

Package ‘clmplus’

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Type Package

Title Tool-Box of Chain Ladder Plus Models

Version 0.1.0

Description Implementation of the chain ladder model under the reverse time framework introduced in Hiabu (2017) <[doi:10.1080/03461238.2016.1240709](https://doi.org/10.1080/03461238.2016.1240709)>. It also implements extensions that add flexibility to the individual development factors modeling by allowing practitioners to set their own hazard rate model.

URL <https://github.com/gpitt71/clmplus>

BugReports <https://github.com/gpitt71/clmplus/issues>

License GPL (>= 2)

Imports StMoMo, ChainLadder, stats, ggplot2, forecast, gridExtra, reshape2

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amases.gtpl

Amases GTPL

Description

Dataset of cumulative paid claims for a small italian company in the line of business: general third party liability.

Usage

```
amases.gtpl
```

Format

Run-off triangle with 12 development periods.

References

Savelli, Nino, and Clemente, Gian Paolo. "Lezioni di matematica attuariale delle assicurazioni danni." EDUCatt-Ente per il diritto allo studio universitario dell'Università Cattolica, 2014

`amases.mod`*Amases MOD*

Description

Dataset of cumulative paid claims for a small italian company in the line of business: motor or damage.

Usage`amases.mod`**Format**

Run-off triangle with 12 development periods.

References

Savelli, Nino, and Clemente, Gian Paolo. "Lezioni di matematica attuariale delle assicurazioni danni." EDUCatt-Ente per il diritto allo studio universitario dell'Università Cattolica, 2014

`amases.mtpl`*Amases MTPL*

Description

Dataset of cumulative paid claims for a small italian company in the line of business: motor third party liability.

Usage`amases.mtpl`**Format**

Run-off triangle with 12 development periods.

References

Savelli, Nino, and Clemente, Gian Paolo. "Lezioni di matematica attuariale delle assicurazioni danni." EDUCatt-Ente per il diritto allo studio universitario dell'Università Cattolica, 2014

cImplus

Fit chain-ladder+ to reverse time triangles.

Description

Generic method to fit the chain ladder +.

Usage

```
cImplus(
  RtTriangle,
  hazard.model = NULL,
  xc = NULL,
  iter.max = 10000,
  tolerance.max = 1e-06,
  link = c("log", "logit"),
  staticAgeFun = TRUE,
  periodAgeFun = "NP",
  cohortAgeFun = NULL,
  constFun = function(ax, bx, kt, b0x, gc, wxt, ages) list(ax = ax, bx = bx, kt = kt, b0x
    = b0x, gc = gc),
  gk.fc.model = "a",
  ckj.fc.model = "a",
  gk.order = c(1, 1, 0),
  ckj.order = c(0, 1, 0),
  ...
)
```

Arguments

RtTriangle	RtTriangle object to be fitted.
hazard.model	hazard model supported from our package, must be provided as a string. The model can be chosen from: <ul style="list-style-type: none"> • 'a': Age model, this is equivalent to the Mack chain-ladder. • 'ac': Age and cohort effects. • 'ap': Age and cohort effects. • 'apc': Age cohort and period effects. • 'lc': Lee-Carter parameters: age and age-period interaction effects. • 'cbd': Cairns-Blake-Dowd mortality model (CBD). • 'm6': CBD with cohorts. • 'm7': CBD m7 extension. • 'm8': CBD m7 extension.
xc	xc constant parameter to be set for the m8 model. Default to NULL.
iter.max	maximum number of iterations for the Newton-Rhapson algorithm. It will be ignored for other fitting procedures.

tolerance.max	maximum tolerance of parameters difference for convergence for the Newton-Rhapson algorithm implementation. Ignored for other fitting procedures.
link	defines the link function and random component associated with the mortality model. "log" would assume that deaths follow a Poisson distribution and use a log link while "logit" would assume that deaths follow a Binomial distribution and a logit link. To be disregarded unless the practitioner specifies his own hazard model in StMoMo.
staticAgeFun	logical value indicating if a static age function α_x is to be included. To be disregarded unless the practitioner specifies his own hazard model in StMoMo.
periodAgeFun	a list of length N with the definitions of the period age modulating parameters $\beta_x^{(i)}$. Each entry can take values: "NP" for non-parametric age terms, "1" for $\beta_x^{(i)} = 1$ or a predefined parametric function of age (see details). Set this to NULL if there are no period terms in the model. To be disregarded unless the practitioner specifies his own hazard model in StMoMo.
cohortAgeFun	defines the cohort age modulating parameter $\beta_x^{(0)}$. It can take values: "NP" for non-parametric age terms, "1" for $\beta_x^{(0)} = 1$, a predefined parametric function of age (see details) or NULL if there is no cohort effect. To be disregarded unless the practitioner specifies his own hazard model in StMoMo.
constFun	function defining the identifiability constraints of the model. It must be a function of the form <code>constFun <- function(ax, bx, kt, b0x, gc, wxt, ages)</code> taking a set of fitted model parameters and returning a list <code>list(ax = ax, bx = bx, kt = kt, b0x = b0x, gc = gc)</code> of the model parameters with the identifiability constraints applied. If omitted no identifiability constraints are applied to the model. To be disregarded unless the practitioner specifies his own hazard model in StMoMo.
gk.fc.model	model to forecast the cohort component for the last accident period. It can be either arima ('a') or linear model ('l'). Disregarded for models that do not have a cohort effect.
ckj.fc.model	model to forecast the calendar period effect. It can be either arima ('a') or linear model ('l'). Disregarded for models that do not have a period effect.
gk.order	order of the arima model with drift for the accident year effect extrapolation. Default to (1,1,0).
ckj.order	order of the arima model with drift for the calendar year effect extrapolation. Default to (0,1,0).
...	parameters to be passed to clmplus.

Value

No return value, called to pass method clmplus.

References

Hiabu, Munir. "On the relationship between classical chain ladder and granular reserving." *Scandinavian Actuarial Journal* 2017 (2017): 708 - 729.

Examples

```
data(sifa.mtpl)
sifa.mtpl.rtt <- RtTriangle(cumulative.payments.triangle=sifa.mtpl)
hz.chl=clmplus(sifa.mtpl.rtt, 'a')
```

clmplus.default *Fit chain-ladder+ to reverse time triangles.*

Description

This function allows to fit chain-ladder+ models to cumulative payments run-off triangles.

Usage

```
## Default S3 method:
clmplus(
  RtTriangle,
  hazard.model = NULL,
  xc = NULL,
  iter.max = 10000,
  tolerance.max = 1e-06,
  link = c("log", "logit"),
  staticAgeFun = TRUE,
  periodAgeFun = "NP",
  cohortAgeFun = NULL,
  constFun = function(ax, bx, kt, b0x, gc, wxt, ages) list(ax = ax, bx = bx, kt = kt, b0x
    = b0x, gc = gc),
  gk.fc.model = "a",
  ckj.fc.model = "a",
  gk.order = c(1, 1, 0),
  ckj.order = c(0, 1, 0),
  ...
)
```

Arguments

RtTriangle	RtTriangle object to be fitted.
hazard.model	hazard model supported from our package, must be provided as a string. The model can be chosen from: <ul style="list-style-type: none"> • 'a': Age model, this is equivalent to the Mack chain-ladder. • 'ac': Age and cohort effects. • 'ap': Age and cohort effects. • 'apc': Age cohort and period effects. • 'cbd': Cairns-Blake-Dowd mortality model (CBD).

- 'lc': Lee-Carter parameters: age and age-period interaction effects.
- 'm6': CBD with cohorts.
- 'm7': CBD m7 extension.
- 'm8': CBD m7 extension.

xc	xc constant parameter to be set for the m8 model. Default to NULL.
iter.max	maximum number of iterations for the Newton-Rhapson algorithm. It will be ignored for other fitting procedures.
tolerance.max	maximum tolerance of parameters difference for convergence for the Newton-Rhapson algorithm implementation. Ignored for other fitting procedures.
link	defines the link function and random component associated with the mortality model. "log" would assume that deaths follow a Poisson distribution and use a log link while "logit" would assume that deaths follow a Binomial distribution and a logit link. To be disregarded unless the practitioner specifies his own hazard model in StMoMo.
staticAgeFun	logical value indicating if a static age function α_x is to be included. To be disregarded unless the practitioner specifies his own hazard model in StMoMo.
periodAgeFun	a list of length N with the definitions of the period age modulating parameters $\beta_x^{(i)}$. Each entry can take values: "NP" for non-parametric age terms, "1" for $\beta_x^{(i)} = 1$ or a predefined parametric function of age (see details). Set this to NULL if there are no period terms in the model. To be disregarded unless the practitioner specifies his own hazard model in StMoMo.
cohortAgeFun	defines the cohort age modulating parameter $\beta_x^{(0)}$. It can take values: "NP" for non-parametric age terms, "1" for $\beta_x^{(0)} = 1$, a predefined parametric function of age (see details) or NULL if there is no cohort effect. To be disregarded unless the practitioner specifies his own hazard model in StMoMo.
constFun	function defining the identifiability constraints of the model. It must be a function of the form <code>constFun <- function(ax, bx, kt, b0x, gc, wxt, ages)</code> taking a set of fitted model parameters and returning a list <code>list(ax = ax, bx = bx, kt = kt, b0x = b0x, gc = gc)</code> of the model parameters with the identifiability constraints applied. If omitted no identifiability constraints are applied to the model. To be disregarded unless the practitioner specifies his own hazard model in StMoMo.
gk.fc.model	model to forecast the cohort component for the last accident period. It can be either arima ('a') or linear model ('l'). Disregarded for models that do not have a cohort effect.
ckj.fc.model	model to forecast the calendar period effect. It can be either arima ('a') or linear model ('l'). Disregarded for models that do not have a period effect.
gk.order	order of the arima model with drift for the accident year effect extrapolation. Default to (1,1,0).
ckj.order	order of the arima model with drift for the calendar year effect extrapolation. Default to (0,1,0).
...	parameters to be passed to clmplus.

Value

No return value, called as clmplus method default.

References

Hiabu, Munir. "On the relationship between classical chain ladder and granular reserving." *Scandinavian Actuarial Journal* 2017 (2017): 708 - 729.

clmplus.RtTriangle *Fit chain-ladder+ to reverse time triangles.*

Description

This function allows to fit chain-ladder+ models to cumulative payments run-off triangles.

Usage

```
## S3 method for class 'RtTriangle'
clmplus(
  RtTriangle,
  hazard.model = NULL,
  xc = NULL,
  iter.max = 10000,
  tolerance.max = 1e-06,
  link = c("log", "logit"),
  staticAgeFun = TRUE,
  periodAgeFun = "NP",
  cohortAgeFun = NULL,
  constFun = function(ax, bx, kt, b0x, gc, wxt, ages) list(ax = ax, bx = bx, kt = kt, b0x
    = b0x, gc = gc),
  gk.fc.model = "a",
  ckj.fc.model = "a",
  gk.order = c(1, 1, 0),
  ckj.order = c(0, 1, 0),
  ...
)
```

Arguments

- | | |
|--------------|--|
| RtTriangle | RtTriangle object to be fitted. |
| hazard.model | hazard model supported from our package, must be provided as a string. The model can be chosen from: <ul style="list-style-type: none"> • 'a': Age model, this is equivalent to the Mack chain-ladder. • 'ac': Age and cohort effects. • 'ap': Age and cohort effects. • 'apc': Age cohort and period effects. |

- 'lc': Lee-Carter parameters: age and age-period interaction effects.
- 'cbd': Cairns-Blake-Dowd mortality model (CBD).
- 'm6': CBD with cohorts.
- 'm7': CBD m7 extension.
- 'm8': CBD m7 extension.

xc	xc constant parameter to be set for the m8 model. Default to NULL.
iter.max	maximum number of iterations for the Newton-Rhapson algorithm. It will be ignored for other fitting procedures.
tolerance.max	maximum tolerance of parameters difference for convergence for the Newton-Rhapson algorithm implementation. Ignored for other fitting procedures.
link	defines the link function and random component associated with the mortality model. "log" would assume that deaths follow a Poisson distribution and use a log link while "logit" would assume that deaths follow a Binomial distribution and a logit link. To be disregarded unless the practitioner specifies his own hazard model in StMoMo.
staticAgeFun	logical value indicating if a static age function α_x is to be included. To be disregarded unless the practitioner specifies his own hazard model in StMoMo.
periodAgeFun	a list of length N with the definitions of the period age modulating parameters $\beta_x^{(i)}$. Each entry can take values: "NP" for non-parametric age terms, "1" for $\beta_x^{(i)} = 1$ or a predefined parametric function of age (see details). Set this to NULL if there are no period terms in the model. To be disregarded unless the practitioner specifies his own hazard model in StMoMo.
cohortAgeFun	defines the cohort age modulating parameter $\beta_x^{(0)}$. It can take values: "NP" for non-parametric age terms, "1" for $\beta_x^{(0)} = 1$, a predefined parametric function of age (see details) or NULL if there is no cohort effect. To be disregarded unless the practitioner specifies his own hazard model in StMoMo.
constFun	function defining the identifiability constraints of the model. It must be a function of the form <code>constFun <- function(ax, bx, kt, b0x, gc, wxt, ages)</code> taking a set of fitted model parameters and returning a list <code>list(ax = ax, bx = bx, kt = kt, b0x = b0x, gc = gc)</code> of the model parameters with the identifiability constraints applied. If omitted no identifiability constraints are applied to the model. To be disregarded unless the practitioner specifies his own hazard model in StMoMo.
gk.fc.model	model to forecast the cohort component for the last accident period. It can be either arima ('a') or linear model ('l'). Disregarded for models that do not have a cohort effect.
ckj.fc.model	model to forecast the calendar period effect. It can be either arima ('a') or linear model ('l'). Disregarded for models that do not have a period effect.
gk.order	order of the arima model with drift for the accident year effect extrapolation. Default to (1,1,0).
ckj.order	order of the arima model with drift for the calendar year effect extrapolation. Default to (0,1,0).
...	parameters to be passed to clmplus.

Value

An object of class "clmplusmodel". A list with the following elements:

model.fit	Hazard model fit from StMoMo.
hazard.model	Hazard model chosen.
exposure	Matrix that contains the exposure derived from the input triangle, under the uniform claims arrival assumption.
ultimate.cost	Ultimate costs vector.
model.fcst	Hazard forecasts.
converged	logical value. Whether the fit converged.
citer	Number of Netwon-Rhapon iterations in case a lee-carter hazard-model was chosen.

References

Hiabu, Munir. "On the relationship between classical chain ladder and granular reserving." *Scandinavian Actuarial Journal* 2017 (2017): 708 - 729.

Examples

```
data(sifa.mtpl)
sifa.mtpl.rtt <- RtTriangle(cumulative.payments.triangle=sifa.mtpl)
hz.chl=clmplus(sifa.mtpl.rtt, 'a')
```

plot.clmplusmodel *Plot the hazard model fitted and forecasted parameters*

Description

This function allows to define the behavior of the triangle payments.

Usage

```
## S3 method for class 'clmplusmodel'
plot(x, cy.type = "fe", ...)
```

Arguments

x	clmplus model to be plotted.
cy.type	whether to show fitted period effect with or without extrapolatio Default is "fe", standing for fitted and extrapolated. Alternative is to specify "f" for fitted effect.
...	Arguments to be passed to plot.

Value

No return value, plots coefficients of the hazard models.

References

Hiabu, Munir. "On the relationship between classical chain ladder and granular reserving." *Scandinavian Actuarial Journal* 2017 (2017): 708 - 729.

Examples

```
data(sifa.mtpl)
sifa.mtpl.rtt <- RtTriangle(cumulative.payments.triangle=sifa.mtpl)
hz.chl<-clmplus(sifa.mtpl.rtt, 'a')
plot(hz.chl)
```

plot.RtTriangle	<i>Plot the payments behavior</i>
-----------------	-----------------------------------

Description

This function allows to define the behavior of the triangle payments.

Usage

```
## S3 method for class 'RtTriangle'
plot(x, ...)
```

Arguments

x	RtTriangle to be plotted.
...	Arguments to be passed to plot.

Value

No return value, plots the run-off triangle cumulative payments and incremental payments.

References

Hiabu, Munir. "On the relationship between classical chain ladder and granular reserving." *Scandinavian Actuarial Journal* 2017 (2017): 708 - 729.

Examples

```
data(sifa.mtpl)
sifa.mtpl.rtt <- RtTriangle(cumulative.payments.triangle=sifa.mtpl)
plot(sifa.mtpl.rtt)
```

plotresiduals *Plot the hazard model residuals*

Description

This function allows to plot the hazard model residuals on the triangle payments.

Usage

```
plotresiduals(clmplusmodel, heat.lim = c(-2.5, 2.5))
```

Arguments

clmplusmodel clmplusmodel object to be plotted.
heat.lim limits in the residuals plot.

Value

No return value, called to pass method plotresiduals.

References

Hiabu, Munir. "On the relationship between classical chain ladder and granular reserving." *Scandinavian Actuarial Journal* 2017 (2017): 708 - 729.

Examples

```
data(sifa.mtpl)
sifa.mtpl.rtt <- RtTriangle(cumulative.payments.triangle=sifa.mtpl)
hz.chl<-clmplus(sifa.mtpl.rtt, 'a')
plotresiduals(hz.chl)
```

plotresiduals.clmplusmodel
 Plot the hazard model residuals

Description

This function allows to plot the hazard model residuals on the triangle payments.

Usage

```
## S3 method for class 'clmplusmodel'
plotresiduals(clmplusmodel, heat.lim = c(-2.5, 2.5))
```

Arguments

`clmplusmodel` clmplusmodel object to be plotted.
`heat.lim` limits in the residuals plot.

Value

No return value, plots the hazard model residuals in triangular form.

References

Hiabu, Munir. "On the relationship between classical chain ladder and granular reserving." *Scandinavian Actuarial Journal* 2017 (2017): 708 - 729.

Examples

```
data(sifa.mtpl)
sifa.mtpl.rtt <- RtTriangle(cumulative.payments.triangle=sifa.mtpl)
hz.chl<-clmplus(sifa.mtpl.rtt, 'a')
plotresiduals(hz.chl)
```

`plotresiduals.default` *Plot the hazard model residuals*

Description

This function allows to plot the hazard model residuals on the triangle payments.

Usage

```
## Default S3 method:
plotresiduals(clmplusmodel, heat.lim = c(-2.5, 2.5))
```

Arguments

`clmplusmodel` clmplusmodel object to be plotted.
`heat.lim` limits in the residuals plot.

Value

No return value, called as plotresiduals method default.

References

Hiabu, Munir. "On the relationship between classical chain ladder and granular reserving." *Scandinavian Actuarial Journal* 2017 (2017): 708 - 729.

Examples

```
data(sifa.mtpl)
sifa.mtpl.rtt <- RtTriangle(cumulative.payments.triangle=sifa.mtpl)
hz.chl<-clmplus(sifa.mtpl.rtt, 'a')
plotresiduals(hz.chl)
```

RtTriangle

Reverse time triangles

Description

This function allows to define the class of triangles for reverse time models.

Usage

```
RtTriangle(cumulative.payments.triangle, k = 1/2)
```

Arguments

```
cumulative.payments.triangle
    Input triangle of cumulative payments.
k
    Claims exposure in the cell, also known as lost exposure.
```

Value

An object of class "RtTriangle". Lists the following elements:

```
cumulative.payments.triangle
    Input triangle of cumulative payments.
occurrence
    Matrix that contains the occurrence derived from the input triangle.
exposure
    Matrix that contains the exposure derived from the input triangle, under the
    uniform claims arrival assumption.
incremental.payments.triangle
    Triangle of incremental payments derived from the input.
J
    Run-off triangle dimension.
diagonal
    Cumulatives payments last diagonal.
```

References

Hiabu, Munir. "On the relationship between classical chain ladder and granular reserving." *Scandinavian Actuarial Journal* 2017 (2017): 708 - 729.

Examples

```
data(sifa.mtpl)
sifa.mtpl.rtt <- RtTriangle(cumulative.payments.triangle=sifa.mtpl)
```

sifa.gtpl

Sifa GTPL

Description

Dataset of cumulative paid claims for a medium italian company in the line of business: general third party liability.

Usage

sifa.gtpl

Format

Run-off triangle with 12 development periods.

References

Savelli, Nino, and Clemente, Gian Paolo. "Lezioni di matematica attuariale delle assicurazioni danni." EDUCatt-Ente per il diritto allo studio universitario dell'Università Cattolica, 2014

sifa.mod

Sifa MOD

Description

Dataset of cumulative paid claims for a medium italian company in the line of business: motor or damage.

Usage

sifa.mod

Format

Run-off triangle with 12 development periods.

References

Savelli, Nino, and Clemente, Gian Paolo. "Lezioni di matematica attuariale delle assicurazioni danni." EDUCatt-Ente per il diritto allo studio universitario dell'Università Cattolica, 2014

sifa.mtpl

Sifa MTPL

Description

Dataset of cumulative paid claims for a medium italian company in the line of business: motor third party liability.

Usage

sifa.mtpl

Format

Run-off triangle with 12 development periods.

References

Savelli, Nino, and Clemente, Gian Paolo. "Lezioni di matematica attuariale delle assicurazioni danni." EDUCatt-Ente per il diritto allo studio universitario dell'Università Cattolica, 2014

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