 1000 # number of observations to simulate
Dist   = "std" # conditional Studen-t distribution


# vector of unconditional reparametrised parameters such that, the unconditional level of
# \eqn{\theta}_{t} is (0, 1.5 ,7), i.e. location = 0, scale = 1.5,
# degrees of freedom = 7.

kappa = c(0.0, log(1.5), log(7-2.01))

# in this way we specify that the shape parameter is constant while the score
# coefficients for the location and the scale
# parameters are 0.001 and 0.01, respectively.

A     = matrix(c(0.001 , 0.0  , 0.0 ,
                 0.0   , 0.01 , 0.0 ,
                 0.0   , 0.0  , 0.0 ), 3, byrow = TRUE)

B = matrix(c(0.7 , 0.0 , 0.0 ,
             0.0 , 0.98, 0.0 ,
             0.0 , 0.0 , 0.0),3,byrow = TRUE) # Matrix of autoregressive parameters.

Sim = UniGASSim(T.sim, kappa, A, B, Dist, ScalingType = "Identity")

Sim
```

`UniGASSpec` *Univariate GAS specification*

Description

Specify the conditional distribution, scaling mechanism and time–varying parameters for univariate GAS models.

Usage

```
UniGASSpec(Dist = "norm", ScalingType = "Identity",
           GASPar = list(location = FALSE, scale = TRUE,
                         skewness = FALSE, shape = FALSE, shape2 = FALSE))
```

Arguments

`Dist`	`character` Indicating the label of the conditional distribution. Available distribution can be displayed using the function DistInfo. Default value`Dist = "norm"`.
`ScalingType`	`character` Indicating the scaling mechanism for the conditional score. Possible choices are `"Identity"`, `"Inv"`, `"InvSqrt"`. Note that, for some distribution only `ScalingType = "Identity"` is supported, see the function DistInfo. When `ScalingType = "InvSqrt"` the inverse of the cholesky decomposition of the information matrix is used. Default value `ScalingType = "Identity"`.
`GASPar`	`list` Containing information about which parameters of the conditional distribution have to be time-varying. `location = TRUE` refers to the location parameter, `scale = TRUE` refers to the scale parameter, `skewness = TRUE` refers to the parameter controlling the skewness, `shape = TRUE` refers to the shape parameter (e.g. the degree of freedom of the Student-t distribution), `shape2 = TRUE` refers to the second shape parameter. If the distribution specified in the `Dist` argument does not have, say, a shape parameter, the condition `shape = TRUE` or `shape = FALSE` is ignored.

Details

All the information regarding the supported univariate conditional distributions can be investigated using the DistInfo function.

Value

An object of the class uGASSpec.

Author(s)

Leopoldo Catania

References

Ardia D, Boudt K and Catania L (2016). "Generalized Autoregressive Score Models in R: The GAS Package." Available at SSRN: http://ssrn.com/abstract=2825380.

Creal D, Koopman SJ, Lucas A (2013). "Generalized Autoregressive Score Models with Applications." Journal of Applied Econometrics, 28(5), 777-795. doi: 10.1002/jae.1279.

Harvey AC (2013). Dynamic Models for Volatility and Heavy Tails: With Applications to Financial and Economic Time Series. Cambridge University Press.

Examples

```
# Specify an univariate GAS model with Student-t
# conditional distribution and time-varying location, scale and shape parameter
library("GAS")

GASSpec = UniGASSpec(Dist = "std", ScalingType = "Identity",
                     GASPar = list(location = TRUE,
                                   scale = TRUE, shape = TRUE))

GASSpec
```

`UniMapParameters` *Mapping function for univariate distributions*

Description

Map unrestricted vector of parameters into the proper space. This function transforms the parameters updated using the GAS recursion into their proper space.

Usage

```
UniMapParameters(Theta_tilde, Dist)
```

Arguments

`Theta_tilde`	`numeric` Vector of reparametrised parameters, see Details.
`Dist`	`character` Label of the conditional distribution, see DistInfo.

Details

The order of the parameters is generally: `location`, `scale`, `skewness`, `shape`, `shape2`. When the distribution defined by `Dist` does not have, say, the `shape` parameter, this should be simply omitted. See also DistInfo for specific distributions.

Value

A numeric vector of parameters.

Author(s)

Leopoldo Catania

Examples

```
# Map unrestricted parameters for the Student-t distribution.
library("GAS")

Dist = "std"

# Vector of unconditional reparametrised parameters such that,
# Theta = c(0, 1.5 ,7), i.e., location = 0, scale = 1.5,
# degrees of freedom = 7.

# LowerNu() prints the lower bound numerical parameter for the degree
# of freedom, see help(LowerNu).

Theta_tilde = c(0.1, log(1.5), log(7 - LowerNu()))

Theta = UniMapParameters(Theta_tilde, Dist)

Theta
```

UniUnmapParameters *Unmapping function for univariate distributions, i.e. inverse of UniMapParameters*

Description

Transform distribution parameters into the unrestricted parameters. The unrestricted vector of parameters is updated using the GAS recursion.

Usage

```
UniUnmapParameters(Theta, Dist)
```

Arguments

Theta	numeric Vector of parameters, see Details.
Dist	character Label of the conditional distribution, see DistInfo.

Details

The order of the parameters is generally: location, scale, skewness, shape, shape2. When the distribution defined by Dist does not have, say, the shape parameter, this should be simply omitted. See also DistInfo for specific distributions.

Value

A numeric vector of parameters.

Author(s)

Leopoldo Catania

Examples

```
# Unmap parameters for the Student-t distribution
library("GAS")

Dist = "std"

# Vector of parameters such that,
# Theta = c(0, 1.5 ,7), i.e., location = 0, scale = 1.5,
# degrees of freedom = 7.

Theta = c(0.1, 1.5, 7)

Theta_tilde = UniUnmapParameters(Theta, Dist)

Theta_tilde

# It works.
all(abs(UniMapParameters(Theta_tilde, Dist) - Theta) < 1e-16)
```

---

usunp *US Monthly Civilian Unemployment Rate (UNRATE) from 1948-01-01 to 2016-05-01*

Description

From https://fred.stlouisfed.org/series/UNRATE: The unemployment rate represents the number of unemployed as a percentage of the labor force. Labor force data are restricted to people 16 years of age and older, who currently reside in 1 of the 50 states or the District of Columbia, who do not reside in institutions (e.g., penal and mental facilities, homes for the aged), and who are not on active duty in the Armed Forces.

Usage

```
data("usunp")
```

Format

A xts object containing 821 observations from 1948-01-01 to 2016-05-01.

References

US. Bureau of Labor Statistics, Civilian Unemployment Rate [UNRATE], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/UNRATE, July 2, 2016.

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