Package 'ccgarch'

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Title Conditional Correlation GARCH models

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Description Functions for estimating and simulating the family of the CC-GARCH models.

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R topics documented:

`analytical.grad` *Analytical gradient of the log-likelihood function of the (E)CCC-GARCH(1,1) model*

Description

This function returns the analytical gradient of the log-likelihood function of the (E)CCC-GARCH(1,1) model.

Usage

```
analytical.grad(a, A, B, R, u, model)
```

Arguments

`a`	a vector of constants in the vector GARCH equation $(N \times 1)$
`A`	an ARCH parameter matrix in the vector GARCH equation $(N \times N)$
`B`	a GARCH parameter matrix in the vector GARCH equation $(N \times N)$
`R`	a constant conditional correlation matrix $(N \times N)$
`u`	a matrix of the data used for estimating the (E)CCC-GARCH(1,1) model $(T \times N)$
`model`	a character string describing the model. `"diagonal"` for the diagonal model and `"extended"` for the extended (full ARCH and GARCH parameter matrices) model

Value

a $npar \times T$ matrix of gradients

Note

In the output, each column (not row) corresponds to the gradient at observation t.

References

Nakatani, T. and T. Ter\"asvirta (2009), "Testing for Volatility Interactions in the Constant Conditional Correlation GARCH Model", *Econometrics Journal*, **12**, 147–163.

Nakatani, T. and T. Ter\"asvirta (2008), "Appendix to *Testing for Volatility Interactions in the Constant Conditional Correlation GARCH Model*" Department of Economic Statistics, Stockholm School of Economics, available at http://swopec.hhs.se/hastef/abs/hastef0649.htm.

`analytical.Hessian` *Analytical Hessian of the (E)CCC-GARCH*

Description

This function computes the analytical Hessian of the log-likelihood function of the (E)CCC-GARCH model.

Usage

```
analytical.Hessian(a, A, B, R, u, model)
```

Arguments

`a`	a vector of constants in the vector GARCH equation $(N \times 1)$
`A`	an ARCH parameter matrix in the vector GARCH equation $(N \times N)$
`B`	a GARCH parameter matrix in the vector GARCH equation $(N \times N)$
`R`	a constant conditional correlation matrix $(N \times N)$
`u`	a matrix of the data data used for estimating the (E)CCC-GARCH(1,1) model $(T \times N)$
`model`	a character string describing the model. `"diagonal"` for the diagonal model and `"extended"` for the extended (full ARCH and GARCH parameter matrices) model

Value

a $npar \times npar$ Hessian matrix of the log-likelihood function of the (E)CCC-GARCH model

References

Nakatani, T. and T. Ter\"asvirta (2009), "Testing for Volatility Interactions in the Constant Conditional Correlation GARCH Model", *Econometrics Journal*, **12**, 147–163.

Nakatani, T. and T. Ter\"asvirta (2008), "Appendix to *Testing for Volatility Interactions in the Constant Conditional Correlation GARCH Model*" Department of Economic Statistics, Stockholm School of Economics, available at http://swopec.hhs.se/hastef/abs/hastef0649.htm.

`d2lv` *Hessian of the DCC log-likelihood function*

Description

This function returns the analytical Hessian of the volatility part of the DCC log-likelihood function.

Usage

```
d2lv(u, B, h, model)
```

Arguments

`u`	a matrix of the data data used for estimating the (E)DCC-GARCH(1,1) model $(T \times N)$
`B`	a GARCH parameter matrix $(N \times N)$
`h`	a matrix of the conditional variances $(T \times N)$
`model`	a character string describing the model. `"diagonal"` for the diagonal model and `"extended"` for the extended (full ARCH and GARCH parameter matrices) model

Value

the Hessian of the volatility part of the DCC log-likelihood function $(T \times N^2)$

References

Engle, R.F. and K. Sheppard (2001), "Theoretical and Empirical Properties of Dynamic Conditional Correlation Multivariate GARCH." *Stern Finance Working Paper Series* FIN-01-027 (Revised in Dec. 2001), New York University Stern School of Business.

Engle, R.F. (2002), "Dynamic Conditional Correlation: A Simple Class of Multivariate Generalized Autoregressive Conditional Heteroskedasticity Models." *Journal of Business and Economic Statistics* **20**, 339–350.

Hafner, C.M. and H. Herwartz (2008), "Analytical Quasi Maximum Likelihood Inference in Multivariate Volatility Models." *Metrika* **67**, 219–239.

`dcc.est` *Dynamic conditional correlations*

Description

This function returns dynamic conditional correlations based on the parameters specified.

Usage

```
dcc.est(dvar, param)
```

Arguments

`dvar`	a matrix of the standardised residuals $(T \times N)$
`param`	a vector of the DCC parameters (2×1)

Value

a list with components:

`DCC`	a matrix of the dynamic conditional correlations $(T \times N^2)$
`Q`	a matrix of the $\mathbf{Q}_t$ $(T \times N^2)$

Note

a constant matrix $\mathbf{Q}$ in the DCC equation is computed by $\mathbf{Q} = cov(dvar)$.

References

Engle, R.F. and K. Sheppard (2001), "Theoretical and Empirical Properties of Dynamic Conditional Correlation Multivariate GARCH." *Stern Finance Working Paper Series* FIN-01-027 (Revised in Dec. 2001), New York University Stern School of Business.

Engle, R.F. (2002), "Dynamic Conditional Correlation: A Simple Class of Multivariate Generalized Autoregressive Conditional Heteroskedasticity Models." *Journal of Business and Economic Statistics* **20**, 339–350.

`dcc.estimation` *Estimating an (E)DCC-GARCH model*

Description

This function carries out the two step estimation of the (E)DCC-GARCH model and returns estimates, standardised residuals, the estimated conditional variances, and the dynamic conditional correlations.

Usage

```
    dcc.estimation(inia, iniA, iniB, ini.dcc, dvar, model,
method="BFGS", gradient=1, message=1)
```

Arguments

`inia`	a vector of initial values for the constants in the GARCH equation `length(inia)=N`
`iniA`	a matrix of initial values for the ARCH parameter matrix $(N \times N)$
`iniB`	a matrix of initial values for the GARCH parameter matrix $(N \times N)$
`ini.dcc`	a vector of initial values for the DCC parameters (2×1)
`dvar`	a matrix of the data $(T \times N)$
`model`	a character string describing the model. `"diagonal"` for the diagonal model and `"extended"` for the extended (full ARCH and GARCH parameter matrices) model
`method`	a character string specifying the optimisation method in `optim`. There are three choices, namely, `Nelder-Mead`, `BFGS` (default) and `CG`.
`gradient`	a switch variable that determines the optimisation algorithm in the second stage optimisation. If `gradient=0` `Nelder-Mead` is invokded. Otherwise `BFGS` is used (default).
`message`	a switch variable to turn off the display of the message when the estimation is completed. If `message=0`, the message is suppressed. Otherwise, the message is displayed (default)

Value

a list with components:

`out`	the parameter estimates and their standard errors
`loglik`	the value of the log-likelihood at the estimates
`h`	a matrix of the estimated conditional variances $(T \times N)$
`DCC`	a matrix of the estimated dynamic conditional correlations $(T \times N^2)$
`std.resid`	a matrix of the standardised residuals $(T \times N)$. See *Note*.
`first`	the results of the first stage estimation
`second`	the results of the second stage estimation

Note

The standardised residuals are calculated by dividing the original series `dvar` by the estimated conditional standard deviations `sqrt(h)`. See Engle (2002), in particular the equations (2) and (14), for details.

`dcc.estimation` calls `dcc.estimation1` and `dcc.estimation2` for the first and second stage estimation, respectively.

The details of the first and second stage estimation are also saved.

The switch variable `simulation` is useful when one uses `dcc.estimation` for simulation. It supresses the display of the completion message.

References

Engle, R.F. and K. Sheppard (2001), "Theoretical and Empirical Properties of Dynamic Conditional Correlation Multivariate GARCH." *Stern Finance Working Paper Series* FIN-01-027 (Revised in Dec. 2001), New York University Stern School of Business.

Engle, R.F. (2002), "Dynamic Conditional Correlation: A Simple Class of Multivariate Generalized Autoregressive Conditional Heteroskedasticity Models." *Journal of Business and Economic Statistics* **20**, 339–350.

See Also

`dcc.estimation1`, `dcc.estimation2`, `loglik.dcc1`, `loglik.dcc2`, `vector.garch`, `dcc.est`

Examples

```
# Simulating data from the original DCC-GARCH(1,1) process
  nobs <- 1000; cut <- 1000
  a <- c(0.003, 0.005, 0.001)
  A <- diag(c(0.2,0.3,0.15))
  B <- diag(c(0.75, 0.6, 0.8))
  uncR <- matrix(c(1.0, 0.4, 0.3, 0.4, 1.0, 0.12, 0.3, 0.12, 1.0),3,3)
  dcc.para <- c(0.01,0.98)
  dcc.data <- dcc.sim(nobs, a, A, B, uncR, dcc.para, model="diagonal")

# Estimating a DCC-GARCH(1,1) model
  dcc.results <- dcc.estimation(inia=a, iniA=A, iniB=B, ini.dcc=dcc.para,
        dvar=dcc.data$eps, model="diagonal")

# Parameter estimates and their robust standard errors
  dcc.results$out
```

`dcc.estimation1` *Maximising the first stage log-likelihood function of the (E)DCC-GARCH model*

Description

This function carries out the first stage (volatility part) estimation of the (E)DCC-GARCH model.

Usage

```
dcc.estimation1(dvar, a, A, B, model, method="BFGS")
```

Arguments

`dvar`	a matrix of the data used for estimating the (E)DCC-GARCH(1,1) model $(T \times N)$
`a`	a vector of constants in the vector GARCH equation $(N \times 1)$
`A`	an ARCH parameter matrix in the vector GARCH equation $(N \times N)$
`B`	a GARCH parameter matrix in the vector GARCH equation $(N \times N)$
`model`	a character string describing the model. `"diagonal"` for the diagonal model and `"extended"` for the extended (full ARCH and GARCH parameter matrices) model
`method`	a character string specifying the optimisation method in `optim`. There are three choices, namely, `"Nelder-Mead"`, `"BFGS"` (default) and `"CG"`.

Value

a list of the estimation results. See the explanations in `optim`.

References

Engle, R.F. and K. Sheppard (2001), "Theoretical and Empirical Properties of Dynamic Conditional Correlation Multivariate GARCH." *Stern Finance Working Paper Series* FIN-01-027 (Revised in Dec. 2001), New York University Stern School of Business.

Engle, R.F. (2002), "Dynamic Conditional Correlation: A Simple Class of Multivariate Generalized Autoregressive Conditional Heteroskedasticity Models." *Journal of Business and Economic Statistics* **20**, 339–350.

See Also

`optim`, `dcc.estimation2`, `dcc.estimation`

`dcc.estimation2` *Maximising the second stage log-likelihood function of the (E)DCC-GARCH model*

Description

This function carries out the second stage (DCC part) estimation of the (E)DCC-GARCH model.

Usage

```
dcc.estimation2(dvar, para, gradient=0)
```

Arguments

`dvar`	a matrix of the standardised residuals $(T \times N)$
`para`	a vector of the DCC parameters (2×1)
`gradient`	a switch variable whether to use the gradient in the constraint optimisation. passed to `constrOptim`

Value

a list of the estimation results. See the explanations for `constrOptim`.

Note

`dcc.estimation2` is a wrapper to `constrOptim`. The restrictions are $\alpha+\beta \leq 1$ and $\alpha, \beta \geq 0$ in the DCC equation.

References

Engle, R.F. and K. Sheppard (2001), "Theoretical and Empirical Properties of Dynamic Conditional Correlation Multivariate GARCH." *Stern Finance Working Paper Series* FIN-01-027 (Revised in Dec. 2001), New York University Stern School of Business.

Engle, R.F. (2002), "Dynamic Conditional Correlation: A Simple Class of Multivariate Generalized Autoregressive Conditional Heteroskedasticity Models." *Journal of Business and Economic Statistics* **20**, 339–350.

See Also

`constrOptim`, `dcc.estimation1`, `dcc.estimation`

`dcc.results` *Computing robust standard errors of the estimates in the (E)DCC-GARCH model*

Description

This function computes the robust standard errors of the estimates of a DCC-GARCH model.

Usage

```
dcc.results(u, garch.para, dcc.para, h, model)
```

Arguments

`u`	a matrix of the data used for estimating the (E)DCC-GARCH model $(T \times N)$
`garch.para`	a vector of the estimates of the volatility parameters
`dcc.para`	a vector of the estimates of the DCC parameters (2×1)
`h`	a matrix of the estimated conditional variances $(T \times N)$
`model`	a character string describing the model. `"diagonal"` for the diagonal model and `"extended"` for the extended (full ARCH and GARCH parameter matrices) model

Value

A matrix with the estimates in the first row, and the standard errors in the second row.

Note

`dcc.results` is called from `dcc.estimation`. When `model="diagonal"`, only the diagonal entries in A and B are used.

References

Engle, R.F. and K. Sheppard (2001), "Theoretical and Empirical Properties of Dynamic Conditional Correlation Multivariate GARCH." *Stern Finance Working Paper Series* FIN-01-027 (Revised in Dec. 2001), New York University Stern School of Business.

Engle, R.F. (2002), "Dynamic Conditional Correlation: A Simple Class of Multivariate Generalized Autoregressive Conditional Heteroskedasticity Models." *Journal of Business and Economic Statistics* **20**, 339–350.

See Also

`dcc.estimation`

`dcc.sim` *Simulating an (E)DCC-GARCH(1,1) process*

Description

This function simulates data either from the original DCC-GARCH by Engle (2002) or from the Extended DCC-GARCH that has non-zero off-diagonal entries in the parameter matrices in the GARCH equation, with multivariate normal or student's t distributions.

The dimension (N) is determined by the number of elements in the a vector.

Usage

```
dcc.sim(nobs, a, A, B, R, dcc.para, d.f=Inf, cut=1000, model)
```

Arguments

`nobs`	a number of observations to be simulated (T)
`a`	a vector of constants in the vector GARCH equation $(N \times 1)$
`A`	an ARCH parameter matrix in the vector GARCH equation $(N \times N)$
`B`	a GARCH parameter matrix in the vector GARCH equation $(N \times N)$
`R`	an unconditional correlation matrix $(N \times N)$
`dcc.para`	a vector of the DCC parameters (2×1)
`d.f`	the degrees of freedom parameter for the t-distribution
`cut`	the number of observations to be thrown away for removing initial effects of simulation
`model`	a character string describing the model. "`diagonal`" for the diagonal model and "`extended`" for the extended (full ARCH and GARCH parameter matrices) model

Value

A list with components:

`z`	a matrix of random draws from $N(\mathbf{0}, \mathbf{I})$. $(T \times N)$
`std.z`	a matrix of the standardised residuals. $std.z_t \sim N(0, \mathbf{R}_t)$ where $\mathbf{R}_t$ is the DCC matrix at t. If d.f is set to a finite positive real number, $\mathbf{z}_t \sim t_{d.f}(0, \mathbf{R}_t)$ $(T \times N)$
`dcc`	a matrix of the simulated dynamic conditional correlations $(T \times N^2)$
`h`	a matrix of the simulated conditional variances $(T \times N)$
`eps`	a matrix of the simulated time series with DCC-GARCH process $(T \times N)$

Note

When `d.f=Inf`, the innovations (the standardised residuals) follow the standard normal distribution. Otherwise, they follow a student's t-distribution with `d.f` degrees of freedom.

When `model="diagonal"`, only the diagonal entries in A and B are used. If the ARCH and GARCH matrices do not satisfy the stationarity condition, the simulation is terminated.

References

Engle, R.F. and K. Sheppard (2001), "Theoretical and Empirical Properties of Dynamic Conditional Correlation Multivariate GARCH." *Stern Finance Working Paper Series* FIN-01-027 (Revised in Dec. 2001), New York University Stern School of Business.

Engle, R.F. (2002), "Dynamic Conditional Correlation: A Simple Class of Multivariate Generalized Autoregressive Conditional Heteroskedasticity Models." *Journal of Business and Economic Statistics* **20**, 339–350.

See Also

`stcc.sim`, `eccc.sim`

Examples

```
# Simulating data from the original DCC-GARCH(1,1) process
nobs <- 1000; cut <- 1000; nu <- 8
a <- c(0.003, 0.005, 0.001)
A <- diag(c(0.2,0.3,0.15))
B <- diag(c(0.75, 0.6, 0.8))
uncR <- matrix(c(1.0, 0.4, 0.3, 0.4, 1.0, 0.12, 0.3, 0.12, 1.0),3,3)
dcc.para <- c(0.01,0.98)

# for normally distributed innovations
dcc.data <- dcc.sim(nobs, a, A, B, uncR, dcc.para, model="diagonal")

# for t distributed innovations
dcc.data.t <- dcc.sim(nobs, a, A, B, uncR, dcc.para, d.f=nu,
model="diagonal")
```

`dlc` *Various partial derivatives of the DCC part of the log-likelihood function*

Description

This function computes various analytical derivatives of the second stage log-likelihood function (the DCC part) of the (E)DCC-GARCH model.

Usage

```
dlc(dcc.para, B, u, h, model)
```

Arguments

dcc.para	the estimates of the (E)DCC parameters (2×1)
B	the estimated GARCH parameter matrix $(N \times N)$
u	a matrix of the used for estimating the (E)DCC-GARCH model $(T \times N)$
h	a matrix of the estimated conditional variances $(T \times N)$
model	a character string describing the model. "diagonal" for the diagonal model and "extended" for the extended (full ARCH and GARCH parameter matrices) model

Value

a list with components:

dlc	the gradient of the DCC log-likelihood function w.r.t. the DCC parameters $(T \times 2)$
dvecP	the partial derivatives of the DCC matrix, P_t w.r.t. the DCC parameters $(T \times N^2)$
dvecQ	the partial derivatives of the Q_t matrices w.r.t. the DCC parameters $(T \times N^2)$
d2lc	the Hessian of the DCC log-likelihood function w.r.t. the DCC parameters $(T \times 4)$
dfdwd2lc	the cross derivatives of the DCC log-likelihood function $(T \times npar.h+2)$ $npar.h$ stand for the number of parameters in the GARCH part, $npar.h = 3N$ for "diagonal" and $npar.h = 2N^2 + N$ for "extended".

References

Engle, R.F. and K. Sheppard (2001), "Theoretical and Empirical Properties of Dynamic Conditional Correlation Multivariate GARCH." *Stern Finance Working Paper Series* FIN-01-027 (Revised in Dec. 2001), New York University Stern School of Business.

Engle, R.F. (2002), "Dynamic Conditional Correlation: A Simple Class of Multivariate Generalized Autoregressive Conditional Heteroskedasticity Models." *Journal of Business and Economic Statistics* **20**, 339–350.

Hafner, C.M. and H. Herwartz (2008), "Analytical Quasi Maximum Likelihood Inference in Multivariate Volatility Models." *Metrika* **67**, 219–239.

`dlv` *Gradient of the GARCH part of the log-likelihood function of an (E)DCC-GARCH model*

Description

This function returns the analytical partial derivatives of the volatility part of the log-likelihood function of the DCC-GARCH model. The function is called from `dcc.results`.

Usage

```
dlv(u, a, A, B, model)
```

Arguments

`u`	a matrix of the data used for estimating an (E)DCC-GARCH model $(T \times N)$
`a`	a vector of the constants in the volatility part $(N \times 1)$
`A`	an ARCH parameter matrix $(N \times N)$
`B`	a GARCH parameter matrix $(N \times N)$
`model`	a character string describing the model.`"diagonal"` for the diagonal model and `"extended"` for the extended (full ARCH and GARCH parameter matrices) model

Value

A matrix of partial derivatives. $(T \times npar.h)$ where $npar.h$ stand for the number of parameters in the GARCH part, $npar.h = 3N$ for `"diagonal"` and $npar.h = 2N^2 + N$ for `"extended"`.

References

Engle, R.F. and K. Sheppard (2001), "Theoretical and Empirical Properties of Dynamic Conditional Correlation Multivariate GARCH." *Stern Finance Working Paper Series* FIN-01-027 (Revised in Dec. 2001), New York University Stern School of Business.

Engle, R.F. (2002), "Dynamic Conditional Correlation: A Simple Class of Multivariate Generalized Autoregressive Conditional Heteroskedasticity Models." *Journal of Business and Economic Statistics* **20**, 339–350.

Hafner, C.M. and H. Herwartz (2008), "Analytical Quasi Maximum Likelihood Inference in Multivariate Volatility Models." *Metrika* **67**, 219–239.

See Also

`dcc.estimation`

`dlv.est` *Gradient of the GARCH part of the log-likelihood function of an (E)DCC GARCH model*

Description

This function returns the gradient of the volatility part of the log-likelihood function of the DCC.

Usage

```
dlv.est(par, dvar, model)
```

Arguments

`par`	a vector of the parameters in the vector GARCH equation
`dvar`	a matrix of the data used for estimating an (E)DCC-GARCH model $(T \times N)$
`model`	a character string describing the model. `"diagonal"` for the diagonal model and `"extended"` for the extended (full ARCH and GARCH parameter matrices) model

Value

A vector of the gradient. $(3N \times 1)$ for `"diagonal"` and $(2N^2 + N \times 1)$ for `"extended"`.

Note

The function can be called from `optim` in `dcc.estimation1`. For obtaining the gradient for all t, use `dlv` instead.

References

Engle, R.F. and K. Sheppard (2001), "Theoretical and Empirical Properties of Dynamic Conditional Correlation Multivariate GARCH." *Stern Finance Working Paper Series* FIN-01-027 (Revised in Dec. 2001), New York University Stern School of Business.

Engle, R.F. (2002), "Dynamic Conditional Correlation: A Simple Class of Multivariate Generalized Autoregressive Conditional Heteroskedasticity Models." *Journal of Business and Economic Statistics* **20**, 339–350.

Hafner, C.M. and H. Herwartz (2008), "Analytical Quasi Maximum Likelihood Inference in Multivariate Volatility Models." *Metrika* **67**, 219–239.

See Also

`dcc.estimation1`, `dlv`

`eccc.estimation` *Estimating an (E)CCC-GARCH model*

Description

This function estimates an (E)CCC-GARCH(1,1) model and returns estimates, estimated volatility and various diagnostic statistics.

Usage

```
eccc.estimation(a, A, B, R, dvar, model, method="BFGS")
```

Arguments

`a`	initial values for constants $(N \times 1)$
`A`	initial values for an ARCH parameter matrix $(N \times N)$
`B`	initial values for a GARCH parameter matrix $(N \times N)$
`R`	initial values a constant conditional correlation matrix $(N \times N)$
`dvar`	a matrix of data used for (E)CCC-GARCH estimation $(T \times N)$
`model`	a character string describing the model. `"diagonal"` for the diagonal model and `"extended"` for the extended (full ARCH and GARCH parameter matrices) model
`method`	a character string specifying the optimisation method in `optim`. There are three choices, namely, `Nelder-Mead`, `BFGS` (default) and `CG`.

Value

A list with components:

`out`	a $(4 \times npar)$ matrix. The estimates are contained in the first row. The remaining rows report standard errors based on three different methods of estimating the asymptotic covariance matrix
`h`	the estimated conditional variances $(T \times N)$
`std.resid`	a matrix of the standardised residuals $(T \times N)$. See *Note*.
`opt`	the detailed results of the optimisation
`para.mat`	vectorised parameter estimates

Note

The standardised residuals are calculated through dividing the original series by the estimated conditional standard deviations. See, for instance, p.303 of Bollerslev (1990) for details.

References

Bollerslev, T. (1990), "Modelling the Coherence in Short-run Nominal Exchange Rates: A Multivariate Generalized ARCH Model", *Review of Economics and Statistics*, **20**, 498–505.

Nakatani, T. and T. Ter\"asvirta (2009), "Testing for Volatility Interactions in the Constant Conditional Correlation GARCH Model", *Econometrics Journal*, **12**, 147–163.

Nakatani, T. and T. Ter\"asvirta (2008), "Appendix to *Testing for Volatility Interactions in the Constant Conditional Correlation GARCH Model*" Department of Economic Statistics, Stockholm School of Economics, available at http://swopec.hhs.se/hastef/abs/hastef0649.htm.

`eccc.sim` *Simulating an (E)CCC-GARCH(1,1) process*

Description

This function simulates data either from the original CCC-GARCH by Bollerslev (1990) or from the Extended CCC-GARCH that has non-zero off-diagonal entries in the parameter matrices in the GARCH equation. The innovations (the standardised residuals) can be either a normal or student's t distribution.

The dimension (N) is determined by the number of elements in the **a** vector.

Usage

```
eccc.sim(nobs, a, A, B, R, d.f=Inf, cut=1000, model)
```

Arguments

`nobs`	a number of observations to be simulated (T)
`a`	a vector of constants in the GARCH equation $(N \times 1)$
`A`	an ARCH parameter matrix in the GARCH equation. $\mathbf{A}$ can be a diagonal matrix for the original CCC-GARCH model or a full matrix for the extended model $(N \times N)$
`B`	a GARCH parameter matrix in the GARCH equation. $\mathbf{B}$ can be a diagonal matrix for the original CCC-GARCH model or a full matrix for the extended model $(N \times N)$
`R`	a constant conditional correlation matrix $(N \times N)$
`d.f`	the degrees of freedom parameter for the t-distribution
`cut`	the number of observations to be thrown away for removing initial effects of simulation
`model`	a character string describing the model. `"diagonal"` for the diagonal model and `"extended"` for the extended (full ARCH and GARCH parameter matrices) model

Value

A list with components:

h	a matrix of the simulated conditional variances $(T \times N)$
eps	a matrix of the simulated time series with (E)CCC-GARCH process $(T \times N)$

Note

When d.f=Inf, the innovations (the standardised residuals) follow the standard normal distribution. Otherwise, they follow a student's t-distribution with d.f degrees of freedom equal.

When model="diagonal", only the diagonal entries in $\mathbf{A}$ and $\mathbf{B}$ are used. If the ARCH and GARCH matrices do not satisfy the stationarity condition, the simulation is terminated.

References

Bollerslev, T. (1990), "Modeling the Coherence in Short-Run Nominal Exchange Rates: A Multivariate Generalized ARCH Approach", *Review of Economics and Statistics*, **72**, 498–505.

Nakatani, T. and T. Ter\"asvirta (2009), "Testing for Volatility Interactions in the Constant Conditional Correlation GARCH Model", *Econometrics Journal*, **12**, 147–163.

Nakatani, T. and T. Ter\"asvirta (2008), "Appendix to *Testing for Volatility Interactions in the Constant Conditional Correlation GARCH Model*" Department of Economic Statistics, Stockholm School of Economics, available at http://swopec.hhs.se/hastef/abs/hastef0649.htm.

See Also

dcc.sim, stcc.sim

Examples

```
# Simulating data from the original CCC-GARCH(1,1) process
nobs <- 1000; cut <- 1000; nu <- 10
a <- c(0.003, 0.005, 0.001)
A <- diag(c(0.2,0.3,0.15))
B <- diag(c(0.79, 0.6, 0.8))
R <- matrix(c(1.0, 0.4, 0.3, 0.4, 1.0, 0.12, 0.3, 0.12, 1.0),3,3)
ccc.data   <- eccc.sim(nobs,a, A, B, R, model="diagonal")
ccc.data.t <- eccc.sim(nobs,a, A, B, R, d.f=nu, model="diagonal")
```

---

fourth *Fourth-order moment condition for the vector GARCH equation*

Description

This function computes the fourth-order moment condition for the vector GARCH equation in the (E)CCC-GARCH models.

Usage

```
fourth(A, B, R)
```

Arguments

A	an ARCH parameter matrix $(N \times N)$
B	a GARCH parameter matrix $(N \times N)$
R	a constant conditional correlation matrix $(N \times N)$

Value

a scalar. If strictly less than unity, the condition is satisfied.

References

He, C. and T. Ter\"asvirta (2004): "An Extended Constant Conditional Correlation GARCH model and its Fourth-moment Structure", *Econometric Theory*, **20**, 904–926.

Nakatani, T. and T. Ter\"asvirta (2009), "Testing for Volatility Interactions in the Constant Conditional Correlation GARCH Model", *Econometrics Journal*, **12**, 147–163.

Nakatani, T. and T. Ter\"asvirta (2008), "Appendix to *Testing for Volatility Interactions in the Constant Conditional Correlation GARCH Model*" Department of Economic Statistics, Stockholm School of Economics, available at http://swopec.hhs.se/hastef/abs/hastef0649.htm.

See Also

stationarity

---

grad.dcc.full *Numerical gradient of the full log-likelihood function of the (E)DCC-GARCH model*

Description

This function computes numerical gradient of the full log-likelihood function of the (E)DCC-GARCH(1,1) model with respect to its parameters.

Usage

```
grad.dcc.full(a, A, B, dcc.para, dvar, d=1e-5, model)
```

Arguments

a	a constant vector in the vector GARCH equation $(N \times 1)$
A	an ARCH parameter matrix in the vector GARCH equation $(N \times N)$
B	a GARCH parameter matrix in the vector GARCH equation $(N \times N)$
dcc.para	a vector of the DCC parameters (2×1)
dvar	a matrix of the data used for estimating the (E)DCC-GARCH model $(T \times N)$
d	a step size for computing numerical gradient
model	a character string describing the model. "diagonal" for the diagonal model and "extended" for the extended (full ARCH and GARCH parameter matrices) model

Value

a matrix of partial derivatives $(T \times npar)$

Note

this function is currently not in use.

---

grad.dcc2 *Numerical gradient of the DCC part of the log-likelihood function*

Description

This function computes numerical gradient of the second stage log-likelihood function of the DCC-GARCH model w.r.t. its parameters.

Usage

```
grad.dcc2(param, dvar, d=1e-5)
```

Arguments

param	a vector of DCC parameters (2×1)
dvar	a matrix of the standardised residuals $(T \times N)$
d	a step size for computing numerical gradient

Value

a vector of partial derivatives (2×1)

Note

The function is used only from dcc.estimation2 when the switch variable gradient!=0. dlc$dlc in dlc contains the analytical gradient of the second stage log-likelihood function.

See Also

dlc, dcc.estimation

---

hh.test *Carrying out the test of Hafner and Herwartz*

Description

This function computes the test statistic and the associated p-value of the test for causality in conditiona variance in the CC-GARCH models.

Usage

```
hh.test(dvar)
```

Arguments

dvar	$(T \times N)$

Value

A vector containing the test statistic and the associated p-value

References

Hafner, C.M. and H. Herwartz (2006), "A Lagrange Multiplier Test for Causality in Variance." *Economics Letters* **93**, 137–141.

See Also

nt.test

---

jb.test *The Lomnicki-Jarque-Bera Test of normality (JB test)*

Description

This function performs the Lomnicki-Jarque-Bera Test of normality and returns test statistics and associated p-values.

Usage

```
jb.test(x)
```

Arguments

x	a vector or matrix of variables to be tested

Value

Vector of test statistics and p-value

References

Jarque, C.M. and A.K. Bera (1987), "A Test for Normality of Observations and Regression Residuals", *International Statistical Review*, **55**, 163–172.

Lomnicki, Z.A. (1961), "Tests for Departure from Normality in the Case of Linear Stochastic Processes", *Metrika*, **4**, 37–62.

See Also

rob.sk, rob.kr, ljung.box.test

Examples

```
# for a vector
x <- rnorm(1000)
jb.test(x)

# for a matrix
X <- matrix(rnorm(10000), 5000,2)
jb.test(X)
```

---

ljung.box.test *The Ljung-Box Test statistic*

Description

This function performs the Ljung-Box Test for a univariate time series.

Usage

```
ljung.box.test(x)
```

Arguments

x	a vector of variables to be tested

Value

LB test statistics and associated p-values for lags 5, 10,..., 50.

Note

Argument x must be a vector. When x is squared residuals, the test is equivalent to the McLeord and Li (1983) test.

References

Ljung, G.M. and G.E.P. Box (1978): "On a Measure of Lack of Fit in Time-Series Models", *Biometrika*, **65**, 297–303.

McLeod, A.I., and W.K. Li (1983): "Diagnostic checking ARMA time series models using squared-residual autocorrelations", *Journal of Time Series Analysis*, **4**, 269–273.

See Also

rob.sk, rob.kr, jb.test

Examples

```
x <- rnorm(1000)
ljung.box.test(x)           # returns the LB Test statistic
ljung.box.test(x^2)         # returns the McLeord-Li Test for no-ARCH effect
```

---

loglik.dcc *The log-likelihood function for the (E)DCC GARCH model*

Description

This function returns a log-likelihood of the (E)DCC-GARCH model.

Usage

```
loglik.dcc(param, dvar, model)
```

Arguments

param	a vector of all the parameters in the (E)DCC-GARCH model
dvar	a matrix of the data used for estimating the (E)DCC-GARCH model $(T \times N)$
model	a character string describing the model. "diagonal" for the diagonal model and "extended" for the extended (full ARCH and GARCH parameter matrices) model

Value

the negative of the full log-likelihood of the (E)DCC-GARCH model

Note

param must be made by stacking all the parameter matrices.

References

Robert F. Engle and Kevin Sheppard (2001), "Theoretical and Empirical Properties of Dynamic Conditional Correlation Multivariate GARCH." *Stern Finance Working Paper Series* FIN-01-027 (Revised in Dec. 2001), New York University Stern School of Business.

Robert F. Engle (2002), "Dynamic Conditional Correlation: A Simple Class of Multivariate Generalised Autoregressive Conditional Heteroskedasticity Models." *Journal of Business and Economic Statistics* **20**, 339–350.

Examples

```
# Simulating data from the original DCC-GARCH(1,1) process
  nobs <- 1000; cut <- 1000
  a <- c(0.003, 0.005, 0.001)
  A <- diag(c(0.2,0.3,0.15))
  B <- diag(c(0.75, 0.6, 0.8))
  uncR <- matrix(c(1.0, 0.4, 0.3, 0.4, 1.0, 0.12, 0.3, 0.12, 1.0),3,3)
  dcc.para <- c(0.01,0.98)
  dcc.data <- dcc.sim(nobs, a, A, B, uncR, dcc.para, model="diagonal")

# Estimating a DCC-GARCH(1,1) model
  dcc.results <- dcc.estimation(inia=a, iniA=A, iniB=B, ini.dcc=dcc.para,
    dvar=dcc.data$eps, model="diagonal")

# Parameter estimates and their robust standard errors
  dcc.results$out

# Computing the value of the log-likelihood at the estimates
  loglik.dcc(dcc.results$out[1,], dcc.data$eps, model="diagonal")
```

`loglik.dcc1` *The 1st stage log-likelihood function for the (E)DCC GARCH*

Description

This function returns a log-likelihood of the (E)DCC-GARCH model in the first stage estimation.

Usage

```
loglik.dcc1(param, dvar, model)
```

Arguments

`param`	initial values for a vector of the parameters $(npar \times 1)$
`dvar`	a matrix of the data $(T \times N)$
`model`	a character string describing the model. `"diagonal"` for the diagonal model and `"extended"` for the extended (full ARCH and GARCH parameter matrices) model

Value

the negative of the first stage log-likelihood

Note

The function is used in `optim` in `dcc.estimation1`.

References

Engle, R.F. and K. Sheppard (2001), "Theoretical and Empirical Properties of Dynamic Conditional Correlation Multivariate GARCH." *Stern Finance Working Paper Series* FIN-01-027 (Revised in Dec. 2001), New York University Stern School of Business.

Engle, R.F. (2002), "Dynamic Conditional Correlation: A Simple Class of Multivariate Generalized Autoregressive Conditional Heteroskedasticity Models." *Journal of Business and Economic Statistics* **20**, 339–350.

See Also

`dcc.estimation`, `dcc.estimation1`

`loglik.dcc2` *The 2nd stage log-likelihood function for the (E)DCC GARCH*

Description

This function returns a log-likelihood of the (E)DCC-GARCH model in the 2nd step estimation.

Usage

```
loglik.dcc2(param, dvar)
```

Arguments

`param`	initial values for the DCC parameters (2×1)
`dvar`	a matrix of the standardised residuals $(T \times N)$

Value

the negative of the second stage log-likelihood

Note

The function is used in `constrOptim` in `dcc.estimation2`.

References

Engle, R.F. and K. Sheppard (2001), "Theoretical and Empirical Properties of Dynamic Conditional Correlation Multivariate GARCH." *Stern Finance Working Paper Series* FIN-01-027 (Revised in Dec. 2001), New York University Stern School of Business.

Engle, R.F. (2002), "Dynamic Conditional Correlation: A Simple Class of Multivariate GeneralizSed Autoregressive Conditional Heteroskedasticity Models." *Journal of Business and Economic Statistics* **20**, 339–350.

See Also

`dcc.estimation`, `dcc.estimation2`

`loglik.eccc` *The log-likelihood function of the (E)CCC-GARCH model*

Description

This function computes a log-likelihood of the (E)CCC-GARCH(1,1) model.

Usage

```
loglik.eccc(param, dvar, model)
```

Arguments

`param`	a vector of all the parameters in the (E)CCC-GARCH model
`dvar`	a matrix of the data used for estimating the (E)DCC-GARCH model $(T \times N)$
`model`	a character string describing the model. `"diagonal"` for the diagonal model and `"extended"` for the extended (full ARCH and GARCH parameter matrices) model

Value

the negative of the (E)CCC-GARCH log-likelihood

References

Nakatani, T. and T. Ter\"asvirta (2009), "Testing for Volatility Interactions in the Constant Conditional Correlation GARCH Model", *Econometrics Journal*, **12**, 147–163.

Nakatani, T. and T. Ter\"asvirta (2008), "Appendix to *Testing for Volatility Interactions in the Constant Conditional Correlation GARCH Model*" Department of Economic Statistics, Stockholm School of Economics, available at http://swopec.hhs.se/hastef/abs/hastef0649.htm.

nt.test *Carrying out the test of Nakatani and Teräsvirta*

Description

This function computes the test statistic and the associated p-value of the test for causality in conditiona variance in the CC-GARCH models.

Usage

```
nt.test(dvar)
```

Arguments

dvar	$(T \times N)$

Value

A matrix containing the test statistics of the standard (non-robust) test and the robust version, and the associated p-values

References

Nakatani, T and T. Ter\"asvirta (2010), "An Alternative Test for Causality in Variance in the Conditional Correlation GARCH models." *mimeo*, Stockholm School of Economics.

See Also

hh.test

p.mat *Re-arranging a vector into parameter matrices*

Description

A utility function that re-arranges a vector of parameters into parameter matrices in the CC-GARCH(1,1) model.

Usage

```
p.mat(para, model, ndim)
```

Arguments

para	a vector of parameters to be re-arranged into parameter matrices
model	a character string describing the model. "diagonal" for the diagonal model and "extended" for the extended (full ARCH and GARCH parameter matrices) model
ndim	the number of dimension of the model

Value

A list with components:

a	a vector of constants in the vector GARCH equation
A	an ARCH parameter matrix
B	a GARCH parameter matrix
R	a constant conditional correlation matrix

References

Nakatani, T. and T. Ter\"asvirta (2009), "Testing for Volatility Interactions in the Constant Conditional Correlation GARCH Model", *Econometrics Journal*, **12**, 147–163.

Nakatani, T. and T. Ter\"asvirta (2008), "Appendix to *Testing for Volatility Interactions in the Constant Conditional Correlation GARCH Model*" Department of Economic Statistics, Stockholm School of Economics, available at http://swopec.hhs.se/hastef/abs/hastef0649.htm.

---

rob.kr *Computing standard and robustified excess kurtosis*

Description

This function computes standard and robustified excess kurtosis of a vector or matrix of variables.

Usage

```
rob.kr(x)
```

Arguments

x	vector or matrix of variables

Value

Vector of excess kurtosis and robustified excess kurtosis

References

Kim, T-H. and H. White (2004), "On More Robust Estimation of Skewness and Kurtosis", *Finance Research Letters*, **1**, 56–73.

See Also

rob.sk, ljung.box.test, jb.test

Examples

```
x <- matrix(rnorm(1000), 100, 10)
rob.kr(x)
```

---

rob.sk *Computing standard and robustified skewness*

Description

This function computes standard and robustified skewness measures of a vector or matrix of variables.

Usage

```
rob.sk(x)
```

Arguments

x	a vector or matrix of variables

Value

Vector of skewness and robustified skewness

References

Kim, T-H. and H. White (2004), "On More Robust Estimation of Skewness and Kurtosis", *Finance Research Letters*, **1**, 56–73.

See Also

rob.kr, ljung.box.test, jb.test

Examples

```
x <- matrix(rnorm(1000), 100, 10)
rob.sk(x)
```

`stationarity` *The stationarity condition in Extended CC-GARCH models*

Description

A utility function that checks if the two parameter matrices in a vector GARCH model satisfy the stationarity condition.

Usage

```
stationarity(A,B)
```

Arguments

`A`	an ARCH parameter matrix in the vector GARCH equation $(N \times N)$
`B`	a GARCH parameter matrix in the vector GARCH equation $(N \times N)$

Value

a scalar. If strictly less than unity, the condition is satisfied.

References

He, C. and T. Ter\"asvirta (2004): "An Extende Constant Conditional Correlation GARCH model and its Fourth-moment Structure", *Econometric Theory*, **20**, 904–926.

Nakatani, T. and T. Ter\"asvirta (2009), "Testing for Volatility Interactions in the Constant Conditional Correlation GARCH Model", *Econometrics Journal*, **12**, 147–163.

Nakatani, T. and T. Ter\"asvirta (2008), "Appendix to *Testing for Volatility Interactions in the Constant Conditional Correlation GARCH Model*" Department of Economic Statistics, Stockholm School of Economics, available at http://swopec.hhs.se/hastef/abs/hastef0649.htm.

See Also

`fourth`

`stcc.sim` *Simulating Data from an STCC-GARCH$(1,1)$ process*

Description

This function simulates data either from the original STCC-GARCH by Silvennoinen and Ter\"asvirta (2005) or from the Extended STCC-GARCH that has non-zero off-diagonal entries in the parameter matrices in the GARCH equation, with multivariate normal or student's t distribution.

The dimension (N) is determined by the number of elements in the **a** vector.

Usage

```
stcc.sim(nobs, a, A, B, R1, R2, tr.par, st.par, d.f=Inf,
         cut=1000, model)
```

Arguments

`nobs`	a number of observations to be simulated (T)
`a`	a vector of constants in the vector GARCH equation $(N \times 1)$
`A`	an ARCH parameter matrix in the vector GARCH equation. $(N \times N)$
`B`	a GARCH parameter matrix in the vector GARCH equation. $(N \times N)$
`R1`	a conditional correlation matrix in regime 1 $(N \times N)$
`R2`	a conditional correlation matrix in regime 2 $(N \times N)$
`tr.par`	a vector of scale and location parameters in the transition function (2×1)
`st.par`	a vector of parameters for the GARCH(1,1) transition variable (3×1)
`d.f`	the degrees of freedom parameter for the t-distribution
`cut`	the number of observations to be thrown away for removing initial effects of simulation
`model`	a character string describing the model. `"diagonal"` for the diagonal model and `"extended"` for the extended (full ARCH and GARCH parameter matrices) model

Value

A list with components:

`h`	a matrix of conditional variances $(T \times N)$
`eps`	a matrix of time series with DCC-GARCH process $(T \times N)$
`tr.var`	a vector of the transition variable
`st`	a vector of time series of the transition function
`vecR`	a $(T \times N^2)$ matrix of Smooth Transition Conditional Correlations

Note

When `d.f=Inf`, the innovations (the standardised residuals) follow the standard normal distribution. Otherwise, they follow a student's t-distribution with `d.f` degrees of freedom equal.

When `model="diagonal"`, only the diagonal entries in $\mathbf{A}$ and $\mathbf{B}$ are used. If the ARCH and GARCH matrices do not satisfy the stationarity condition, the simulation is terminated.

References

Silvennoinen, A. and T. Ter\"asvirta (2005), "Multivariate Autoregressive Conditional Heteroskedasticity with Smooth Transitions in Conditional Correlations." *SSE/EFI Working Paper Series in Economics and Finance* No. 577, Stockholm School of Economics, available at http://swopec.hhs.se/hastef/abs/hastef0577.htm.

See Also

`dcc.sim`, `eccc.sim`

Examples

```
# Simulating data from the original STCC-GARCH(1,1) process
nobs <- 1000; cut <- 1000
a <- c(0.003, 0.005, 0.001)
A <- diag(c(0.2,0.3,0.15))
B <- diag(c(0.79, 0.6, 0.8))
# Conditional Correlation Matrix for regime 1
R1 <- matrix(c(1.0, 0.4, 0.3, 0.4, 1.0, 0.12, 0.3, 0.12, 1.0),3,3)
# Conditional Correlation Matrix for regime 2
R2 <- matrix(c(1.0, 0.01, -0.3, 0.01, 1.0, 0.8, -0.3, 0.8, 1.0),3,3)
# a parameter vector for the scale and location parameters
# in the logistic function
tr.para <- c(5,0)
# a parameter vector for a GARCH(1,1) transition variable
st.para <- c(0.02,0.04, 0.95)
nu <- 15
stcc.data <- stcc.sim(nobs, a, A, B, R1, R2,
                      tr.par=tr.para, st.par=st.para, model="diagonal")
stcc.data.t. <- stcc.sim(nobs, a, A, B, R1, R2,
                      tr.par=tr.para, st.par=st.para, d.f=nu, model="diagonal")
```

`tr.func` *Logistic transition function*

Description

This function computes values from a Logistic transition function.

Usage

```
tr.func(tr.par, tr.var)
```

Arguments

`tr.par`	a vector of parameters (2×1)
`tr.var`	a vector of transition variable $(T \times 1)$

Value

a vector of transition function $(T \times 1)$

Note

this function is used in `stcc.sim`

References

Ter\"asvirta, T. (1994): "Specification, Estimation, and Evaluation of Smooth Transition Autoregressive Models", *Journal of the American Statistical Association*, **89**, 208–218.

See Also

`stcc.sim`

`uni.vola` *Computing univariate GARCH(1,1) conditional variances*

Description

This function returns an univariate GARCH(1,1) conditional variances.

Usage

```
uni.vola(a,u)
```

Arguments

`a`	a vector of parameters in the GARCH(1,1) equation (3×1)
`u`	a vector of the data $(T \times 1)$

Value

a vector of GARCH(1,1) conditional variances $(T \times 1)$

References

Bollerslev, T. (1986): "Generalized Autoregressive Conditional Heteroskedasticity", *Journal of Econometrics*, **31**, 307–327.

See Also

uni.vola.sim

Examples

```
a <- c(0.01, 0.04, 0.95)    #  a <- c(a constant, ARCH parameter, GARCH parameter)
u <- rnorm(1000)
h <- uni.vola(a, u)
```

---

uni.vola.sim — *Simulating a series with univariate GARCH(1,1) conditional variances*

Description

This function simulates an univariate time series with GARCH(1,1) conditional variances.

Usage

```
uni.vola.sim(a, nobs, d.f=Inf, cut=1000)
```

Arguments

a	a vector of parameters (3×1)
nobs	a number of observations simulated (T)
d.f	degrees of freedom parameter for t-distribution
cut	a number of observations to be removed to minimise the initial effects

Value

A list with components:

h	GARCH(1,1) conditional variances $(T \times 1)$
eps	a series of error term with the conditional variances "h" $(T \times 1)$

Note

When d.f=Inf, the innovations (the standardised residuals) follow the standard normal distribution. Otherwise, they follow a student's t-distribution with d.f degrees of freedom.

References

Bollerslev, T. (1986), "Generalized Autoregressive Conditional Heteroskedasticity", *Journal of Econometrics*, **31**, 307–327.

Fiorentini, G., G. Calzolari and L. Panattoni (1996), "Analytic Derivatives and the Computation of GARCH Estimates", *Journal of Applied Econometrics*, **11**, 399–417.

See Also

uni.vola

Examples

```
nobs <- 1000
nu <- 8
a <- c(0.1,0.2,0.7)           #  a <- c(a constant, ARCH parameter, GARCH parameter)
# with normal innovations
eps <- uni.vola.sim(a, nobs)
# with t innovations
eps.t <- uni.vola.sim(a, nobs, d.f = df)
```

---

vdR *Computing partial derivatives of the CCC matrix*

Description

This function computes partial derivatives of the CCC matrix with respect to its correlation coefficients.

Usage

```
vdR(n)
```

Arguments

n	the number of dimension of the model

Value

a matrix of zeros and ones $((N(N-1))/2 \times N^2)$

References

Nakatani, T. and T. Ter\"asvirta (2009), "Testing for Volatility Interactions in the Constant Conditional Correlation GARCH Model", *Econometrics Journal*, **12**, 147-163.

Nakatani, T. and T. Ter\"asvirta (2008), "Appendix to *Testing for Volatility Interactions in the Constant Conditional Correlation GARCH Model*" Department of Economic Statistics, Stockholm School of Economics, available at http://swopec.hhs.se/hastef/abs/hastef0649.htm.

`vec.garch.derivative` *Computing partial derivatives of a vector GARCH(1, 1) equation*

Description

This function computes partial derivatives of a vector GARCH(1, 1) equation with respect to its parameters.

Usage

```
vec.garch.derivative(dvar, B, h)
```

Arguments

`dvar`	a matrix of the data used for estimating an ECCC or DCC GARCH model $(T \times N)$
`B`	a GARCH parameter matrix in the vector GARCH equation $(N \times N)$
`h`	a matrix of conditional variances $(T \times N)$

Value

a vector of partial derivatives $(T \times N * npar.h)$

References

Nakatani, T. and T. Ter\"asvirta (2009), "Testing for Volatility Interactions in the Constant Conditional Correlation GARCH Model", *Econometrics Journal*, **12**, 147–163.

Nakatani, T. and T. Ter\"asvirta (2008), "Appendix to *Testing for Volatility Interactions in the Constant Conditional Correlation GARCH Model*" Department of Economic Statistics, Stockholm School of Economics, available at http://swopec.hhs.se/hastef/abs/hastef0649.htm.

`vector.garch` *A vector GARCH(1,1) conditional variances*

Description

This function computes a vector GARCH(1,1) conditional variances.

Usage

```
vector.garch(dvar, a, A, B)
```

Arguments

`dvar`	a matrix of the data, used as epsilon $(T \times N)$
`a`	initial values for constants in the vector GARCH equation $(N \times 1)$
`A`	initial values for an ARCH parameter matrix in the vector GARCH equation $(N \times N)$
`B`	initial values for a GARCH parameter matrix in the vector GARCH equation $(N \times N)$

Value

a matrix of conditional variances $(T \times N)$

References

Nakatani, T. and T. Ter\"asvirta (2009), "Testing for Volatility Interactions in the Constant Conditional Correlation GARCH Model", *Econometrics Journal*, **12**, 147-163.

Nakatani, T. and T. Ter\"asvirta (2008), "Appendix to *Testing for Volatility Interactions in the Constant Conditional Correlation GARCH Model*" Department of Economic Statistics, Stockholm School of Economics, available at http://swopec.hhs.se/hastef/abs/hastef0649.htm.

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