Package 'ProfileLadder'

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Type Package

Title Functional Profile Chain Ladder for Claims Reserving

Version 0.1.2

Description Functional claims reserving methods based on aggregated chain-
ladder data, also known as the run-off triangle (functional) development profiles, imple-
mented in three nonparametric algorithms (PARALLAX, REACT, and MACRAME) pro-
posed in Maciak, Mizera, and Pešta (2022) <doi:10.1017/asb.2022.4>.

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Repository CRAN

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Contents

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as.profileLadder   *S3 Method class* profileLadder

Description

A function to make the work with the functional development profiles within run-off triangles more easy and straightforward (particularly when vizualizing the functional profiles in a plot)

Usage

```
as.profileLadder(x)
```

Arguments

x   an object of the class matrix or triangle

Value

an object of the class profileLadder which is a list with the following elements:

reserve	basic summary of the run-off triangle and the true/estimated reserve (if it is available otherwise NA values are provided instead)
method	type of the printed triangle (either a run-off triangle itself if no estimation method is applied or the completed triangle where the missing fragments are imputed by one of the algorithm, PARALLAX, REACT, or MACRAME)
completed	completed development profiles estimated by using one of the estimation algorithm (i.e., PARALLAX, REACT, or MACRAME)—if applied—value NA provided otherwise
inputTriangle	standard (triangular shaped) run-off triangle
trueComplete	true completed development profiles of the run-off triangle (if available) or NA returned otherwise

See Also

parallelReserve(), mcReserve(), permuteReserve(), plot.profileLadder()

Examples

```
data(CameronMutual)
print(CameronMutual)

x <- as.profileLadder(CameronMutual)

print(x)
plot(x)
```

CameronMutual   *Cameron Mutual Insurance Company data*

Description

An illustrative dataset—a matrix (of the dimensions 10x10) with ten completed years of claims payment developments of the Cameron Mutual Insurance company from the period 1988 – 1997. The data matrix contains ten origin/occurrence years (in rows where the first row represents the incident year 1988) with ten consecutive development periods/years (in columns).

Usage

```
data(CameronMutual)
```

Format

CameronMutual:

A simple `10x10` matrix of a class `triangle` with ten origin years (rows) each being fully developed within ten consecutive development periods/years (columns)

origin matrix rows with the occurrence year (origin)

dev matrix columns with the development period (development)

Details

The run-off triangle (the upper-left triangular part of the data matrix) contains only positive increments making the triangle suitable for the standard modelling approach—the over-dispersed Poisson model (GLM regression model).

In practice, the upper-left triangle (the run-off triangle) is typically observed (known) while the bottom-right triangular part of the data matrix is treated as a future payments outcome (an "unknown" truth) that should be estimated/predicted. The Cameron Mutual Insurance data matrix is fully observed to allow for some goodness-of-fit evaluations.

Source

https://www.casact.org/publications-research/research/research-resources
(PP Auto Data Set, NAIC group code: 5320)

References

Meyers, G. G. and P. Shi (2011). Loss reserving data pulled from NAIC Schedule P. Available from
https://www.casact.org/publications-research/research/research-resources

Maciak, M., Mizera, I., and Pešta, M. (2022). Functional Profile Techniques for Claims Reserving.
ASTIN Bulletin, 52(2), 449-482. DOI:10.1017/asb.2022.4 (Portfolio #1)

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covid19CZ	*First cases of Covid-19 in the Czech Republic*

Description

An illustrative dataset—a matrix (of the dimensions 4x8) with the cumulative counts of the first
reported cases of the Covid-19 pandemic in the Czech Republic. Four cohorts are defined by the
Czech counties where the first reported case occurred during the period March 1st – 7th, 2020
(e.g., Prague, Vsetín, or Děčín), March 8th – March 14th (e.g, Brno, České Budějovice, Kladno,
Mladá Boleslav, Plzeň), March 15th – March 21st (e.g., Chomutov, Český Krumlov, Písek, Tábor),
and, finally, during the week in March 22nd – March 28th, 2020 (e.g., Jindřichův Hradec, Klatovy,
Teplice).

Usage

```
data(covid19CZ)
```

Format

covid19CZ:

A simple 4x8 matrix of a class `triangle` with four cohorts (rows) consecutively observed for
8 weeks (starting in March 1st 2020 with the first case in the first cohort (first row) reported in
March 1st)

Details

The cumulative reported cases are provided in the table for 8 consecutive development periods
(where the periods represent seven consecutive days) starting in March 1st, 2020.

Source

Institute of Health Information and Statistics of the Czech Republic https://www.uzis.cz:443/

GFCIB *Guarantee Fund of the Czech Insurers' Bureau data*

Description

Illustrative datasets provided by the Guarantee Fund of the Czech Insurers' Bureau (GFCIB) for the mandatory car insurance in the Czech Republic. The quarterly based payments are aggregated in four run-off triangles with the paid amounts for four separate lines of business: bodily injury, material damage, technical provision, and annuities.

Usage

```
data(GFCIB)
```

Format

GFCIB:

Four data matrices of the dimensions 60x60 of a class `triangle` with 15 origin years (provided on a quarterly basis in individual rows) and 60 development periods/quartals (columns)

origin matrix rows with the occurrence quartal (origin)

dev matrix columns with the development period (development)

Details

The data are structured in the the list object GCCIB with four elements—one for each line of business: \\$bodilyInjury, \\$materialDamage, \\$provisions, and \\$annuity. The run-off triangles are all aggregated over the period from the first quartal of 2008 (Q1) till the last quartal of 2022 (Q4).

Source

The Czech Insurers' Bureau https://www.ckp.cz

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incrExplor *Exploratory function for run-off triange increments*

Description

The function takes a cumulative or incremental run-off triangle (partially or completely observed) and provides some basic exploratory and graphical inspection of the observed incremental payments. The function serves as a useful tool for a user-based insight when manualy defining the states of the Markov Chain that is used to drive the reserve prediction in the MACRAME algorithm implemented in the function mcReserve().

Usage

```
incrExplor(
  triangle,
  method = c("median", "mean", "max", "min"),
  out = 1,
  states = NULL,
  breaks = NULL,
  plotOption = FALSE,
  plotScale = 1
)
```

Arguments

triangle	cumulative or incremental run-off triangle (an object of the class `triangle` or `matrix`) specified in terms of a partially observed (run-off triangle) or a fully observed (completed triangle) matrix. Only the upper-left triangular part (run-off trangle) is used to provide the output analysis of the incremental payments and the underlying Markov chain setting options
method	method form `c("median", "mean", "max", "min")` used to summarize the run-off triangle increments within the given set of bins. Each bin with the increments is represented by a corresponding Markov state value (obtained by the `method` choice with `median` being the DEFAULT option)
out	integer value (or a vector of integers) to indicate which columns of the run-off triangle should be excluded from the exploratory analysis of the increments. By DEFAULT, the first incremental payments—i.e., the first column of the run-off triangle—are not considered (`out = 1`). No colums are exluded for `out = 0` and the whole run-off triangle is analyzed by `incrExplor()`. To specify multiple columns that should be excluded, one can use `out = c(1,2,3)` which will exlude the first three columns from the exploratory analysis
states	either an integer value to indicate an explicit number of the Markov chain states to be used or a vector of explicit Markov chain states can be provided. The DEFAULT option (`states = NULL`) provides a fully data-driven (automatic) definition of the Markov chain states as proposed in Maciak, Mizera, and Pešta (2022)
breaks	numeric vector of explicit (unique and monotonously increasing) break points to define the bins for the run-off triangle increments. If `states` is equal to some integer number (i.e., the explicit number of the Markov chain states is requested by `states`) then the value of `breaks` is ignored. If both `states` and `breaks` are specified (i.e., numeric vectors are provided for both) then the set of states in `states` must be given in a way that exactly one state value belongs to exactly one bin defined by the break points specified by `breaks`
plotOption	logical to indicate whether a graphical output supplementing the empirical exploratory should be provided (`TRUE`) or not (`FALSE` – DEFAULT)
plotScale	positive scaling factor for adjusting the overall graphical output (the DEFAULT value is `plotScale = 1`)

Value

A list with the following elements:

incrTriangle	an object of the class `triangle` with the incremental run-off triangle
triangleType	type of the input run-off triangle provided for the input object `triangle` (cumulative or incremental)
defaultStates	the set of explicit states as used (by DEFAULT) by the `mcReserve()` estimation algorithm
defaultBreaks	the set of explicit breaks as used (by DEFAULT) by the `mcReserve()` estimation algorithm
increments	table with basic empirical characteristics of the increments of the input run-off triangle (without the first origin payments—the values in the first column of the run-off triangle). Two sets of increments are provided: the raw incremental payments in the first row of the table and the standardized increments (i.e., row incremental payments divided by the maximum payment within the row (while not considering the columns specified by the out parameter)
userDefined	a list with all information regarding the USER modified input (numeric vector `increments` with the increments being analyzed; numeric value in `outColumns` denoting the excluded columns in the run-off triangle; `method` used to summarize the increments within the bins; numeric vector with the resulting Markov chain states in `states` and the corresponding numeric vector with the break points in `breaks` defining the bins for the run-off triangle increments)

References

Maciak, M., Mizera, I., and Pešta, M. (2022). Functional Profile Techniques for Claims Reserving. ASTIN Bulletin, 52(2), 449-482. DOI:10.1017/asb.2022.4

See Also

`mcReserve()`, `permuteReserve()`

Examples

```
data(CameronMutual)

## default Markov Chain states with (roughly) equally occupied bins
incrExplor(CameronMutual)

## five Markov Chain states (with roughly equally occupied bins)
incrExplor(CameronMutual, states = 5)

## explicitly defined breaks for five increment bins while the Markov states
## are obtained as medians of the increments within each bin
incrExplor(CameronMutual, breaks = c(20, 500, 1000, 2000))

## explicitly defined breaks for five bins and the Markov states
## are given as the maximum increments within each bin
incrExplor(CameronMutual, breaks = c(20, 500, 1000, 2000), method = "max")
```

```
## manually defined breaks for the bins and the corresponding states
## exactly one state must be within each break
incrExplor(CameronMutual, breaks = c(20, 500, 1000),
                          states = c(10, 250, 800, 1500))
```

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mcReserve   *MACRAME based development profile reserve*

Description

The function takes a cumulative (or incremental) run-off triangle (partially or completely observed) and returns the reserve estimate obtained by the MACRAME algorithm (see Maciak, Mizera, and Pešta (2022) for further details).

Usage

```
mcReserve(
  chainLadder,
  cum = TRUE,
  residuals = FALSE,
  states = NULL,
  breaks = NULL,
  MC = FALSE
)
```

Arguments

chainLadder	a cumulative or incremental run-off triangle (the triangle must be of the class `triangle` or `matrix`) in terms of a square matrix with a fully observed upper-left triangular part. If the lower-right part is also provided the function will also return standard residuals but only the upper-left (run-off) triangle is be used for the reserve estimation purposes
cum	logical to indicate the time of the input triangle provided (DEFAULT value is `TRUE` for the cumulative triangle, `FALSE` if `chainLadder` is of the incremental type)
residuals	logical to indicate whether (incremental) residuals should be provided in output or not. If the run-off triangle is completely observed then the residuals are obtained in terms of the true increments minus the predicted ones. If the bottom-right triangle is not provided (`NA` values) then the residuals are obtained in terms of a back-fitting approach (see Maciak, Mizera, and Pešta (2022) for further details). However, the back-fitted residuals are only calculated when no user specification of the states (in `states`) and breaks (in `breaks`) is provided

states	numeric value to provide either the number of the Markov states to be used or it can provide an explicit set of the states to be used. The default setting (states = NULL) provides the set of states in a fully data-driven manner as proposed in Maciak, Mizera, and Pešta (2022) while any choice of breaks is ignored. If the number of states is specified by states, the states are obtained analogously as in Maciak, Mizera, and Pešta (2022), however, the number of actual states for the estimation is adjusted and the parameter breaks is again ignored
	If parameter states provides an explicit vector of Markov chain states (the smallest state should be larger than the smallest observed increment in the run-off triangle and, similarly, the largest state should be smaller than the largest observed increment) then the corresponding bins (breaks) for the run-off triangle increments are defined automatically by the midpoints between the provided states (with breaks being set to NULL DEFAULT)
breaks	vector parameter which provides explicit (unique and monotonly increasing) break points (disjoint bins) for the run-off triangle incremenets. Each bin should be represented by the corresponding Markov chain state—either the values given in states or provided automatically if states is not a valid vector of the Markov states. If the breaks are provided as breaks = c(-Inf, ... , Inf) defining k bins all together then states should be a vector of the same length k. Alternatively, the breaks can be also specified by a set of finite numbers defining again k bins—in such cases, the parameter states should be of the length length(states) = k + 1. Each value in states should represent one bin defined by breaks
MC	logical (by DEFAULT set to FALSE) to indicate whether some backgrpound information about the underlying Markov chain process (e.g., Markov chain states or the estimated transition probability matrix) should be printed in the output or not

Value

An object of the type list with with the following elements:

reserve	numeric vector with four values: Total paid amount (i.e., the sum of the last observed diagonal in a cumulative run-off triangle); Total estimated amount (i.e., the sum of the last column in the completed cumulative triangle); Estimated reserve (i.e., the sum of the last column in the completed cumulative triangle minus the sum of the last observed diagonal in chainLadder); True reserve if a completed chainLadder is provided in the output (i.e., the sum of the last column in chainLadder minus the sum of the last diagonal in chainLadder)
method	algorithm used for the reserve estimation
fullTriangle	completed run-off triangle (the upper-left triangular part is identical with the input triangle in chainLadder and the lower-right trianglular part is completed by the MACRAME algorithm
inputTriangle	the input run-off triangle provided in chainLadder
trueCompleted	true completed triangle (if available) where the upper-left part is used by the MACRAME algorithm to estimate the reserve and the lower-right part is provided for some evaluation purposes. If the full triangle is not available NA is returned instead

residuals	a triangle with the corresponding residuals (for `residuals` = TRUE). The residuals are either provided in the upper-left triangle (so-called back-fitted incremental residuals if true completed triangle is not available) or the residuals are given in the lower-right triangle (i,e., standard incremental residuals—if the true completed triangle is given)

References

Maciak, M., Mizera, I., and Pešta, M. (2022). Functional Profile Techniques for Claims Reserving. ASTIN Bulletin, 52(2), 449-482. DOI:10.1017/asb.2022.4

See Also

[incrExplor()](), [permuteReserve()]()

Examples

```
## run-off (upper-left) triangle with NA values
if (requireNamespace("ChainLadder")) {
data(MW2014, package = "ChainLadder")
print(MW2014)

## MACRAME prediction  with (DEFAULT) Markov chain setting
## provided in the output
mcReserve(MW2014, residuals = TRUE, MC = TRUE)}

## completed run-off triangle with 'unknown' truth (lower-bottom run-off triangle)
## with incremental residuals (true increments minus predicted ones) being provided
data(CameronMutual)
mcReserve(CameronMutual, residuals = TRUE)

## the same output in terms of the reserve estimate but back-fitted residuals
## are provided instead (as the run-off triangle is provided only)
data(observed(CameronMutual))
mcReserve(observed(CameronMutual), residuals = TRUE)
```

MidwestMutual	*Midwest Family Mutual Insurance Company data*

Description

An illustrative dataset—a matrix (of the dimensions 10x10) with ten completed years of claims payment developments of the Midwest Family Mutual Insurance company from the period 1988 – 1997. The data matrix contains ten origin/occurrence years (with the first row representing the incident year 1988) and ten consecutive development periods/years (in columns).

Usage

```
data(MidwestMutual)
```

Format

MidwestMutual:

A simple `10x10` matrix of a class `triangle` with ten origin years (rows) each being fully developed within ten consecutive development periods/years (columns)

origin matrix rows with the occurrence year (origin)

dev matrix columns with the development period (development)

Details

The run-off triangle (the upper-left triangular part of the data matrix) contains only positive increments making the triangle suitable for the standard modelling approach—the over-dispersed Poisson model (GLM approach).

In practice, the run-off triangle only (the upper triangular part) of the data matrix is known while the bottom-right triangular part is treated as a future outcome (an "unknown" truth) that should be estimated/predicted. The Midwest Family Mutual Insurance data matrix is fully observed to allow for some retrospective goodness-of-fit evaluations.

Source

https://www.casact.org/publications-research/research/research-resources
(Other Liability Data Set, NAIC group code: 23574)

References

Meyers, G. G. and P. Shi (2011). Loss reserving data pulled from NAIC Schedule P. Available from https://www.casact.org/publications-research/research/research-resources

Maciak, M., Mizera, I., and Pešta, M. (2022). Functional Profile Techniques for Claims Reserving. ASTIN Bulletin, 52(2), 449-482. DOI:10.1017/asb.2022.4 (Portfolio #2)

NevadaGeneral	*Nevada General Insurance Company data*

Description

An illustrative dataset—a matrix (of the dimensions 10x10) with ten completed years of claims payment developments of the Nevada General Insurance company from the period 1988 – 1997. However, the data matrix only contains four non-zero origin/occurrence years (from the period 1994 – 1997) all being fully developed for ten consecutive development periods/years (in columns). The remaining matrix rows are all zeros. The resulting run-off triangle (the upper-left triangular part of the data matrix) is, therefore, sparse and very uninformative.

Usage

```
data(NevadaGeneral)
```

Format

NevadaGeneral:

A simple `10x10` matrix of a class `triangle` with ten origin years (rows) each being fully developed within ten consecutive development periods (columns). However, only for development profiles are nonzero and standard (parametric) reserving techniques (e.g. the ODP model) are not applicable

origin matrix rows with the occurrence year (origin)

dev matrix columns with the development period (development)

Details

In practice, the reserve for such sparse run-off triangles is not estimated by any stochastic model but, instead, an expert judgement is used to declare the reserve. Nevertheless, the nonparametric estimation performed by PARALLAX, REACT, or MACRAME can still provide resonable reserve estimates

Source

https://www.casact.org/publications-research/research/research-resources
(PP Auto Data Set, NAIC group code: 10007)

References

Meyers, G. G. and P. Shi (2011). Loss reserving data pulled from NAIC Schedule P. Available from
https://www.casact.org/publications-research/research/research-resources

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observed   *Observed run-off triangle layout vs. predicted (unknown) layout*

Description

Simple layout function to make work with (cumulative or incremental) run-off triangles more easy and straightforward.

Usage

```
observed(object, cum = TRUE)
```

Arguments

object   either an integer value to denote the dimension of the run-off triangle layout (i.e.,
                   the value that represents the number of origins (rows) and also the number of
                   the development periods (columns)). Alternatively, a cumulatige or incremental
                   run-off triangle (i.e, an object of the class `matrix` or `triangle`) can be provided
                   in `object`. In such case the output returns the standard run-off triangle with
                   NA values in the lower-right triangular part of the matrix (regardless of wheter
                   the input triangle in `object` forms a run-off triangle or it is a fully observed
                   triangle—data matrix)

cum logical to indicate whether the output run-off triangle is supposed to be of a cumulative type (DEFAULT) or an incremental type (cum = FALSE). If the input in object is an integer value (i.e., the dimension of the run-off triangle) then the choice of the cum parameter is ignored

Value

If object is an integer value then the function returns a TRUE/FALSE layout matrix with the TRUE values for the observed (known) part of the run-off triangle (the upper-left triangular part of the matrix) and values FALSE otherwise. If object is a matrix (an object of the class matrix or triangle) then the function returns the observed (known) part of the run-off triangle with NA values elsewhere. Depending on the choice of the cum parameter, either a cumulative (DEFAULT) or incremental (cum = FALSE) run-off triangle is returned

See Also

[plot.profileLadder()](), [parallelReserve()](), [mcReserve()]()

Examples

```
print(observed(5))
print(!observed(5))

data(CameronMutual)
observed(CameronMutual)
observed(CameronMutual, cum = FALSE)
```

---

parallelReserve   *Parallel based development profile reserve*

Description

The function takes a cumulative (or incremental) run-off triangle (partially or completely observed) and returns the reserve estimate obtained by the PARALLAX or REACT algorithm (see Maciak, Mizera, and Pešta (2022) for more details). If the full square is provided as the input then the algorithms still rely only on the partially observed data—run-off triangle only (i.e., the top-left triangular part of the data)—when estimating the underlying reserve but, in addition, incremental residuals (true increments minus predicted increments) are returned for retrospective validation purposes. If the run-off triangle is provided,then algorithm caclulates back-fitted (incremental) residuals instead (see Maciak, Mizera, and Pešta (2022) for details).

Usage

```
parallelReserve(
  chainLadder,
  method = "parallax",
  cum = TRUE,
  residuals = FALSE
)
```

Arguments

chainLadder	cumulative or incremental run-off triangle (the triangle must be of the class triangle or matrix) in terms of a square matrix (i.e., a fully observed run-off triangle) or a standard run-off triangle instead (i.e, the top-left triangular part of the matrix
method	prediction method to be used: PARALLAX (DEFAULT method = "parallax") or REACT (method = "react")
cum	logical (TRUE for a cumulative triangle and FALSE for an incremental triangle)
residuals	logical to indicate whether incremental residuals should be provided or not. If the run-off triangle is complete then the residuals are obtained in terms of true increments minus the predicted increments. If the bottom-right part of the triangle is not available the residuals are provided in terms of the backfitting approach (see Maciak, Mizera, and Pesta (2022) for further details)

Value

An object of the class list with with the following elements:

reserve	numeric vector with four values summarizing the reserve: Total paid amount (i.e., the sum of the last observed diagonal in a cumulative run-off triangle); Total estimated amount (i.e., the sum of the last column in the completed cumulative triangle); Estimated reserve (i.e., the sum of the last column in the completed cumulative triangle minus the sum of the last observed diagonal in chainLadder); True reserve—if the completed (true) chainLadder is provided in the input (i.e., the sum of the last column in chainLadder minus the sum of the last diagonal in chainLadder)
method	algorithm used for the reserve estimation (PARALLAX or REACT)
completed	completed functional development profiles (the lower-right triangular part in completed) estimated by the PARALLAX algorithm or the REACT algorithm
inputTriangle	the run-off triangle considered as the input for the underlying estimation algorithm (PARALLAX or REACT)
trueCompleted	true (complete) run-off triangle (if available) and NA value provided otherwise
residuals	a triangle with the corresponding residuals (for residuals = TRUE). The residuals are either provided in the upper-left triangle (so-called back-fitted incremental residuals if true completed triangle is not available) or the residuals are given in the lower-right triangle (i,e., standard incremental residuals—if the true completed triangle is given)

References

Maciak, M., Mizera, I., and Pešta, M. (2022). Functional Profile Techniques for Claims Reserving. ASTIN Bulletin, 52(2), 449-482. DOI:10.1017/asb.2022.4

See Also

[permuteReserve()](), [mcReserve()]()

Examples

```
## run-off (upper-left) triangle with NA values (bottom-right part)
if (requireNamespace("ChainLadder")) {
data(MW2014, package = "ChainLadder")
print(MW2014)
parallelReserve(MW2014, residuals = TRUE)}

## completed run-off triangle with 'unknown' truth (lower-bottom part)
## for the estimation purposes only the upper-left triangle is used
data(CameronMutual)
parallelReserve(CameronMutual, residuals = TRUE)

## the previous output is identical (in term of the reserve prediction)
## but back-fitted residuals are provided in the output instead
print(observed(CameronMutual))
parallelReserve(observed(CameronMutual), residuals = TRUE)
```

| permuteReserve | *Permutation bootstrap reserve (PARALLAX, REACT, MACRAME)* |

Description

The function takes the output from the function parallelReserve() or mcReserve and estimates the overall reserve distribution in terms of the permutation bootstrap approach proposed in Maciak, Mizera, and Pešta (2022).

Usage

```
permuteReserve(object, B = 500, std = TRUE, quantile = 0.995)
```

Arguments

object	an object of the class profileLadder (output from parallelReserve() or mcReserve() respectively)
B	number of permutations to be performed (DEFAULT B = 500)
std	logical to indicate whether the run-off triangle should be standardized by the first column increments (DEFAULT) or not (std = FALSE). For more details about the triangle standardization, see Maciak, Mizera, and Pešta (2022)
quantile	quantile level for the BootVar. characteristic of the bootstrapped distribution (the DEFAULT choice quantile = 0.995 is explicitly required by the Solvency II principle used by actuaries in practice)

Value

An object of the class permutedReserve which is a list with the following elements:

eSummary   numeric vector with four values summarizing the estimated reserve: Paid amount
                (i.e., the sum of the last observed diagonal in the given cumulative run-off tri-
                angle); Estimated ultimate (i.e., the sum of the last column in the completed
                cumulative triangle); Estimated reserve (i.e., the sum of the last column in the
                completed cumulative triangle minus the sum of the last observed diagonal);
                True reserve if a completed (true) run-off triangle is available

pSummary   numeric vector with four values summarizing the overall reserve distribution:
                Boot.Mean gives the verage of B permutation bootstrap reserves; Std.Er. pro-
                vides the corresponding standard error of B permutation bootstrap reserves; The
                value of BootCov% stands for a percentage proportion between the standard er-
                ror and the average; Finally, BootVar.995 provides the estimated 0.995 quantile
                (by DEFAULT) of the boostrap reserve distribution (for quantile = 0.995 and,
                otherwise, it is modified acordingly) given relatively with respect to the permu-
                tation bootstrapped mean reserve

pReserves   a numeric vector of the length B with the estimated (permuted) reserves for each
                row-permuted run-off triangle in B independent Monte Carlo simulation runs

pUltimates   A matrix of the dimensions B x n (where n stands for the number of the ori-
                gin/development periods) with B simulated ultimate payments – the last column
                in the completed run-off triangle

pLatest   A matrix of the dimensions B x n (where n again stands for the number of the
                origin/development periods) with B simulated diagonals

trueComplete   The true complete run-off triangle (if available) and NA value otherwise

info   a numeric vector summarizing the bootstrap compuational efficiency: In partic-
                ular, the OS/Architecture type, the number of permutations (B), the input run-off
                triangle dimension (n) and the computation time needed for the permutation
                bootstrap calculations

References

Maciak, M., Mizera, I., and Pešta, M. (2022). Functional Profile Techniques for Claims Reserving.
ASTIN Bulletin, 52(2), 449-482. DOI:10.1017/asb.2022.4

European Parliament and Council (2009). Directive 2009/138/EC of the European Parliament and
of the Council of 25 November 2009 on the taking-up and pursuit of the business of Insurance and
Reinsurance (Solvency II). Official Journal of the European Union, 1–155.
<https://data.europa.eu/eli/dir/2009/138/oj>

See Also

[parallelReserve()](), [mcReserve()](), [plot.permutedReserve()]()

Examples

```
## REACT algorithm and the permutation bootstrap reserve
data(CameronMutual)
```

```
output <- parallelReserve(CameronMutual, method = "react")
permuteReserve(output, B = 100)

## MACRAME algorithm with a pre-specified number of states
output <- mcReserve(CameronMutual, states = 5)
permuteReserve(output, B = 100)
```

---

plot.permutedReserve   *Plotting the output of the permutation bootstrap*

Description

The function provides a graphical visualization of the results obtained from the permutation bootstrap (see Maciak, Mizera, and Pesta (2022) for further details) applied to the output of one of the nonparametric functional based estimation algorithm—PARALLAX or REACT implemented in the `parallelReserve()` function or MACRAME implemented in the `mcReserve()` function.

Usage

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

Arguments

x	an object of the class `permutedReserve` – i.e., the output of the `permuteReserve()` function
...	other graphical parameters to plot

Value

The function returns a layout for four plots. The first panel shows a simple barplot type visualization of the estimated reserve, the estimated ultimate and the true reserve (if available). The second panel provides a histogram for (permuted) bootstrapped reserves with a nonparametric estimate of the corresponding density. The third panel provides a detailed inspection of the bootstrapped ultimates (with true ultimates if provided) and, finaly, the last panel shows the observed diagonal vs. simulated ones.

See Also

permuteReserve()

Examples

```
## reserve estimated by MACRAME and the corresponding visualization
x <- mcReserve(CameronMutual)
plot(permuteReserve(x, B = 100))
```

---

plot.profileLadder   *Plotting development profiles*

Description

The function provides a graphical representation of the completed functional profiles estimated by the PARALLAX, REACT, or MACRAME algorithm (see Maciak, Mizera, and Pesta (2022) for further details). The function takes an object of the class `profileLadder` which is the output of the `parallelReserve()` function or the `mcReserve()` function. Alternatively, the function can be also applied to visualise the run-off triangle itself—if the triangle is of the class `profileLadder`.

Usage

```
## S3 method for class 'profileLadder'
plot(x, xlab = "Development Year", ylab = "Cumulative Claims", main = "", ...)
```

Arguments

x	an object of the class `profileLadder` (output form `parallelReserve()`, `mcReserve()`, or `as.profileLadder()`
xlab	label for the x axis
ylab	label for the y axis
main	title of the plot
...	other graphical parameters to plot

Value

A graph with the observed functional development profiles from the input run-off triangle, the estimated/predicted functional segments (i.e., functional profile completion provided by the corresponding estimation method—PARALLAX, REACT, or MACRAME) the and the true future profiles (if these are available)

See Also

as.profileLadder(), parallelReserve(), mcReserve()

Examples

```
## completed run-off triangle with the 'unknown' (future) payments
print(triangle <- GFCIB$bodilyInjury[1:15, 1:15])
plot(mcReserve(triangle))

## completed run-off triangle with unknown future
print(observed(triangle))
plot(mcReserve(observed(triangle)))

## the run-off triangle with future payments without MACRAME completion
```

```
plot(as.profileLadder(triangle))
```

---

print.permutedReserve *Print objects of the S3 class* permutedReserve

---

Description

Function to organize and print the output provided by the permutation bootstrap method implemented in the function permuteReserve()

Usage

```
## S3 method for class 'permutedReserve'
print(x, ...)
```

Arguments

x   an object of the class permutedReserve resulting from a call of the functions
                permuteReserve()

...   further arguments passed to print

Value

Displays information about the estimated reserve (by one of the estimation algorithms – PARALLAX, REACT, or MACRAME) and the overall reserve distribution resulting from a call of the permuteReserve() function

See Also

permuteReserve()

Examples

```
## reserve point prediction by the PARALLAX method
output <- parallelReserve(CameronMutual)

## reserve distribution prediction by the permutation bootstrap
x <- permuteReserve(output, B = 100)

## summary of the results
print(x)
```

---

print.profileLadder   *Print objects of the S3 class* profileLadder

---

Description

Function to organize and print the outputs provided by the function parallelReserve() and the function mcReserve

Usage

```
## S3 method for class 'profileLadder'
print(x, ...)
```

Arguments

x	an object of the class profileLadder resulting from a call of one of the functions parallelReserve(), mcReserve, or as.profileLadder()
...	further arguments passed to print

Value

displays information resulting from a call of the parallelReserve() function or the mcReserve function

See Also

[as.profileLadder()](), [parallelReserve()](), [mcReserve()]()

Examples

```
data(CameronMutual)
x <- as.profileLadder(CameronMutual)
print(x)
```

---

summary.profileLadder   *Summary method for an object of the S3 class method* profileLadder

---

Description

The function provides an overall summary of the output from the functions parallelReserve() and mcReserve() (summary of the object of the class profileLadder)

Usage

```
## S3 method for class 'profileLadder'
summary(object, plotOption = FALSE, ...)
```

Arguments

`object`	an object of the class `profileLadder` – i.e., either a run-off triangle itself or the output form the `parallelReserve()` or `mcReserve()` functions
`plotOption`	logical to indicate whether a graphical output should be also provided (set by DEFAULT to `FALSE`). If the incremental residuals (standard or back-fitted) are provided within the object x the plot provides a summary of the residuals (otherwise a simple barplot summarizing the estimated reserve is given)
`...`	not used

Value

Summary of the completed functional profiles and the estimated reserve (provided by the function `parallelReserve()` or `mcReserve()`). Summary of the incremental residuals (standard or back-fitted) is also provided if the residuals are available. The output is a list with the following items:

`origins`	a matrix with the row-specific summary of the completed functional profiles (except the first fully developed profile—i.e., the first row in the run-off triangle). The first column of the matrix (`First`) gives the first origin payments; The second column (`Latest`) gives the last available (cumulative) payments (i.e., values from the last running diagonal in the run-off triangle); The third column (`Dev.To.Date`) gives a relative proportion of the paid amount (`Latest`) with respect to the estimated ultimate (`Ultimate`) given in the fourth column; Finally, the last column (`IBNR`) gives the estimated amount still left to pay (Incurred But Not Reported)
`overall`	Table with the summary of the true/estimated reserve: `Paid amount` represents the sum of the last running diagonal; `Estimated reserve` gives the reserve estimate provided by one of the estimation algorithm (PARALLAX, REACT, or MACRAME); `True reserve` is given as a sum of the last column (if available, NA otherwise); Finally, some Accuracy in terms of `Reserve%` is given as a percentage of the estimated reserve with respect to the true reserve (see Maciak, Mizera, and Pešta (2022) and `Dev.To.Date` gives the proportion of the overall estimatd ultimate and the overall paid amount
`resids`	Table with basic empirical description characteristics of the residuals (standard or back-fitted) if the residuals are provided in x

See Also

[as.profileLadder()](), [parallelReserve()](), [mcReserve()]()

Examples

```
data(CameronMutual)
summary(CameronMutual)

## standard summary output
summary(mcReserve(CameronMutual))

## summary output with plotOption = TRUE
```

```
summary(mcReserve(CameronMutual), plotOption = TRUE)

## summary output with (standard) residuals and plotOption = TRUE
summary(mcReserve(CameronMutual, residuals = TRUE), plotOption = TRUE)

## summary output with (back-fitted) residuals and plotOption = TRUE
summary(mcReserve(observed(CameronMutual), residuals = TRUE), plotOption = TRUE)
```

---

xNetSubscribe   *Data provider monthly income*

Description

An illustrative dataset—a matrix (of the dimensions 12x12) with a monthly-based income (in EUR) of a local internet data provider with the income structured by the customers subscribing within the given month (in 2023) reported in the rows and monthly-based payments reported in columns. The data matrix represents the incremental type of the run-off triangle.

Usage

```
data(xNetSubscribe)
```

Format

xNetSubscribe:

A simple 12x12 (trangular) matrix of the class `triangle` with twelve consecutive months (January 2023 – December 2023) when new customers subscribed to the stream service (rows) and monthly-based payments (columns)

Index