

# Package ‘betategarch’

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**Title** Simulation, estimation and forecasting of Beta-Skew-t-EGARCH models

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**URL** <http://www.sucarrat.net/>

**Description** Simulation, estimation and forecasting of first-order Beta-Skew-t-EGARCH models with leverage (one-component, two-component, skewed versions).

**License** GPL-2

**NeedsCompilation** yes

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betategarch-package     *Simulation, estimation and forecasting of Beta-Skew-t-EGARCH models*

---

## Description

This package provides facilities for the simulation, estimation and forecasting of first order Beta-Skew-t-EGARCH models with leverage (one-component and two-component versions), see Harvey and Sucarrat (2013).

Let  $y[t]$  denote a financial return at time  $t$  equal to

$$y[t] = \sigma[t] * \epsilon[t]$$

where  $\sigma[t] > 0$  is the scale or volatility (generally not equal to the conditional standard deviation), and where  $\epsilon[t]$  is IID and  $t$ -distributed (possibly skewed) with  $df$  degrees of freedom. Then the first order log-volatility specification of the one-component Beta-Skew-t-EGARCH model can be parametrised as

$$\begin{aligned} \sigma[t] &= \exp(\lambda[t]), \\ \lambda[t] &= \omega + \lambda_{dagger}, \\ \lambda_{dagger}[t] &= \phi_1 * \lambda_{dagger}[t-1] + \kappa_1 * u[t-1] + \kappa_{star} * \text{sign}[-y] * (u[t-1] + 1). \end{aligned}$$

So the scale or volatility is given by  $\sigma[t] = \exp(\lambda[t])$ . The  $\omega$  is the unconditional or long-term log-volatility,  $\phi_1$  is the GARCH parameter ( $|\phi_1| < 1$  implies stability),  $\kappa_1$  is the ARCH parameter,  $\kappa_{star}$  is the leverage or volatility-asymmetry parameter and  $u[t]$  is the conditional score or first derivative of the log-likelihood with respect to  $\lambda$ . The score  $u[t]$  is zero-mean and IID, and  $(u[t]+1)/(df+1)$  is Beta distributed when there is no skew in the conditional density of  $\epsilon[t]$ . The two-component specification is given by

$$\begin{aligned} \sigma[t] &= \exp(\lambda[t]), \\ \lambda[t] &= \omega + \lambda_{1dagger} + \lambda_{2dagger}, \\ \lambda_{1dagger}[t] &= \phi_1 * \lambda_{dagger}[t-1] + \kappa_1 * u[t-1], \\ \lambda_{2dagger}[t] &= \phi_2 * \lambda_{dagger}[t-1] + \kappa_2 * u[t-1] + \kappa_{star} * \text{sign}[-y] * (u[t-1] + 1). \end{aligned}$$

The first component,  $\lambda_{1dagger}$ , is interpreted as the long-term component, whereas the second component,  $\lambda_{2dagger}$ , is interpreted as the short-term component.

## Details

Package:	betategarch
Type:	Package
Version:	3.2
Date:	2014-09-18
License:	GPL-2
LazyLoad:	yes

The two main functions of the package are [tegarchSim](#) and [tegarch](#). The first simulates a Beta-Skew-t-EGARCH models whereas the second estimates one. The second object returns an object (a

list) of class 'tegarch', and a collection of methods can be applied to this class: `coef.tegarch`, `fitted.tegarch`, `logLik.tegarch`, `predict.tegarch`, `print.tegarch`, `residuals.tegarch`, `summary.tegarch` and `vcov.tegarch`. In addition, the output produced by the `tegarchSim` function and the `fitted.tegarch` and `residuals.tegarch` methods are of the `Z`'s ordered observations (`zoo`) class, which means a range of time-series methods are available for these objects.

### Author(s)

Genaro Sucarrat, <http://www.sucarrat.net/>

### References

Fernandez and Steel (1998), 'On Bayesian Modeling of Fat Tails and Skewness', Journal of the American Statistical Association 93, pp. 359-371.

Harvey and Sucarrat (2013), 'EGARCH models with fat tails, skewness and leverage', forthcoming in Computational Statistics and Data Analysis. Working paper version: Cambridge Working Papers in Economics 1236, Faculty of Economics, University of Cambridge.

### Examples

```
#simulate 500 observations from model with default parameter values:
set.seed(123)
y <- tegarchSim(500)

#estimate and store as 'mymod':
mymod <- tegarch(y)

#print estimates and standard errors:
print(mymod)

#graph of fitted volatility (conditional standard deviation):
plot(fitted(mymod))

#plot forecasts of volatility 1-step ahead up to 10-steps ahead:
plot(predict(mymod, n.ahead=10))
```

---

coef.tegarch

*Extraction methods for 'tegarch' objects*

---

### Description

Extraction methods for objects of class 'tegarch' (i.e. the result of estimating a Beta-Skew-t-EGARCH model)

**Usage**

```
## S3 method for class 'tegarch'
coef(object, ...)
## S3 method for class 'tegarch'
fitted(object, verbose = FALSE, ...)
## S3 method for class 'tegarch'
logLik(object, ...)
## S3 method for class 'tegarch'
print(x, ...)
## S3 method for class 'tegarch'
residuals(object, standardised = TRUE, ...)
## S3 method for class 'tegarch'
summary(object, verbose = FALSE, ...)
## S3 method for class 'tegarch'
vcov(object, ...)
```

**Arguments**

object	an object of class 'tegarch'
x	an object of class 'tegarch'
verbose	logical. If FALSE (default) then only basic information is returned
standardised	logical. If TRUE (default) then the standardised residuals are returned. If FALSE then the scaled (by sigma) residuals are returned
...	additional arguments

**Details**

Empty

**Value**

coef:	A numeric vector containing the parameter estimates
fitted:	A zoo object. If verbose=FALSE (default), then the zoo object is a vector containing the fitted conditional standard deviations. If verbose = TRUE, then the zoo object is a matrix containing the return series y, fitted scale (sigma), fitted conditional standard deviation (stdev), fitted log-scale (lambda), dynamic component(s) (lambdadagger in the 1-component specification, lambda1dagger and lambda2dagger in the 2-compoment specification), the score (u), scaled residuals (epsilon) and standardised residuals (residstd)
logLik:	The value of the log-likelihood at the maximum
print:	Prints the most important parts of the estimation results
residuals:	A zoo object. If standardised = TRUE (default), then the zoo object is a vector with the standardised residuals. If standardised = FALSE, then the zoo vector contains the scaled residuals
summary:	A list. If verbose = FALSE, then only the most important entries are returned. If verbose = TRUE, then all entries apart from the 1st. (the y series) is returned

vcov: The variance-covariance matrix of the estimated coefficients. The matrix is obtained by inverting the numerically estimated Hessian

### Author(s)

Genaro Sucarrat, <http://www.sucarrat.net/>

### References

Fernandez and Steel (1998), 'On Bayesian Modeling of Fat Tails and Skewness', Journal of the American Statistical Association 93, pp. 359-371.

Harvey and Sucarrat (2013), 'EGARCH models with fat tails, skewness and leverage', forthcoming in Computational Statistics and Data Analysis. Working paper version: Cambridge Working Papers in Economics 1236, Faculty of Economics, University of Cambridge.

### See Also

[tegarch](#), [coef](#), [fitted](#), [logLik](#), [predict](#), [predict.tegarch](#), [print](#), [summary](#), [vcov](#)

### Examples

```
#simulate 500 observations from model with default parameter values:
set.seed(123)
y <- tegarchSim(500)

#estimate and store as 'mymodel':
mymod <- tegarch(y)

#print estimation result:
print(mymod)

#extract coefficients:
coef(mymod)

#extract log-likelihood:
logLik(mymod)

#plot fitted conditional standard deviations:
plot(fitted(mymod))

#plot all the fitted series:
plot(fitted(mymod, verbose=TRUE))

#histogram of standardised residuals:
hist(residuals(mymod))
```

---

dST

*The skewed t distribution*


---

### Description

Density, random number generation, mean, variance, skewness and kurtosis functions for the uncentred skewed t distribution. The skewing method is that of Fernandez and Steel (1998).

### Usage

```
dST(y, df = 10, sd = 1, skew = 1, log = FALSE)
rST(n, df = 10, skew = 1)
STmean(df, skew = 1)
STvar(df, skew = 1)
STskewness(df, skew = 1)
STkurtosis(df, skew = 1)
```

### Arguments

y	numeric vector of quantiles
n	integer, the number of observations
df	degrees of freedom, greater than 0 and less than Inf
sd	scale, greater than 0 and less than Inf
skew	skewness, greater than 0 and less than Inf. Symmetry obtains when skew = 1 (default).
log	logical. TRUE returns the natural log of the density value, FALSE (default) returns the density value.

### Details

Empty

### Value

dST:	a numeric value, either the density value or the natural log of the density value
rST:	a numeric vector with n random numbers
STmean:	The mean of an uncentred skewed t variable
STvar:	The variance of an uncentred skewed t variable
STskewness:	3rd. moment of a standardised skewed t variable
STkurtosis:	4th. moment of a standardised skewed t variable

### Note

Empty

**Author(s)**

Genaro Sucarrat, <http://www.sucarrat.net/>

**References**

Fernandez and Steel (1998), 'On Bayesian Modeling of Fat Tails and Skewness', *Journal of the American Statistical Association* 93, pp. 359-371.

**See Also**

[tegararchSim](#)

**Examples**

```
##generate 1000 random numbers from the skewed t:
set.seed(123)
eps <- rST(500, df=5) #symmetric t
eps <- rST(500, df=5, skew=0.8) #skewed to the left
eps <- rST(500, df=5, skew=2) #skewed to the right

##compare empirical mean with analytical:
mean(eps)
STmean(5, skew=2)

##compare empirical variance with analytical:
var(eps)
STvar(5, skew=2)
```

---

nasdaq

*Daily Apple stock returns*

---

**Description**

The dataset contains two variables, day and nasdaqret. Day is the date of the return and nasdaqret is the daily (closing value) log-return in percent of the Apple stock over the period 10 September 1985 - 10 May 2011 (a total of 6835 observations).

**Usage**

```
data(nasdaq)
```

**Format**

A data frame with 3215 observations:

day a factor

nasdaqret a numeric vector

**Details**

The data is studied in more detail in Harvey and Sucarrat (2013).

**Source**

The source of the original raw data is <http://yahoo.finance.com/>.

**References**

Harvey and Sucarrat (2013), 'EGARCH models with fat tails, skewness and leverage', forthcoming in Computational Statistics and Data Analysis. Working paper version: Cambridge Working Papers in Economics 1236, Faculty of Economics, University of Cambridge.

**Examples**

```
data(nasdaq) #load data into workspace
mymod <- tegarch(nasdaq[, "nasdaqret"]) #estimate volatility model of Apple returns
print(mymod)
```

---

predict.tegarch	<i>Generate volatility forecasts n-steps ahead</i>
-----------------	--

---

**Description**

Generates volatility forecasts from a model fitted by [tegarch](#) (i.e. a Beta-Skew-t-EGARCH model)

**Usage**

```
## S3 method for class 'tegarch'
predict(object, n.ahead = 1, initial.values = NULL, n.sim = 10000,
        verbose = FALSE, ...)
```

**Arguments**

object	an object of class 'tegarch'.
n.ahead	the number of steps ahead for which prediction is required.
initial.values	a vector containing the initial values of lambda and lambda dagger (lambda1 dagger and lambda2 dagger for 2-component models). If NULL (default) then the fitted values associated with the last return-observation are used
n.sim	number of simulated skew t variates.
verbose	logical. If FALSE (default) then only the conditional standard deviations are returned. If TRUE then also the scale is returned.
...	additional arguments



## Details

The forecast formulas of exponential ARCH models are much more complicated than those of ordinary or non-exponential ARCH models. This is particularly the case when the conditional density is skewed. The forecast formula of the conditional scale of the Beta-Skew-t-EGARCH model is not available in closed form. Accordingly, some terms (expectations involving the skewed  $t$ ) are estimated numerically by means of simulation.

## Value

A zoo object. If `verbose = FALSE`, then the zoo object is a vector with the forecasted conditional standard deviations. If `verbose = TRUE`, then the zoo object is a matrix with forecasts of both the conditional scale and the conditional standard deviation

## Author(s)

Genaro Sucarrat, <http://www.sucarrat.net/>

## References

Fernandez and Steel (1998), 'On Bayesian Modeling of Fat Tails and Skewness', Journal of the American Statistical Association 93, pp. 359-371.

Harvey and Sucarrat (2013), 'EGARCH models with fat tails, skewness and leverage', forthcoming in Computational Statistics and Data Analysis. Working paper version: Cambridge Working Papers in Economics 1236, Faculty of Economics, University of Cambridge.

## See Also

[tegarch](#), [predict](#)

## Examples

```
##simulate series with 500 observations:
set.seed(123)
y <- tegarchSim(500, omega=0.01, phi1=0.9, kappa1=0.1, kappastar=0.05, df=10, skew=0.8)

##estimate a 1st. order Beta-t-EGARCH model and store the output in mymod:
mymod <- tegarch(y)

#plot forecasts of volatility 1-step ahead up to 10-steps ahead:
plot(predict(mymod, n.ahead=10))
```

---

 tegarch

---

*Estimate first order Beta-Skew-t-EGARCH models*


---

### Description

Fits a first order Beta-Skew-t-EGARCH model to a univariate time-series by exact Maximum Likelihood (ML) estimation. Estimation is via the `nlmminb` function

### Usage

```
tegarch(y, asym = TRUE, skew = TRUE, components = 1, initial.values = NULL,
        lower = NULL, upper = NULL, hessian = TRUE, lambda.initial = NULL,
        c.code = TRUE, logl.penalty = NULL, aux = NULL, ...)
```

### Arguments

<code>y</code>	numeric vector, typically a financial return series.
<code>asym</code>	logical. TRUE (default) includes leverage or volatility asymmetry in the log-scale specification
<code>skew</code>	logical. TRUE (default) enables and estimates the skewness in conditional density (epsilon). The skewness method is that of Fernandez and Steel (1998)
<code>components</code>	Numeric value, either 1 (default) or 2. The former estimates a 1-component model, the latter a 2-component model
<code>initial.values</code>	NULL (default) or a vector with the initial values. If NULL, then the values are automatically chosen according to model (with or without skewness, 1 or 2 components, etc.)
<code>lower</code>	NULL (default) or a vector with the lower bounds of the parameter space. If NULL, then the values are automatically chosen
<code>upper</code>	NULL (default) or a vector with the upper bounds of the parameter space. If NULL, then the values are automatically chosen
<code>hessian</code>	logical. If TRUE (default) then the Hessian is computed numerically via the <code>optimHess</code> function. Setting <code>hessian=FALSE</code> speeds up estimation, which might be particularly useful in simulation. However, it also slows down the extraction of the variance-covariance matrix by means of the <code>vcov</code> method.
<code>lambda.initial</code>	NULL (default) or a vector with the initial value(s) of the recursion for <code>lambda</code> and <code>lambdadagger</code> . If NULL then the values are chosen automatically
<code>c.code</code>	logical. TRUE (default) is faster since it makes use of compiled C-code
<code>logl.penalty</code>	NULL (default) or a numeric value. If NULL then the log-likelihood value associated with the initial values is used. Sometimes estimation can result in NA and/or +/-Inf values, which are fatal for simulations. The value <code>logl.penalty</code> is the value returned by the log-likelihood function in the presence of NA or +/-Inf values
<code>aux</code>	NULL (default) or a list, see code. Useful for simulations (speeds them up)
<code>...</code>	further arguments passed to the <code>nlminb</code> function

**Value**

Returns a list of class 'tegarch' with the following elements:

y	the series used for estimation.
date	date and time of estimation.
initial.values	initial values used in estimation.
lower	lower bounds used in estimation.
upper	upper bounds used in estimation.
lambda.initial	initial values of lambda provided by the user, if any.
model	type of model estimated.
hessian	the numerically estimated Hessian.
sic	the value of the Schwarz (1978) information criterion.
par	parameter estimates.
objective	value of the log-likelihood at the maximum.
convergence	an integer code. 0 indicates successful convergence, see the documentation of nlminb.
iterations	number of iterations, see the documentation of nlminb.
evaluations	number of evaluations of the objective and gradient functions, see the documentation of nlminb.
message	a character string giving any additional information returned by the optimizer, or NULL. For details, see PORT documentation and the nlminb documentation.
NOTE	an additional message returned if one tries to estimate a 2-component model without leverage.

**Note**

Empty

**Author(s)**

Genaro Sucarrat, <http://www.sucarrat.net/>

**References**

Fernandez and Steel (1998), 'On Bayesian Modeling of Fat Tails and Skewness', Journal of the American Statistical Association 93, pp. 359-371.

Nelson, Daniel B. (1991): 'Conditional Heteroskedasticity in Asset Returns: A New Approach', Econometrica 59, pp. 347-370.

Harvey and Sucarrat (2013), 'EGARCH models with fat tails, skewness and leverage', forthcoming in Computational Statistics and Data Analysis. Working paper version: Cambridge Working Papers in Economics 1236, Faculty of Economics, University of Cambridge.

Schwarz (1978), 'Estimating the Dimension of a Model', The Annals of Statistics 6, pp. 461-464.

**See Also**

[tegarchSim](#), [coef.tegarch](#), [fitted.tegarch](#), [logLik.tegarch](#), [predict.tegarch](#), [print.tegarch](#), [residuals.tegarch](#), [summary.tegarch](#), [vcov.tegarch](#)

**Examples**

```
##simulate series with 500 observations:
set.seed(123)
y <- tegarchSim(500, omega=0.01, phi1=0.9, kappa1=0.1, kappastar=0.05,
  df=10, skew=0.8)

##estimate a 1st. order Beta-t-EGARCH model and store the output in mymod:
mymod <- tegarch(y)

#print estimates and standard errors:
print(mymod)

#graph of fitted volatility (conditional standard deviation):
plot(fitted(mymod))

#graph of fitted volatility and more:
plot(fitted(mymod, verbose=TRUE))

#plot forecasts of volatility 1-step ahead up to 20-steps ahead:
plot(predict(mymod, n.ahead=20))

#full variance-covariance matrix:
vcov(mymod)
```

---

 tegarchLogl

*Auxiliary functions*


---

**Description**

tegarchLogl, tegarchLogl2, tegarchRecursion and tegarchRecursion2 are auxiliary functions called by [tegarch](#), and which are not intended to be used for the average user. Henceforth they are thus only scarcely documented, but most should either be self-explanatory (for the non-average user!) or more or less documented in relation with the [tegarch](#) and [tegarchSim](#) functions.

**Usage**

```
##the '2' relates to the 2-component specification:
tegarchLogl(y, pars, lower = -Inf, upper = Inf, lambda.initial = NULL,
  logl.penalty = -1e+100, c.code = TRUE, aux = NULL)
tegarchLogl2(y, pars, lower = -Inf, upper = Inf, lambda.initial = NULL,
  logl.penalty = -1e+101, c.code = TRUE, aux = NULL)
tegarchRecursion(y, omega = 0.1, phi1 = 0.4, kappa1 = 0.2, kappastar = 0.1,
  df = 10, skew = 0.6, lambda.initial = NULL, c.code = TRUE, verbose = FALSE,
```

```

    aux = NULL)
tegarchRecursion2(y, omega = 0.1, phi1 = 0.4, phi2 = 0.2, kappa1 = 0.05,
  kappa2 = 0.1, kappastar = 0.02, df = 10, skew = 0.6, lambda.initial = NULL,
  c.code = TRUE, verbose = FALSE, aux = NULL)

```

### Arguments

y	numeric vector, typically a financial return series
omega	numeric
phi1	numeric, must be less than 1 in absolute value
phi2	numeric, must be less than 1 in absolute value
kappa1	numeric
kappa2	numeric
kappastar	numeric
df	numeric, the value of df (degrees of freedom)
skew	numeric (positive), the value of skew (skewness parameter)
verbose	logical. If FALSE (default) then only lambda is returned. If TRUE then a matrix with y and the fitted values of, amongst other, sigma, the log-scale (lambda), the conditional standard deviation (stdev), u, epsilon and the standardised residuals (residstd) are returned
pars	numeric vector, the parameter values
lower	numeric vector, the lower bounds used during estimation
upper	numeric vector, the upper bounds used during estimation
lambda.initial	NULL (default) or initial value(s) of the recursion for lambda. If NULL, then the values are chosen automatically
logl.penalty	numeric value
c.code	logical. TRUE (default) is faster since it makes use of compiled C-code
aux	NULL (default) or a list, see <a href="#">tegarch</a> code

### Details

tegarchLogl and tegarchLogl2 return the value of the log-likelihood for a 1-component and 2-component model, respectively.

### Value

tegarchLogl: The log-likelihood value (i.e. a numeric) of a 1-component specification

tegarchLogl2: The log-likelihood value (i.e. a numeric) of a 2-component specification

tegarchRecursion:

A numeric vector containing the lambda values if verbose=FALSE (default). If verbose=TRUE then a matrix with y and the fitted values of sigma, the log-scale (lambda), the conditional standard deviation (stdev), u, epsilon and the standardised residuals (residstd) are returned

tegarchRecursion2:

A numeric vector containing the lambda values if verbose=FALSE (default). If verbose=TRUE, then a matrix then a matrix with y and the fitted values of sigma, the log-scale (lambda), the conditional standard deviation (stdev), u, epsilon and the standardised residuals (residstd) are returned

### Author(s)

Genaro Sucarrat, <http://www.sucarrat.net/>

### References

Fernandez and Steel (1998), 'On Bayesian Modeling of Fat Tails and Skewness', Journal of the American Statistical Association 93, pp. 359-371.

Harvey and Sucarrat (2013), 'EGARCH models with fat tails, skewness and leverage', forthcoming in Computational Statistics and Data Analysis. Working paper version: Cambridge Working Papers in Economics 1236, Faculty of Economics, University of Cambridge.

### See Also

[tegarch](#), [tegarchSim](#), [fitted.tegarch](#)

---

tegarchSim

*Simulate from a first order Beta-Skew-t-EGARCH model*

---

### Description

Simulate the y series (typically interpreted as a financial return or the error in a regression) from a first order Beta-Skew-t-EGARCH model. Optionally, the conditional scale (sigma), log-scale (lambda), conditional standard deviation (stdev), dynamic components (lambdadagger in the 1-component specification, lambda1dagger and lambda2dagger in the 2-component specification), score (u) and centred innovations (epsilon) are also returned.

### Usage

```
tegarchSim(n, omega = 0, phi1 = 0.95, phi2 = 0, kappa1 = 0.01, kappa2 = 0,
  kappastar = 0, df = 10, skew = 1, lambda.initial = NULL, verbose = FALSE)
```

### Arguments

n	integer, length of y (i.e. no of observations)
omega	numeric, the value of omega
phi1	numeric, the value of phi1
phi2	numeric, the value of phi2

kappa1	numeric, the value of kappa1
kappa2	numeric, the value of kappa2
kappastar	numeric, the value of kappastar
df	numeric, the value of df (degrees of freedom)
skew	numeric, the value of skew (skewness parameter)
lambda.initial	NULL (default) or initial value(s) of the recursion for lambda or log-volatility. If NULL then the values are chosen automatically
verbose	logical, TRUE or FALSE (default). If TRUE then a matrix with n rows containing y, sigma, lambda, lambdadagger, u and epsilon is returned. If FALSE then only y is returned

### Details

Empty

### Value

A [zoo](#) vector of length n or a [zoo](#) matrix with n rows, depending on the value of verbose.

### Author(s)

Genaro Sucarrat, <http://www.sucarrat.net/>

### References

Fernandez and Steel (1998), 'On Bayesian Modeling of Fat Tails and Skewness', Journal of the American Statistical Association 93, pp. 359-371.

Harvey and Sucarrat (2013), 'EGARCH models with fat tails, skewness and leverage', forthcoming in Computational Statistics and Data Analysis. Working paper version: Cambridge Working Papers in Economics 1236, Faculty of Economics, University of Cambridge.

### See Also

[tegarch](#), [zoo](#)

### Examples

```
##1-component specification: simulate series with 500 observations:
set.seed(123)
y <- tegarchSim(500, omega=0.01, phi1=0.9, kappa1=0.1, kappastar=0.05,
  df=10, skew=0.8)

##simulate the same series, but with more output (volatility, log-volatility or
##lambda, lambdadagger, u and epsilon)
set.seed(123)
y <- tegarchSim(500, omega=0.01, phi1=0.9, kappa1=0.1, kappastar=0.05, df=10, skew=0.8,
```

```
verbose=TRUE)  
  
##plot the simulated values:  
plot(y)  
  
##2-component specification: simulate series with 500 observations:  
set.seed(123)  
y <- tegarchSim(500, omega=0.01, phi1=0.95, phi2=0.9, kappa1=0.01, kappa2=0.05,  
  kappastar=0.03, df=10, skew=0.8)
```



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