Package 'clmplus'

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Type Package

Title Tool-Box of Chain Ladder Plus Models

Version 1.0.1

Description Implementation of the age–period–cohort models for claim development presented in Pittarello G, Hiabu M, Villegas A (2025) "Replicating and Extending Chain-Ladder via an Age–Period–Cohort Structure on the Claim Development in a Run-Off Triangle" <doi:10.1080/10920277.2025.2496725>.

URL https://github.com/gpitt71/clmplus,
https://gpitt71.github.io/clmplus/

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

License GPL (>= 2)

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

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Contents

`AggregateDataPP` *Pre-process Run-Off Triangles*

Description

Pre-process Run-Off Triangles.

Usage

```
AggregateDataPP(
  cumulative.payments.triangle,
  entries.weights = NULL,
  eta = 1/2
)
```

Arguments

`cumulative.payments.triangle`	`triangle` `matrix` or `matrix` `array` object, input triangle of cumulative payments.
`entries.weights`	`triangle` `matrix` or `matrix` `array` model entries weights.
`eta`	`numeric`, individual claims exposure in the cell, also known as lost exposure. It must be in the interval (0,1].

Value

An object of class `AggregateDataPP`. Lists the following elements:

`cumulative.payments.triangle`
: `triangle matrix` object, input triangle of cumulative payments.

`occurrance`
: `matrix array` object, the occurrence derived from the input triangle.

`exposure`
: `matrix array` object, the exposure derived from the input triangle, under the `eta` claims arrival assumption.

`incremental.payments.triangle`
: `triangle matrix` object, incremental payments derived from the input.

`fit.w`
: `matrix array` object, the weights used during estimation.

`J`
: `integer`, Run-off triangle dimension.

`diagonal`
: `numeric`, cumulative payments last diagonal.

`eta`
: `numeric`, Expected time-to-event in the cell. I.e., lost exposure.

References

Pittarello, G., Hiabu, M., & Villegas, A. M. (2023). Replicating and extending chain-ladder via an age-period-cohort structure on the claim development in a run-off triangle. arXiv preprint arXiv:2301.03858.

Examples

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

---

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

clmplus *Fit Chain Ladder plus on Run-off Triangles.*

Description

Method to Estimate Chain Ladder plus models.

Usage

```
clmplus(
  AggregateDataPP,
  hazard.model = NULL,
  link = c("log", "logit"),
  staticAgeFun = TRUE,
  periodAgeFun = "NP",
  cohortAgeFun = NULL,
  effect_log_scale = TRUE,
 constFun = function(ax, bx, kt, b0x, gc, wxt, ages) list(ax = ax, bx = bx, kt = kt, b0x
    = b0x, gc = gc),
  ...
)
```

Arguments

`AggregateDataPP`
: `AggregateDataPP` object, reverse time triangle to be fitted.

`hazard.model`
: `character`, hazard model supported from our package. The model can be chosen from:
  - '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.

`link`
: `character`, 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`, indicates 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`
: `list`, 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` `character` or `function`, 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.

`effect_log_scale` `logical`, whether effects should be on the logarithmic scale. By default, `TRUE`.

`constFun` `function`, it defines the identifiability constraints of the model. It must be a function of the form `constFun <- function(ax, bx, kt, b0x, gc, wxt, ages)` taking a set of fitted model parameters and returning a list `list(ax = ax, bx = bx, kt = kt, b0x = b0x, gc = gc)` 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.

`...` parameters to be passed to clmplus.

Value

No return value, called to pass method `clmplus.AggregateDataPP`. See `clmplus.AggregateDataPP` documentation.

References

Pittarello, Gabriele, Munir Hiabu, and Andrés M. Villegas. "Replicating and extending chain ladder via an age-period-cohort structure on the claim development in a run-off triangle." arXiv preprint arXiv:2301.03858 (2023).

Examples

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

`clmplus.AggregateDataPP`

Fit Chain Ladder Plus to reverse time triangles.

Description

Method to fit Chain Ladder plus models to `AggregateDataPP` objects.

Usage

```
## S3 method for class 'AggregateDataPP'
clmplus(
  AggregateDataPP,
  hazard.model = NULL,
  link = c("log", "logit"),
  staticAgeFun = TRUE,
  periodAgeFun = "NP",
  cohortAgeFun = NULL,
  effect_log_scale = TRUE,
 constFun = function(ax, bx, kt, b0x, gc, wxt, ages) list(ax = ax, bx = bx, kt = kt, b0x
    = b0x, gc = gc),
  ...
)
```

Arguments

AggregateDataPP	AggregateDataPP object, reverse time triangle to be fitted.
hazard.model	character, hazard model supported from our package. The model can be chosen from: • '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.
link	character, 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, indicates 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	list, 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	character or function, 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.
effect_log_scale	logical, whether effects should be on the logarithmic scale. By default, TRUE.

constFun — function, it defines the identifiability constraints of the model. It must be a function of the form constFun <- function(ax, bx, kt, b0x, gc, wxt, ages) taking a set of fitted model parameters and returning a list list(ax = ax, bx = bx, kt = kt, b0x = b0x, gc = gc) 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.

... — parameters to be passed to clmplus.

Value

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

model.fit — fitStMoMo object, specified hazard model fit from StMoMo.

apc_input — list object. A list containing the following model inputs in age-period-cohort notation: J (integer) Run-off triangle dimension. eta (numeric) Expected time-to-event in the cell. I.e., lost exposure. diagonal (numeric) Cumulative payments last diagonal. hazard.model (character), hazard model specified from the user. Set to user.specific when a custom model is passed.

hazard_scaled_deviance_residuals — matrix array Triangle of the scaled deviance residuals.

fitted_development_factors — matrix array Triangle of the fitted development factors.

fitted_effects — list List of the development-accident-calendar effects fitted.

References

Pittarello, Gabriele, Munir Hiabu, and Andrés M. Villegas. "Replicating and extending chain ladder via an age-period-cohort structure on the claim development in a run-off triangle." arXiv preprint arXiv:2301.03858 (2023).

Examples

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

---

clmplus.default *Fit Chain Ladder Plus to reverse time triangles.*

Description

Default method to fit Chain Ladder plus models.

Usage

```
## Default S3 method:
clmplus(
  AggregateDataPP,
  hazard.model = NULL,
  link = c("log", "logit"),
  staticAgeFun = TRUE,
  periodAgeFun = "NP",
  cohortAgeFun = NULL,
  effect_log_scale = TRUE,
 constFun = function(ax, bx, kt, b0x, gc, wxt, ages) list(ax = ax, bx = bx, kt = kt, b0x
    = b0x, gc = gc),
  ...
)
```

Arguments

AggregateDataPP	AggregateDataPP object, reverse time triangle to be fitted.
hazard.model	character, hazard model supported from our package. The model can be chosen from: • '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.
link	character, 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, indicates 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	list, 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	character or function, 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.
effect_log_scale	logical, whether effects should be on the logarithmic scale. By default, TRUE.

constFun	function, it defines the identifiability constraints of the model. It must be a function of the form constFun <- function(ax, bx, kt, b0x, gc, wxt, ages) taking a set of fitted model parameters and returning a list list(ax = ax, bx = bx, kt = kt, b0x = b0x, gc = gc) 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.
...	parameters to be passed to clmplus.

Value

No return value, called to pass method clmplus.AggregateDataPP. See clmplus.AggregateDataPP documentation.

References

Pittarello, Gabriele, Munir Hiabu, and Andrés M. Villegas. "Replicating and extending chain ladder via an age-period-cohort structure on the claim development in a run-off triangle." arXiv preprint arXiv:2301.03858 (2023).

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

---

plot.AggregateDataPP *Plot the payments behavior*

Description

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

Usage

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

Arguments

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

Value

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

References

Pittarello, Gabriele, Munir Hiabu, and Andrés M. Villegas. "Replicating and extending chain ladder via an age-period-cohort structure on the claim development in a run-off triangle." arXiv preprint arXiv:2301.03858 (2023).

Examples

```
data(sifa.mtpl)
sifa.mtpl.pp <- AggregateDataPP(cumulative.payments.triangle=sifa.mtpl)
plot(sifa.mtpl.pp)
```

`plot.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'
plot(x, heat.lim = c(-2.5, 2.5), ...)
```

Arguments

`x`	`clmplusmodel` object, model fit to plot.
`heat.lim`	limits in the residuals plot.
`...`	Extra arguments to be passed to the plot function.

Value

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

References

Pittarello, Gabriele, Munir Hiabu, and Andrés M. Villegas. "Replicating and extending chain ladder via an age-period-cohort structure on the claim development in a run-off triangle." arXiv preprint arXiv:2301.03858 (2023).

Examples

```
data(sifa.mtpl)
sifa.mtpl.rtt <- AggregateDataPP(cumulative.payments.triangle=sifa.mtpl)
clm.fit<-clmplus(sifa.mtpl.rtt, 'a')
plot(clm.fit)
```

`plot.clmpluspredictions` *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 'clmpluspredictions'
plot(x, cy.type = "fe", ...)
```

Arguments

`x`	`clmpluspredictions`, Model effects (fitted and extrapolated) to be plotted.
`cy.type`	`character`, 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

Pittarello, G., Hiabu, M., & Villegas, A. M. (2023). Replicating and extending chain-ladder via an age-period-cohort structure on the claim development in a run-off triangle. arXiv preprint arXiv:2301.03858.

Examples

```
data(sifa.mtpl)
sifa.mtpl.rtt <- AggregateDataPP(cumulative.payments.triangle=sifa.mtpl)
clm.fit<-clmplus(sifa.mtpl.rtt, 'a')
clm <- predict(clm.fit)
plot(clm)
```

predict.clmplusmodel *Predict the Reserve using Chain Ladder Plus Models*

Description

Predict the lower triangle with a clmplus model.

Usage

```
## S3 method for class 'clmplusmodel'
predict(
  object,
  gk.fc.model = "a",
  ckj.fc.model = "a",
  gk.order = c(1, 1, 0),
  ckj.order = c(0, 1, 0),
  forecasting_horizon = NULL,
  ...
)
```

Arguments

object	clmplusmodel, Model to predict from.
gk.fc.model	character, 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	character, 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	integer, order of the arima model with drift for the accident year effect extrapolation. Default to (1,1,0).
ckj.order	integer, order of the arima model with drift for the calendar year effect extrapolation. Default to (0,1,0).
forecasting_horizon	integer, between 1 and the triangle width. Calendar periods ahead for the predictions. Default predictions are to run-off.
...	Extra arguments to be passed to the predict function.

Value

Returns the following output:

reserve	numeric The reserve for each accident period.
ultimate_cost	numeric The ultimate cost for each accident period.

`full_triangle` `matrix array` The complete run-off triangle of cumulative payments, it includes the (input) upper triangle and the predicted (output) lower triangle.

`lower_triangle` `matrix array` The predicted lower triangle of cumulative payments.

`development_factors_predicted` `matrix array` The predicted lower triangle of the extrapolated development factors.

`apc_output` `list` The following output from the age-period-cohort representation: `model.fit` (`fitStMoMo`) age-period-cohort model fit. `alphaij` (`matrix array`) predicted claim development. `lower_triangle_apc` (`matrix array`) predicted lower triangle of cumulative payments in age-period-cohort form. `development_factors_apc` (`matrix array`) development factors in age-period-cohort representation.

References

Pittarello, Gabriele, Munir Hiabu, and Andrés M. Villegas. "Replicating and extending chain ladder via an age-period-cohort structure on the claim development in a run-off triangle." arXiv preprint arXiv:2301.03858 (2023).

`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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