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Title Robust Bootstrap Forecast Densities for GARCH Models

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Description Bootstrap forecast densities for GARCH (Generalized Autoregressive Conditional Heteroskedastic) returns and volatilities using the robust residual-based bootstrap procedure of Trucios, Hotta and Ruiz (2017) <DOI:10.1080/00949655.2017.1359601>.

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Contents

`RobGARCHBoot-package` *Robust Bootstrap Forecast Densities for GARCH Models*

Description

Bootstrap forecast densities for returns and volatilities using the robust residual-based bootstrap procedure of Trucíos et at. (2017). The package also includes the robust GARCH (Generalized Autoregressive Conditional Heteroskedastic) estimator of Boudt et al. (2013) with the modification introduced by Trucíos et at. (2017). The robust cDCC estimator used in Trucíos et al. (2018) is also implemented.

Details

This package provides a robust bootstrap procedure to obtain forecast densities for both return and volatilities in a GARCH context. The forecast densities are useful to obtain forecast intervals as well as to estimate risk measures such as Value-at-Risk (VaR) and Expected Shortfall (ES). We also provide the robust GARCH estimator of Boudt et al. (2013) with the modification introduced by Trucíos et at. (2017). This procedure has shown good finite sample properties in both Monte Carlo experiments and empirical data. See; Trucíos et al. (2017), Trucíos (2019) and Trucíos et al. (2020) for recent implementations.

Author(s)

Carlos Trucíos <ctrucios@gmail.com>

References

Boudt, Kris, Jon Danielsson, and Sébastien Laurent. Robust forecasting of dynamic conditional correlation GARCH models. International Journal of Forecasting 29.2 (2013): 244-257.

Trucíos, Carlos, Luiz K. Hotta, and Esther Ruiz. Robust bootstrap forecast densities for GARCH returns and volatilities. Journal of Statistical Computation and Simulation 87.16 (2017): 3152-3174.

Trucíos, Carlos, Luiz K. Hotta, and Esther Ruiz. Robust bootstrap densities for dynamic conditional correlations: implications for portfolio selection and value-at-risk. Journal of Statistical Computation and Simulation 88.10 (2018): 1976-2000.

Trucíos, Carlos. Forecasting Bitcoin risk measures: A robust approach. International Journal of Forecasting 35.3 (2019): 836-847.

Trucíos, Carlos, Aviral K. Tiwari, and Faisal Alqahtani. Value-at-risk and expected shortfall in cryptocurrencies' portfolio: a vine copula–based approach. Applied Economics 52.24 (2020): 2580-2593.

`fitted_Vol` *Estimated Volatility*

Description

Using the robust estimated parameters of Boudt et al. (2013) with the modification introduced by Trucíos et at. (2017), we obtain the estimated volatility.

Usage

```
fitted_Vol(theta,r)
```

Arguments

`theta`	Vector of robust estimated parameters obtained from ROBUSTGARCH function.
`r`	Vector of time series returns.

Details

More details can be found in Boudt et al. (2013) and Trucíos et at. (2017).

Value

The function returns the estimated volatility from 1 to T+1.

Author(s)

Carlos Trucíos

References

Boudt, Kris, Jon Danielsson, and Sébastien Laurent. Robust forecasting of dynamic conditional correlation GARCH models. International Journal of Forecasting 29.2 (2013): 244-257.

Trucíos, Carlos, Luiz K. Hotta, and Esther Ruiz. Robust bootstrap forecast densities for GARCH returns and volatilities. Journal of Statistical Computation and Simulation 87.16 (2017): 3152-3174.

Examples

```
# Using the Bitcoin daily returns, we estimate the parameter of the GARCH model in a robust way
param = ROBUSTGARCH(returnsexample)
# With the estimated parameters, we estimate the volatiltiy in a robust way
vol = fitted_Vol(param, returnsexample)
```

`loglik_cDCC` *Loss function used in cDCC robust estimation.*

Description

Loss function used in cDCC robust estimation.

Usage

```
loglik_cDCC(par, Qb, s, sigma)
```

Arguments

`par`	teste
`Qb`	teste
`s`	teste
`sigma`	teste

Details

This function is used in the robust estimation. We can use it to evaluate the value of the robust cDCC loss function using several values of the vector parameters.

Value

Returns the value of the loss function.

Author(s)

Carlos Trucíos

References

Boudt, Kris, Jon Danielsson, and Sébastien Laurent. Robust forecasting of dynamic conditional correlation GARCH models. International Journal of Forecasting 29.2 (2013): 244-257.

Trucíos, Carlos, Luiz K. Hotta, and Esther Ruiz. Robust bootstrap densities for dynamic conditional correlations: implications for portfolio selection and value-at-risk. Journal of Statistical Computation and Simulation 88.10 (2018): 1976-2000.

Examples

```
# Estimating the parameters of the cDCC model in a robust way.
cDCC = Robust_cDCC(returns3)
param = cDCC[[1]]
Qbar = cDCC[[2]]
vol1 = fitted_Vol(param[1:3],returns3[,1])
vol2 = fitted_Vol(param[4:6],returns3[,2])
```

```
vol3 = fitted_Vol(param[7:9],returns3[,3])
e = matrix(c(returns3[,1]/vol1[1:nrow(returns3)],
             returns3[,2]/vol2[1:nrow(returns3)],
             returns3[,3]/vol3[1:nrow(returns3)]), ncol=3)

loglik_cDCC(param[10:11],Qbar,e, 0.8309765)
```

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returns3 *Matrix of time series returns for illustrative purposes*

Description

Three-variate time series returns for illustrative purposes

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returnsexample *Time series returns for illustrative purposes*

Description

Cryptocurrencies report large returns over time. In this sense and with illustrative purposes, we use Bitcoin daily returns from July 2014 to February 2017.

RobGARCHBoot *Robust GARCH bootstrap procedure*

Description

Robust GARCH (Generalized Autoregressive Conditional Heteroskedastic) Bootstrap procedure of Trucíos et al. (2017)

Usage

```
RobGARCHBoot(data, n.boot = 1000, n.ahead = 1, ins = FALSE)
```

Arguments

data	Vector of time series returns.
n.boot	Number of bootsrap replications. By default n.boot = 1000
n.ahead	Numbers of steps-ahead. By default n.ahead = 1
ins	If TRUE in-sample bootstrap returns are calculated. By default ins = FALSE

Details

More details can be found in Trucíos et at. (2017), Hotta and Trucíos (2018), and Trucíos (2019).

Value

The function returns two lists with the empirical H-steps-ahead bootstrap densities for returns and squared volatilities. If ins = TRUE, a third list with in-sample bootstrap returns is also provided.

Author(s)

Carlos Trucíos

References

Hotta, Luiz Koodi, and Carlos Trucíos. Inference in (M)GARCH models in the presence of additive outliers: Specification, estimation, and prediction. Advances in Mathematics and Applications. Springer, Cham, 2018. 179-202.

Trucíos, Carlos, Luiz K. Hotta, and Esther Ruiz. Robust bootstrap forecast densities for GARCH returns and volatilities. Journal of Statistical Computation and Simulation 87.16 (2017): 3152-3174.

Trucíos, Carlos. Forecasting Bitcoin risk measures: A robust approach. International Journal of Forecasting 35.3 (2019): 836-847.

Examples

```
# Robust bootstrap forecast densities for returns and volatilities
boot = RobGARCHBoot(returnsexample, n.boot = 1000, n.ahead = 1)

# Obtaining the forecast intervals for returns (95%)
quantile(boot[[1]], prob = c(0.025, 0.975))
# Obtaining the forecast intervals for volatilities (95%)
quantile(boot[[2]], prob = c(0.025, 0.975))

# Risk measures can also be obtained
VaR1 = quantile(boot[[1]], prob = 0.01)
```

`RobGARCHBootParallel` *Parallel implementation of the Robust GARCH bootstrap procedure*

Description

Robust GARCH (Generalized Autoregressive Conditional Heteroskedastic) Bootstrap procedure of Trucíos et al. (2017)

Usage

```
RobGARCHBootParallel(data, n.boot = 1000, n.ahead = 1, ncl = 2)
```

Arguments

`data`	Vector of time series returns.
`n.boot`	Number of bootsrap replications. By default n.boot = 1000
`n.ahead`	Numbers of steps-ahead. By default n.ahead = 1
`ncl`	Numbers of parallel processes. By default ncl = 2

Details

More details can be found in Trucíos et at. (2017), Hotta and Trucíos (2018), and Trucíos (2019).

Value

The function returns two lists with the empirical H-steps-ahead bootstrap densities for returns and squared volatilities.

Author(s)

Carlos Trucíos

References

Hotta, Luiz Koodi, and Carlos Trucíos. Inference in (M)GARCH models in the presence of additive outliers: Specification, estimation, and prediction. Advances in Mathematics and Applications. Springer, Cham, 2018. 179-202.

Trucíos, Carlos, Luiz K. Hotta, and Esther Ruiz. Robust bootstrap forecast densities for GARCH returns and volatilities. Journal of Statistical Computation and Simulation 87.16 (2017): 3152-3174.

Trucíos, Carlos. Forecasting Bitcoin risk measures: A robust approach. International Journal of Forecasting 35.3 (2019): 836-847.

Examples

```
# Robust bootstrap forecast densities for returns and volatilities
boot = RobGARCHBootParallel(returnsexample, n.boot = 1000, n.ahead = 1)

# Obtaining the forecast intervals for returns (95%)
quantile(boot[[1]], prob = c(0.025, 0.975))
# Obtaining the forecast intervals for volatilities (95%)
quantile(boot[[2]], prob = c(0.025, 0.975))

# Risk measures can also be obtained
VaR1 = quantile(boot[[1]], prob = 0.01)
```

ROBUSTGARCH *Robust GARCH Estimator*

Description

Robust GARCH (Generalized Autoregressive Conditional Heteroskedastic) estimator of Boudt et al. (2013) with the modification introduced by Trucíos et at. (2017).

Usage

```
ROBUSTGARCH(y)
```

Arguments

y	Vector of time series returns.

Details

More details can be found in Boudt et al. (2013) and Trucíos et at. (2017).

Value

The function returns the estimated parameters.

Author(s)

Carlos Trucíos

References

Boudt, Kris, Jon Danielsson, and Sébastien Laurent. Robust forecasting of dynamic conditional correlation GARCH models. International Journal of Forecasting 29.2 (2013): 244-257.

Trucíos, Carlos, Luiz K. Hotta, and Esther Ruiz. Robust bootstrap forecast densities for GARCH returns and volatilities. Journal of Statistical Computation and Simulation 87.16 (2017): 3152-3174.

Examples

```
# Estimating the parameters of the GARCH model in a robust way.
ROBUSTGARCH(returnsexample*100)
```

ROBUSTGARCHloss_RCPP *Loss function used in GARCH robust estimation.*

Description

Loss function used in GARCH (Generalized Autoregressive Conditional Heteroskedastic) robust estimation.

Usage

```
ROBUSTGARCHloss_RCPP(theta, r, sigma2)
```

Arguments

theta	Vector of robust estimated (or initial values) parameters obtained from ROBUSTGARCH function.
r	Vector of time series returns.
sigma2	robust squared volatility estimation (or initial value of squared volatility)

Details

This function is used in the robust estimation. We can use it to evaluate the value of the loss function using several values of the vector parameters (theta)

Value

Returns the value of the loss function

Author(s)

Carlos Trucíos

References

Boudt, Kris, Jon Danielsson, and Sébastien Laurent. Robust forecasting of dynamic conditional correlation GARCH models. International Journal of Forecasting 29.2 (2013): 244-257.

Trucíos, Carlos, Luiz K. Hotta, and Esther Ruiz. Robust bootstrap forecast densities for GARCH returns and volatilities. Journal of Statistical Computation and Simulation 87.16 (2017): 3152-3174.

Examples

```
# Using the Bitcoin daily returns, we estimate the parameter of the GARCH model in a robust way
param = ROBUSTGARCH(returnsexample)
# We can evaluate the loss function using the estimated parameters
ROBUSTGARCHloss_RCPP(param[2:3], returnsexample, param[1]/(1-param[2]-param[3]))
```

`Robust_cDCC` *Robust cDCC Estimator*

Description

Robust cDCC estimator as in Trucíos et at. (2018), which is a slight modification of the procedure of Boud et al. (2013).

Usage

```
Robust_cDCC(r)
```

Arguments

`r`	Matrix of time series returns.

Details

More details can be found in Boudt et al. (2013) and Trucíos et at. (2018).

Value

The function returns the estimated parameters and the Qbar matrix.

Author(s)

Carlos Trucíos

References

Boudt, Kris, Jon Danielsson, and Sébastien Laurent. Robust forecasting of dynamic conditional correlation GARCH models. International Journal of Forecasting 29.2 (2013): 244-257.

Trucíos, Carlos, Luiz K. Hotta, and Esther Ruiz. Robust bootstrap densities for dynamic conditional correlations: implications for portfolio selection and Value-at-Risk. Journal of Statistical Computation and Simulation 88.10 (2018): 1976-2000.

Examples

```
# Estimating the parameters of the cDCC model in a robust way.
cDCC = Robust_cDCC(returns3)
#parameters
cDCC[[1]]
#Qbar
cDCC[[2]]
```

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