Package ‘gammadlm’

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Type Package

Title Maximum Likelihood Estimation of the Gamma Distributed-Lag Model with Multiple Explanatory Variables

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Description Implementation of the hill climbing algorithm for maximum likelihood estimation of the Gamma distributed-lag model with multiple explanatory variables (Magrini, 2022 <doi:10.17713/ajs.v51i2.1244>). Data may have a panel structure, even unbalanced.

Depends R (>= 3.5.0)

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`gammadlm-package` *Maximum Likelihood Estimation of the Gamma Distributed-Lag Model with Multiple Explanatory Variables*

Description

Implementation of the hill climbing algorithm for maximum likelihood estimation of the Gamma distributed-lag model with multiple explanatory variables (Magrini, 2022 <doi:10.17713/ajs.v51i2.1244>). Data may have a panel structure, even unbalanced.

Details

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License:	GPL-2

Let Y be the response variable and $X_1, \ldots, X_J$ be J explanatory variables. Also, let y_t and $x_{j,t}$ be, respectively, the value of Y and of X_j ($j = 1, \ldots, J$) observed at time t. Under the assumption that the time series of Y and of $X_1, \ldots, X_J$ are all second-order stationary (i.e., expected value and autocorrelation function independent of time), the Gamma distributed-lag model explaining Y from $X_1, \ldots, X_J$ is defined as:

$$y_t = \alpha + \sum_{j=1}^{J} \sum_{k=0}^{\infty} \beta_{j,k}(\theta_j, \delta_j, \lambda_j, \eta_j)\, x_{j,t-k} + \varepsilon_t$$

$$\beta_{j,k}(\theta_j, \delta_j, \lambda_j, \eta_j) = \theta_j\, w_{j,k}(\delta_j, \lambda_j, \eta_j)$$

$$w_{j,k}(\delta_j, \lambda_j, \eta_j) = \frac{(k+1-\eta_j)^{\frac{\delta_j}{1-\delta_j}}\, \lambda_j^{k-\eta_j}}{\sum_{l=0}^{\infty} (l+1-\eta_j)^{\frac{\delta_j}{1-\delta_j}}\, \lambda_j^{l-\eta_j}}$$

where:

- α is the intercept;
- $\beta_{j,k}$ is the dynamic multiplier for X_j at time lag k, equal to the scale parameter θ_j times the weight $w_{j,k}$. The set $\{w_{j,k} : k = 0, 1, \ldots, \infty\}$ includes the weights for X_j and is defined by the shape parameters $0 \leq \delta_j < 1$ and $0 \leq \lambda_j < 1$ and the offset η_j (typically set to 0). The set $\{\beta_{j,k} : k = 0, 1, \ldots, \infty\}$ is called *lag distribution* of X_j;
- ε_t is the random error at time t.

If the time series of some variables is nonstationary, it is possible to exploit the Box-Cox transformation and differencing in order to achieve stationarity.

In case of a panel structure, one intercept is specified for each unit of observation, while each explanatory variable has the same lag distribution across all units:

$$y_{i,t} = \alpha_i + \sum_{j=1}^{J} \sum_{k=0}^{\infty} \beta_{j,k}(\theta_j, \delta_j, \lambda_j, \eta_j)\, x_{i,j,t-k} + \varepsilon_{i,t}$$

where:

- $y_{i,t}$ and $x_{i,j,t}$ are, respectively, the value of Y and of X_j ($j = 1, \dots, J$) observed on unit i at time t;
- α_i is the intercept for unit i;
- $\varepsilon_{i,t}$ is the random error for unit i at time t.

The main functions of the package are:

- tsEM, to impute missing values based on the Expectation-Maximization algorithm;
- unirootTest, to assess stationarity;
- gammadlm, to estimate the model through the hill climbing algorithm;
- lagCoef, to see the estimated dynamic multipliers;
- plot.gammadlm, to display the estimated lag distributions.

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References

A. Magrini (2022). A hill climbing algorithm for maximum likelihood estimation of the Gamma distributed-lag model with multiple explanatory variables. *Austrian Journal of Statistics*, 51(2): 40-46. DOI: 10.17713/ajs.v51i2.1244

`btc` *Bitcoin and US stock indices data*

Description

Daily close exchange rate of Bitcoin and of three composite indices of the US stock market from 17 September 2014 to 30 September 2020.

Usage

```
data(btc)
```

Format

A data.frame with a total of 1521 observations on the following 5 variables:

`Date` Day of observation.

`DJA` Exchange rate of Dow Jones Average index.

`IXIC` Exchange rate of Nasdaq Composite index.

`GSPC` Exchange rate of Standard\&Poor 500 index.

`BTC` Exchange rate of Bitcoin.

fadn *Farm performance and subsidies in EU countries*

Description

Data on farm performance and public subsidies in EU countries in the period 1989-2019 from the Farm Accountancy Data Network (FADN, European Commission, 2020). Values refer to nationally representative farms.

Usage

```
data(fadn)
```

Format

A data.frame with a total of 668 observations on the following 15 variables:

`Country` Country name.

`Country_code` Country code.

`Year` Time of measurement (year).

`Labour` Total labour input (annual work unit), item `SE010`.

`Land` Total utilised agricultural area (ha), `SE025`.

`Capital` Total intermediate consumption (euro), item `SE275`.

`Int_cons` Depreciation of fixed capital, excluding land (euro), item `SE360`.

`Inputs_total` Total inputs (euro), item `SE270`.

`Output_total` Total output (euro), item `SE131`.

`TFP` Total factor productivity, computed as the ratio of total output to total input, item `SE132`.

`Net_income` Farm net income (euro), item `SE420`.

`Subs_prod` Subsidies on production (euro), item `SE610+SE615`.

`Subs_inv` Subsidies on investments (euro), item `SE406`.

`Subs_rur` Total support for rural development (euro), item `SE624`.

`Subs_dec` Decoupled payments (euro), item `SE630`.

References

European Commission (2020). Farm Accountancy Data Network (FADN) public database. Accessed: 2022/06/21. https://agridata.ec.europa.eu/extensions/FarmEconomyFocus/FADNDatabase.html

gammadlm *Estimation of a Gamma distributed-lag model*

Description

Maximum likelihood estimation of a Gamma distributed-lag model with multiple explanatory variables using the hill climbing algorithm. Data may have a panel structure, even unbalanced.

Usage

```
gammadlm(y.name, x.names, z.names=NULL, unit=NULL, time=NULL, data,
  offset=rep(0,length(x.names)), box.cox=1, ndiff=0, add.intercept=TRUE,
  control=list(nstart=NULL, delta.lim=NULL, lambda.lim=NULL, peak.lim=NULL,
  length.lim=NULL), quiet=FALSE)
```

Arguments

`y.name`	Character including the name of the response variable, that must be a quantitative variable. If a vector with length greater than 1 is provided, only the first element is considered.
`x.names`	Character vector of length 1 or greater including the names of the explanatory variables with lags, that must be quantitative variables. If the name of the response variable is indicated in `x.names`, then the autoregressive lag distribution will be estimated.
`z.names`	Character vector including the names of the explanatory variables without lags (optional). They may be either quantitative or qualitative variables. If `NULL` (the default), no explanatory variable without lags is included in the model.
`unit`	Character containing the name of the variable that identifies the units of observation. If a vector with length greater than 1 is provided, only the first element is considered. If `NULL` (the default), a single unit of observation is assumed.
`time`	Character containing the name of the time variable, which must be in numeric or date format. If a vector with length greater than 1 is provided, only the first element is considered. If `NULL` (the default), data are assumed to be temporally ordered.
`data`	Object of class `data.frame` containing the variables in the model. Variables in `y.name`, `x.names`, `z.names`, `unit` and `time` cannot contain missing values. It is possible to use function tsEM to impute missing values of quantitative variables.
`offset`	Named vector with non-negative real values indicating the offset for variables in `x.names`. If `offset` is of length one and has no names, the same offset is used for all variables in `x.names`. If a variable in `x.names` has no name in `offset` or a negative value is provided, value 0 is assumed. If the name of the response variable is indicated in `x.names` and a value less than 1 is provided, value 1 is assumed. Default value of `offset` is 0.
`box.cox`	Named vector with non-negative real values indicating the parameters of the Box-Cox transformation (Box & Cox, 1964) for variables in `x.names`. If `box.cox` has no names and length greater than one, the same ordering as in `x.names` is assumed. If `box.cox` has no names and length equal to one, the same parameter is used for all variables in `x.names`. Value 0 of the parameter equates to the logarithmic transformation, while value 1 means no transformation. Default is 1 for all variables in `x.names`.

ndiff	Named vector with non-negative integer values indicating the number of differences for variables in x.names. If ndiff has no names and length greater than one, the same ordering as in x.names is assumed. If ndiff has no names and length equal to one, the same number of differences is used for all variables in x.names. Value 0 means no differencing. Default is 0 for all variables in x.names.
add.intercept	Logical value indicating whether the intercept should be included in the model. Default is TRUE. See 'Details'.
control	A list including control options for the hill climbing algorithm.

- nstart: positive integer value indicating the number of restarts. If equal to 1 or NULL (the default), shape parameters are initialized for one explanatory variable at a time based on OLS-grid search.
- delta.lim: a named list with one component for each variable in x.names, that must be either a numerical vector of length 2 indicating the minimum and the maximum value of δ, or a numerical value indicating the exact value of δ. If there is no component in delta.lim for a certain variable in x.names, then the theoretical range [0,1) is assumed for δ.
- lambda.lim: the same as delta.lim, but it is about λ parameters.
- peak.lim: the same as delta.lim, but it is about the peak of the lag distributions.
- length.lim: the same as delta.lim, but it is about the 99.9th percentile of the lag distributions.

quiet	Logical value indicating whether prompt messages should be suppressed. Default is FALSE.

Details

Second-order stationarity of all time series (expected value and autocorrelation function independent of time) is a basic assumption of the model, that is guaranteed if no time series contains unit roots. Box-Cox transformation (argument box.cox) and/or differencing (argument ndiff) can be exploited in order to achieve second-order stationarity of each time series.

If the response variable is not differenced, the intercept captures the effect of time-invariant factors. Otherwise, time-invariant factors are canceled out and the intercept represents the coefficient of a linear trend (drift). When unit is not NULL (panel data), unit-specific intercepts are included if the response variable is not differenced, otherwise a unique intercept (drift) for all units is included.

All S3 methods for class lm are also available for class gammadlm:

- plot: to display the estimated lag distributions;

- summary: to see the summary of parameter estimation;

- residuals: to get the residuals;

- fitted.values: to get the fitted values;

- predict: to obtain predictions.

Furthermore, method lagCoef can be used to see the estimated dynamic multipliers.

Value

An object of class lm and gammadlm, including all the components of an object of class lm plus the following components:

- par: matrix including the shape parameters for each variable in x.names (by column);

- `offset`: vector including the offset of the lag distributions;
- `add.intercept`: value passed to argument `add.intercept`;
- `local.max`: list including the best model for each restart.
- `variables`: list including the names of the variables provided to arguments `y.name`, `x.names`, `z.names`, `unit` and `time`.
- `control`: list including control options used in parameter estimation;
- `unit.id`: list including the row names of the observations for each unit. `NULL` if `unit` is `NULL`;
- `box.cox`: named vector including the parameter of the Box-Cox trasnformation for each time series;
- `ndiff`: named vector including the order fo differencing for each time series;
- `lag.order`: lag orders of residuals and squared residuals estimated by minimizing the Bayesian Information Criterion (see 'Note'). If `unit` is not `NULL`, lag orders will be provided as a matrix with one row for each unit of observation;
- `data.orig`: data.frame including the data before Box-Cox transformation and differencing.
- `data.used`: data.frame including the data used for parameter estimation.

Note

The first order difference of logarithmic values (`box.cox=0` and `ndiff=1`) provides the log returns, which approximate the relative changes with respect to the previous time point.

If a variable contains negative values, the Box-Cox transformation will be not applied and a warning is returned. If `box.cox=0` (logarithmic transformation) and the variable contains positive and null values, argument `box.cox` will be set to 0.5 (squared root transformation) and a warning is returned.

If the number of differencing exceeds `n-5`, where `n` is the sample size, differencing will be not applied and a warning is returned.

The absence of unit roots in the residuals is automatically checked and a warning is returned in case of failure.

When the `summary` method is called on an object of class `gammadlm`, the Heteroskedasticity and Autocorrelation Consistent (HAC, Newey & West, 1987) estimator of the covariance matrix of least squares estimates is applied, based on the lag order of residuals and squared residuals (see `lag.order` in 'Values'). The same holds for the `confint` method.

References

G. E. P. Box, and D. R. Cox (1964). An analysis of transformations. *Journal of the Royal Statistical Society*, Series B (Methodological), 26(2): 211-252. DOI: 10.1111/j.2517-6161.1964.tb00553.x

A. Magrini (2022). A hill climbing algorithm for maximum likelihood estimation of the Gamma distributed-lag model with multiple explanatory variables. *Austrian Journal of Statistics*, 51(2): 40-46. DOI: 10.17713/ajs.v51i2.1244

W. K. Newey, K. D. West (1987). A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. *Econometrica*, 55(3): 703-708

See Also

unirootTest; tsEM; lagCoef; plot.gammadlm.

Examples

```
# load data on Bitcoin and US stock market price
data(btc)
mydata <- btc[which(btc$Date>="2020-04-01"),]

# model with pre-specified shape parameters (simple OLS)
#   on data in logarithmic differences (yearly relative changes)
dval <- list(DJA=0.85,IXIC=0.75,GSPC=0.55)
lval <- list(DJA=0.05, IXIC=0.35,GSPC=0.45)
m0 <- gammadlm(y.name="BTC", x.names=c("DJA","IXIC","GSPC"), time="Date", data=mydata,
  box.cox=0, ndiff=1, control=list(delta.lim=dval, lambda.lim=lval))
summary(m0)  ## summary of estimation

# hill climbing algorithm without random restarts
#   (initialization based on independent OLS-grid searches)
m1 <- gammadlm(y.name="BTC", x.names=c("DJA","IXIC","GSPC"), data=mydata,
  box.cox=0, ndiff=1)
summary(m1)

# add constraints: peak>=1 and 3<=length<=15
pklim <- list(DJA=c(1,Inf),IXIC=c(1,Inf),GSPC=c(1,Inf))
lenlim <- list(DJA=c(3,15),IXIC=c(3,15),GSPC=c(3,15))
m2 <- gammadlm(y.name="BTC", x.names=c("DJA","IXIC","GSPC"), data=mydata,
  box.cox=0, ndiff=1, control=list(peak.lim=pklim, length.lim=lenlim))
summary(m2)

## Not run:
# 50 random restarts without constraints
set.seed(100)
m3 <- gammadlm(y.name="BTC", x.names=c("DJA","IXIC","GSPC"), data=mydata,
  box.cox=0, ndiff=1, control=list(nstart=50))
summary(m3)  ## better fit than m1

# 50 random restarts with constraints: NOT RUN
set.seed(100)
m4 <- gammadlm(y.name="BTC", x.names=c("DJA","IXIC","GSPC"), data=mydata,
  box.cox=0, ndiff=1, control=list(peak.lim=pklim, length.lim=lenlim, nstart=50))
summary(m4)  ## better fit than m2
## End(Not run)


###  Example with panel data  ###

## Not run:
# load data on farm performance and subsidies in EU countries, 2004-2019
data(fadn)

# considered variables:
#  Y: productivity
#  X1-X4: subsidies by typology
#  Z1: utilized agricultural area (dimensional class),
#  Z2: total output (economic class)
y_name <- "TFP"
x_name <- c("Subs_prod","Subs_inv","Subs_rur","Subs_dec")
z_name <- c("Land","Output_total")
```

```
# model on data in differences: in this case, the intercept
#   represents the coefficient of a linear trend (drift)
m_fadn <- gammadlm(y.name=y_name, x.names=x_name, z.names=z_name,
  unit="Country", time="Year", data=fadn, box.cox=1, ndiff=1,
  control=list(peak.lim=c(1,Inf), length.lim=c(3,10)))
summary(m_fadn)
## End(Not run)
```

`gammaWeights` *Functionalities for the Gamma lag distribution*

Description

Obtain weights, quantiles and kernel projection for the desired Gamma lag distribution.

Usage

```
gammaWeights(k, par, offset=0, normalize=TRUE)
gammaQuantile(prob, par, offset=0)
gammaKernel(x, par, unit=NULL, offset=0, normalize=TRUE)
```

Arguments

`k`	Numerical vector indicating the lags for which the weights should be computed.
`prob`	Numerical vector indicating the order of the quantiles to be computed.
`x`	Numerical vector representing temporally ordered data for which the kernel projection should be returned.
`par`	Numerical vector of length 2 representing the shape parameters of the Gamma lag distribution.
`unit`	Character containing the name of the units of observation in case of a panel structure. If a vector with length greater than 1 is provided, only the first element is considered. If `NULL` (the default), a single unit of observation is assumed.
`offset`	Numerical value representing the offset of the Gamma lag distribution. Default is 0.
`normalize`	Logical value indicating whether the weights should be normalized to have sum 1. Default is `TRUE`.

Details

Function `gammaWeights` provides the weights, function `gammaQuantile` computes the quantiles, and function `gammaKernel` returns the kernel projection.

Examples

```
## examples for a Gamma lag distribution with delta=0.6 and lambda=0.3

# weights
gammaWeights(0:12, par=c(0.6,0.3))  ## at lags from 0 to 12
gammaWeights(10, par=c(0.6,0.3))    ## at lag 10

# quantiles
```

```
gammaQuantile(0.5, par=c(0.6,0.3))   ## median
gammaQuantile(0.95, par=c(0.6,0.3))  ## 95th percentile
gammaQuantile(0.99, par=c(0.6,0.3))  ## 99th percentile

# kernel projection
set.seed(100); xval <- rnorm(10)
gammaKernel(xval, par=c(0.6,0.3))

# kernel projection under a panel structure
set.seed(100); xval <- rnorm(20)
gr <- c(rep(0,10),rep(1,10))
gammaKernel(xval, par=c(0.6,0.3), unit=gr)
```

`lagCoef` *Estimated dynamic multipliers*

Description

See the estimated dynamic multipliers for each explanatory variable with lags.

Usage

```
lagCoef(x, conf=0.95, cumulative=FALSE, max.lag=NULL, max.quantile=0.999)
```

Arguments

`x`	An object of class `gammadlm`.
`conf`	Numerical value indicating the level of confidence intervals. If `NULL`, confidence intervals are not provided. Default is 0.95.
`cumulative`	Logical value indicating whether cumulative multipliers should be returned. Default is `FALSE`.
`max.lag`	Non-negative integer value indicating the lag up to which multipliers should be returned. If `NULL` (the default), it is set accordingly to argument `max.quantile`.
`max.quantile`	Numerical value indicating the order of the quantile lag up to which multipliers should be returned. Default is 0.999 (99.9th percentile).

Value

A list with one component for each explanatory variable with lags. Each component is an object of class `data.frame` containing estimation, asymptotic standard error and confidence interval for each lag up to `max.lag`.

See Also

gammadlm; plot.gammadlm.

Examples

```
## Not run:
data(btc)
mydata <- btc[which(btc$Date>="2020-04-01"),]
mydataLR <- preProcess(c("BTC","DJA","IXIC","GSPC"),
  time="Date", data=mydata, box.cox=0, ndiff=1)
m0 <- gammadlm(y.name="BTC", x.names=c("DJA","IXIC","GSPC"), data=mydataLR)

lagCoef(m0)  ## multipliers shown up to the 99.9th percentile lag
lagCoef(m0, max.lag=11)  ## multipliers shown up to lag 11
lagCoef(m0, cumulative=TRUE)  ## cumulative multipliers
## End(Not run)
```

---

plot.gammadlm *Graphics for the estimated lag distributions*

Description

Display the estimated lag distribution of each explanatory variable with lags.

Usage

```
## S3 method for class 'gammadlm'
plot(x, x.names=NULL, conf=0.95, max.lag=NULL, max.quantile=0.999,
  xlim=NULL, ylim=NULL, add.legend=TRUE, cex.legend=1, digits=4, grid.length=100,
  main=NULL, ylab=NULL, xlab=NULL, ...)
```

Arguments

`x`	Object of class `gammadlm`.
`x.names`	Character vector including the name of the variables for which the lag distribution should be displayed. Unknown variables will be ignored. If `NULL` (the default), the lag distribution of all the variables with lags will be displayed.
`conf`	Numerical value indicating the level of confidence bands. Default is 0.95. If `NULL`, confidence bands will not be displayed.
`max.lag`	Non-negative integer value indicating the lag up to which each lag distribution should be displayed. If `NULL` (the default), it is set accordingly to argument `max.quantile`.
`max.quantile`	Numerical value indicating the order of the quantile up to which each lag distribution should be displayed. Default is 0.999 (99.9th percentile).
`xlim`	Numerical vector of length 2 indicating the range of the x-axis, which is applied to all graphics (optional).
`ylim`	Numerical vector of length 2 indicating the range of the y-axis, which is applied to all graphics (optional).
`add.legend`	Logical value indicating whether a legend with numerical information should be added to the graphics. Default is `TRUE`.
`cex.legend`	Size of the legend. Default is 1.
`digits`	Integer non-negative value indicating the number of decimal places to be used in the legend. Default is 4. Ignored if `add.legend=FALSE`.

`grid.length`	Numerical value no less than 100 indicating the resolution of the interpolation. Default is 100.
`main`	Vector of characters including the title for each graphic. If `NULL` (the default), the name of the explanatory variables is used.
`ylab`	Text for y-axis, which is applied to all graphics (optional).
`xlab`	Text for x-axis, which is applied to all graphics (optional).
`...`	Further graphical parameters.

See Also

gammadlm.

Examples

```
## Not run:
data(btc)
mydata <- btc[which(btc$Date>="2020-04-01"),]
mydataLR <- preProcess(c("BTC","DJA","IXIC","GSPC"),
  time="Date", data=mydata, box.cox=0, ndiff=1)
m0 <- gammadlm(y.name="BTC", x.names=c("DJA","IXIC","GSPC"), data=mydataLR)

plot(m0)  ## all the lag distributions
plot(m0, x.names=c("DJA","IXIC"))  ## just the ones of 'DJA' and 'IXIC'
## End(Not run)
```

`tsEM` *Imputation of multivariate time series data*

Description

Imputation of a multivariate time series based on the Expectation-Maximization algorithm. Data may have a panel structure, even unbalanced.

Usage

```
tsEM(var.names, unit=NULL, time=NULL, data, nlags=NULL, tol=1e-4, maxit=1000, quiet=FALSE)
```

Arguments

`var.names`	Character vector including the name of the variables in the imputation model. See 'Details'.
`unit`	Character containing the name of the variable that identifies the units of observation. If a vector with length greater than 1 is provided, only the first element is considered. If `NULL` (the default), a single unit of observation is assumed.
`time`	Character containing the name of the time variable, which must be in numeric or date format. If a vector with length greater than 1 is provided, only the first element is considered. If `NULL` (the default), data are assumed to be temporally ordered.
`data`	Object of class `data.frame` containing the variables in `var.names`, `unit` and `time`.

nlags	Non-negative integer number indicating the lag order of the imputation model. It will be automatically bounded in order to keep the number of free parameters lower than half the sample size. If NULL (the default), it will be automatically determined based on empirical correlations among variables in var.names.
tol	Positive number indicating the tolerance. Default is 1e-4.
maxit	Positive integer indicating the number of iterations. Default is 1000.
quiet	Logical value indicating whether prompt messages should be suppressed. Default is FALSE.

Details

The imputation model is a nonstationary vector autoregressive (VAR) model, where quantitative and categorical variables provided to argument var.names are considered, respectively, endogenous and exogenous.

Missing values of quantitative variables are replaced by their conditional expected value under the imputation model, which is estimated through the Expectation-Maximization algorithm (Dempster et al., 1977).

The optimal Box-Cox transformation (Box & Cox, 1964) for each quantitative variable is determined automatically, and the transformation is inverted before returning the imputed data.

Value

The object provided to argument data where variables in var.names have been imputed.

References

G. E. P. Box, and D. R. Cox (1964). An analysis of transformations. *Journal of the Royal Statistical Society*, Series B (Methodological), 26(2): 211-252. DOI: 10.1111/j.2517-6161.1964.tb00553.x

A. P. Dempster, N. M. Laird, and D. B. Rubin (1977). Maximum likelihood from incomplete data via the EM algorithm. *Journal of the Royal Statistical Society*n Series B (Methodological), 39(1): 1-38. DOI: 10.1111/j.2517-6161.1977.tb01600.x

Examples

```
data(btc)
mydata <- btc[which(btc$Date>="2020-04-01"),]

# add some missing values
mydata0 <- mydata
mydata0$BTC[sample(1:nrow(mydata),30)] <- NA
mydata0$DJA[sample(1:nrow(mydata),30)] <- NA
mydata0$GSPC[sample(1:nrow(mydata),30)] <- NA
mydata0$IXIC[sample(1:nrow(mydata),30)] <- NA
summary(mydata0)
plot(ts(mydata0[,c("BTC","DJA","IXIC","GSPC")]), main="")

mydataI <- tsEM(var.names=c("BTC","DJA","IXIC","GSPC"), time="Date",
  data=mydata0)
summary(mydataI)
plot(ts(mydataI[,c("BTC","DJA","IXIC","GSPC")]), main="")
```

`unirootTest` *Unit root tests*

Description

Augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests for a multivariate time series, eventually structured as a balanced or unbalanced panel.

Usage

```
unirootTest(var.names, unit=NULL, time=NULL, data, box.cox=1, ndiff=0, max.lag=NULL)
```

Arguments

`var.names`	Character vector including the name of the variables to be differenced.
`unit`	Character containing the name of the variable that identifies the units of observation. If a vector with length greater than 1 is provided, only the first element is considered. If `NULL` (the default), a single unit of observation is assumed.
`time`	Character containing the name of the time variable, which must be in numeric or date format. If a vector with length greater than 1 is provided, only the first element is considered. If `NULL` (the default), data are assumed to be temporally ordered.
`data`	Object of class `data.frame` containing the variables in `var.names`, `unit` and `time`.
`box.cox`	Named vector with non-negative real values indicating the parameters of the Box-Cox transformation (Box & Cox, 1964) for variables in `x.names`. If `box.cox` has no names and length greater than one, the same ordering as in `x.names` is assumed. If `box.cox` has no names and length equal to one, the same parameter is used for all variables in `x.names`. Value 0 of the parameter equates to the logarithmic transformation, while value 1 means no transformation. Default is 1 for all variables in `x.names`.
`ndiff`	Named vector with non-negative integer values indicating the number of differences for variables in `x.names`. If `ndiff` has no names and length greater than one, the same ordering as in `x.names` is assumed. If `ndiff` has no names and length equal to one, the same number of differences is used for all variables in `x.names`. Value 0 means no differencing. Default is 0 for all variables in `x.names`.
`max.lag`	Non-negative integer value representing the maximum lag length at which to perform the tests (see 'Details'). If `NULL` (the default), it is taken as the squared root of the length of the time series. .

Details

The variables subjected to the tests must be quantitative. Missing values internal to the time series are imputed through linear interpolation, otherwise they are deleted out.

The lag length at which to perform the tests is selected through BIC-based backward elimination starting from the lag length specified in argument `max.lag`.

The null hypothesis of the ADF test is the presence of unit roots, while the null hypothesis of the KPSS test is the absence of unit roots. Therefore, p-value higher than 0.05 for the ADF test or p-value lower than 0.05 for the KPSS test suggest the presence of unit roots and the need of further differencing.

In case of a panel structure, p-values are combined according to the method by Demetrescu *et al.* (2006).

Value

One list for each variable in `var.names`, each with three components:

- `statistic`: test statistic for each test;
- `lag.order`: lag length selected for each test;
- `p.value`: p-value of each test, which is a single value if `unit` is `NULL`, otherwise one value for each unit of observation plus another one indicating the combined p-value;
- `box.cox`: parameter of the Box-Cox transformation for each variable subjected to the tests;
- `ndiff`: order of differencing for each variable subjected to the tests.

Note

The first order difference of logarithmic values (`box.cox`=0 and `ndiff`=1) provides the log returns, which approximate the proportional changes with respect to the previous time point.

If a variable contains negative values, the Box-Cox transformation will be not applied and a warning is returned.

If the number of differencing exceeds `n-5`, where `n` is the sample size, differencing will be not applied and a warning is returned.

References

M. Demetrescu, U. Hassler, and A. Tarcolea (2006). Combining significance of correlated statistics with application to panel data. *Oxford Bulletin of Economics and Statistics*, 68(5), 647-663. DOI: 10.1111/j.1468-0084.2006.00181.x

D. A. Dickey, and W. A. Fuller (1981). Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica*, 49(4): 1057-1072. DOI: 10.2307/1912517

D. Kwiatkowski, P. C. B. Phillips, P. Schmidt, and Y. Shin (1992). Testing the null hypothesis of stationarity against the alternative of a unit root. *Journal of Econometrics*, 54(1-3): 159-178. DOI: 10.1016/0304-4076(92)90104-Y

Examples

```
data(btc)
mydata <- btc[which(btc$Date>="2020-04-01"),]

# tests on time series in level ('box.cox'=1 by default):
#   there are some unit roots
unirootTest(c("BTC","DJA","IXIC","GSPC"), time="Date",
  data=mydata)

# tests on time series in log return: ok
unirootTest(c("BTC","DJA","IXIC","GSPC"), time="Date",
  data=mydata, box.cox=0, ndiff=1)
```

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