

# Functional profile completion: An R package

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HiTEc & CoDES 2025 — Workshop on Complex Data in Econometrics and Statistics

Cyprus University of Technology | Limassol, Cyprus | July 8–9, 2025



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## ProfileLadder: Motivation and brief some ideas behind...

**The aim:** to provide an overall framework for a very general and practically non-restrictive and easily applicable risk assessment and forecasting based on aggregated data...

**In non-life insurance** in particular, it accounts for a stochastic prediction of the overall loss reserves that are required by some regulator to be kept to cover possible (future) claims...

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- ❑ **Standard actuarial R package ChainLadder** `install.packages("ChainLadder")`
  - ❑ implements all common and typically used reserving methods – utilizing **parametric statistical techniques** and the aggregated **data structured in the run-off triangles** (e.g., the Mack model, over-dispersed Poisson model, Tweedie model, ...)

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- ❑ **Newly deployed R package ProfileLadder** `install.packages("ProfileLadder")`
  - ❑ non-restrictive, functional-based, non-parametric approaches **proposed and theoretically proved** relatively recently in M., Mizera, and Pešta (2022) (e.g., parallel approximation model and Markov chain based approximation, ...)

# A long term collaboration with Michal, Ivan, and Rasti



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# ProfileLadder package on CRAN

## Package ‘ProfileLadder’

June 11, 2025

**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, implemented in three nonparametric algorithms (PARALLAX, REACT, and MACRAME) proposed in Maciak, Mizera, and Pešta (2022) <[doi:10.1017/asb.2022.4](https://doi.org/10.1017/asb.2022.4)>.

**Depends** R (>= 4.0.0)

**License** GPL (>= 2)

**Encoding** UTF-8

**Imports** ChainLadder (>= 0.2.12), raw (>= 0.1.8)

**LazyData** true

**Config/testthat/edition** 3

**RoxygenNote** 7.3.2

**Maintainer** Matúš Maciak <[maciak@karlin.mff.cuni.cz](mailto:maciak@karlin.mff.cuni.cz)>

**NeedsCompilation** no

**Author** Matúš Maciak [aut, cre],  
Rastislav Matúš [ctb],  
Ivan Mizera [aut],  
Michal Pešta [aut]

**Repository** CRAN

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## Brief overview...

No R package details, no R implementation details, no theoretical details...  
Just some rough (background) ideas and functionality principles...

- ❑ **Triangular (ladder) data and their (incomplete) functional representation**  
*Incremental/cumulative run-off triangles and loss development profiles*
- ❑ **Non-parametric reserving techniques using the R package ProfileLadder**  
*Three key estimating/predicting algorithms—similar but different in their nature*
- ❑ **Way beyond: practical actuarial software tools and further add-ons**  
*The package beyond the three main functional-based algorithms*

## Run-off triangles: Incremental or cumulative data

Accident year $i$	Development year $j$				
	1	2	...	$n-1$	$n$
1	$Y_{1,1}$	$Y_{1,2}$	...	$Y_{1,n-1}$	$Y_{1,n}$
2	$Y_{2,1}$	$Y_{2,2}$	...	$Y_{2,n-1}$	
...	...	...			
$\vdots$	$\vdots$	$\vdots$		$Y_{i,n+1-i}$	
$n-1$	$Y_{n-1,1}$	$Y_{n-1,2}$			
$n$	$Y_{n,1}$				

Table: Run-off triangle with the **observed cumulative claim amounts**  $Y_{i,j}$  for  $i+j \leq n+1$ . Sometimes also represented in terms of **incremental payments**,  $X_{i,j} = Y_{i,j} - Y_{i,j-1}$ , for  $Y_{i,0} = 0$ .

# Run-off triangles: Incomplete development profiles

Accid. year $i$	Development year $j$									
	1	2	3	4	5	6	7	8	9	10
1	5244	9228	10823	11352	11791	12082	12120	12199	12215	12215
2	5984	9939	11725	12346	12746	12909	13034	13109	13113	13115
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6	3937	6524	7989	8543	8757	8901	9013	9012	9046	9164
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9	5129	8202	9185	9681	9951	10033	10133	10182	10182	10183
10	3689	6043	6789	7089	7164	7197	7253	7267	7266	7266

(a) Complete portfolio 1

Accid. year $i$	Development year $j$									
	1	2	3	4	5	6	7	8	9	10
1	794	1277	1848	2080	2352	2441	2442	2452	2452	2452
2	847	1427	1796	2084	2322	2331	2367	2393	2393	2459
3	701	1317	1912	2147	2196	2285	2290	2291	2359	2359
4	808	1423	1844	1993	2091	2093	2110	2122	2142	2142
5	756	1465	1819	1993	2096	2160	2206	2216	2219	2217
6	771	1266	1489	1685	1822	1836	1857	1910	1919	1918
7	723	1562	1895	2115	2266	2314	2314	2313	2313	2313
8	862	1397	1679	1775	1858	1858	1859	1863	1863	1863
9	930	1523	1971	2150	2197	2224	2292	2332	2341	2341
10	825	1312	1556	1724	1825	1854	1872	1872	1872	1872

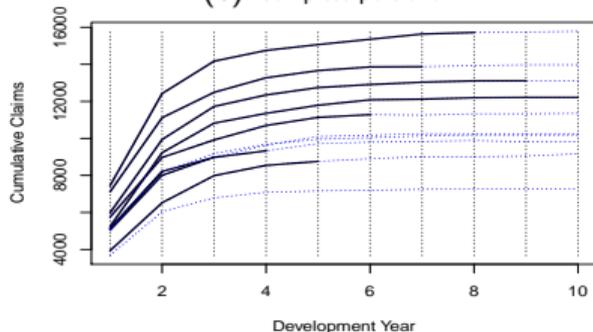
(b) Complete portfolio 2

# Run-off triangles: Incomplete development profiles

Accid. year $i$	Development year $j$									
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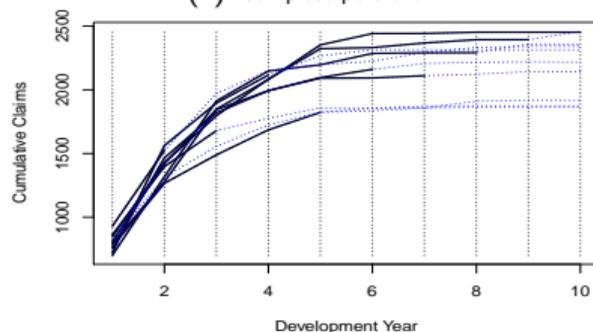
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(e) Complete portfolio 1



(g) Development profiles for portfolio 1

(f) Complete portfolio 2



(h) Development profiles for portfolio 2

## Functional-based approaches: PARALLAX/REACT/MACRAME

### Why?

- ❑ Parametric benchmark techniques (development ratios, the Mack model, or ODP models) require rather strict assumptions with limited flexibility and practical applicability
- ❑ In practice, overall reserves for many portfolios (lines of business respectively) are only estimated in terms of some “expert judgement” with no theoretical foundations

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### How?

- ▶ The building block of all of the proposed methods are so-called functional development profiles, respectively the “patterns of loss emergence” (Clark, 2003)
- ▶ The overall reserves are modeled in non-parametric ways with no practical limitations for the underlying data (Maciak, Mizera, Pešta, 2022)
- ▶ Complex software toolbox in the R package ProfileLadder including exploratory and confirmatory statistical tools (Maciak, Matúš, Mizera, and Pešta, 2025?)

## Three estimation algorithms embeded in two R functions

- Standard parametric techniques from ChainLadder package, e.g., ODP model

```
R> glmReserve(chainladder)
```

	Latest	Dev.To.Date	Ultimate	IBNR		S.E	CV
2	13113	1.0000000	13113	0		0.01035287	Inf
3	15720	0.9992372	15732	12	29.38975320	2.4491461	
4	13872	0.9934116	13964	92	73.46098788	0.7984890	
5	11282	0.9850694	11453	171	96.26787355	0.5629700	
6	8757	0.9688019	9039	282	120.58781735	0.4276164	
7	9325	0.9397360	9923	598	177.57019068	0.2969401	
8	8984	0.8905630	10088	1104	246.00693847	0.2228324	
9	8202	0.7789914	10529	2327	379.54811405	0.1631062	
10	3689	0.4788422	7704	4015	622.22022041	0.1549739	
total	92944	0.9152986	101545	8601	880.66723938	0.1023913	

## Three estimation algorithms embeded in two R functions

- ❑ **PARALLAX** – parallel approximation by missing fragments

```
R> parallelReserve(chainladder)
```

- ❑ **REACT** – approximation by the most recent segment

```
R> parallelReserve(chainladder, method = "react")
```

- ❑ **MACRAME** – Markov Chain based approximation of missing fragments

```
R> mcReserve(chainladder)
```

## Three estimation algorithms embeded in two R functions

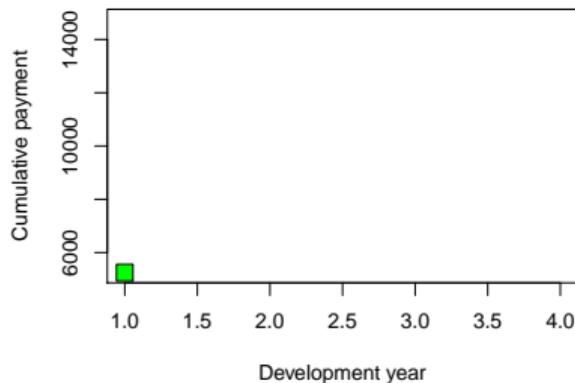
- ❑ **PARALLAX** – parallel approximation by missing fragments

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	First	Latest	Dev.To.Date	Ultimate	IBNR
2	5984	13113	1.0000000	13113	0
3	7452	15720	0.9997456	15724	4
4	7115	13872	0.9943373	13951	79
5	5753	11282	0.9883487	11415	133
6	3937	8757	0.9690163	9037	280
7	5127	9325	0.9496894	9819	494
8	5046	8984	0.9142159	9827	843
9	5129	8202	0.8361709	9809	1607
10	3689	3689	0.4197292	8789	5100
total	49232	92944	0.9158488	101484	8540

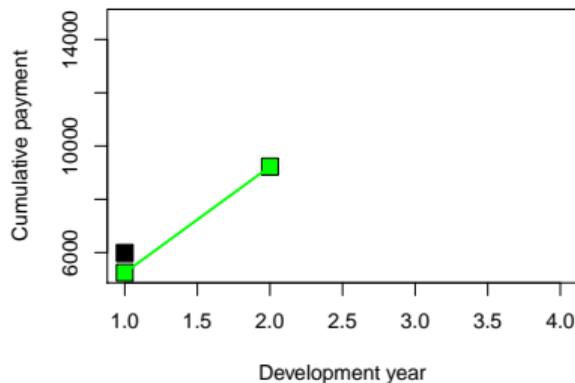
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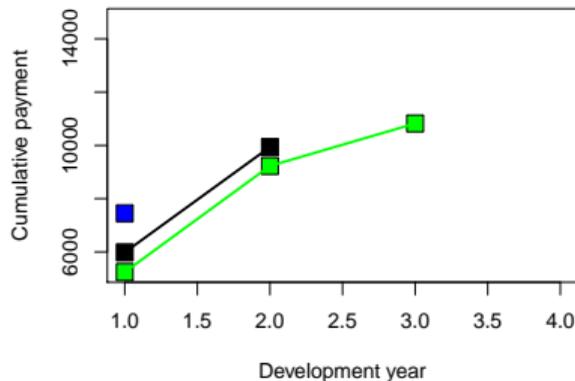
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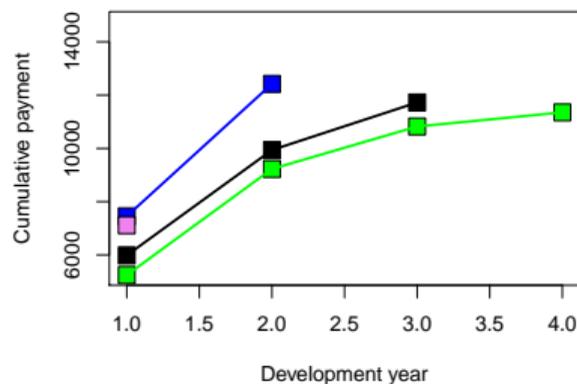
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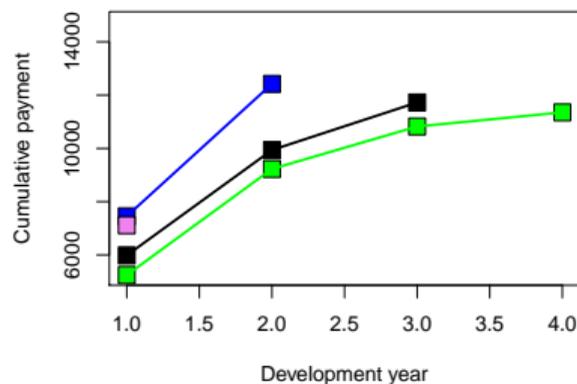
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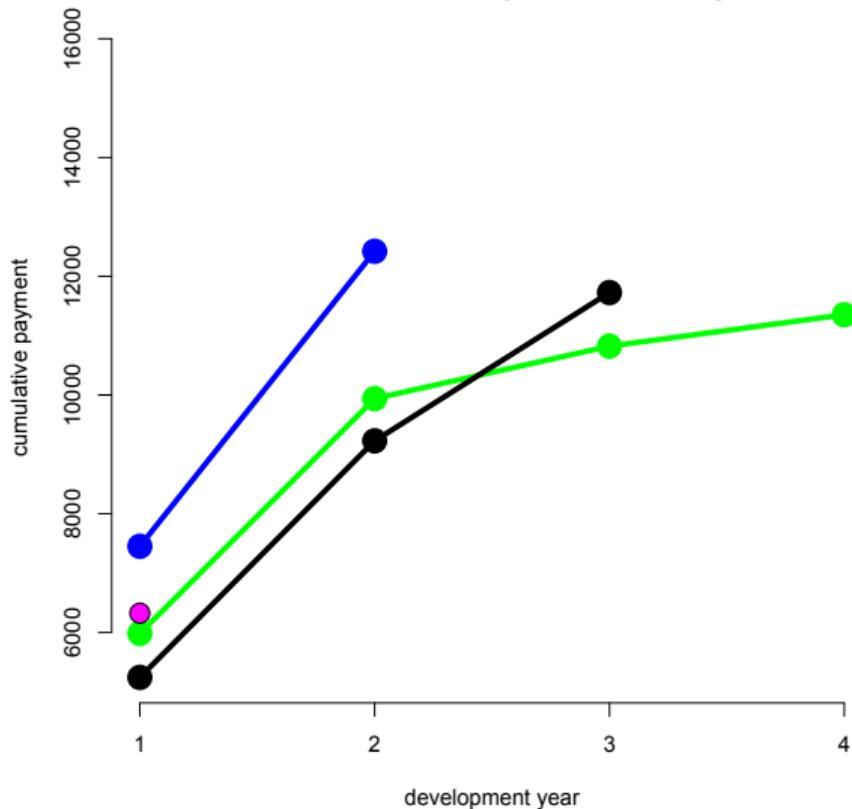
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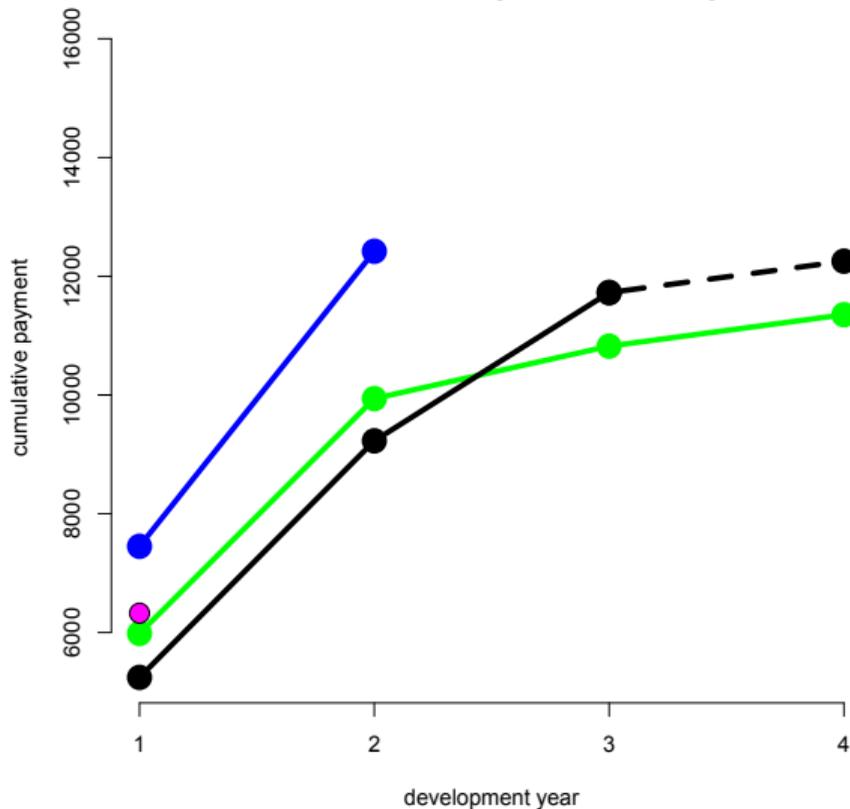


And so on ...

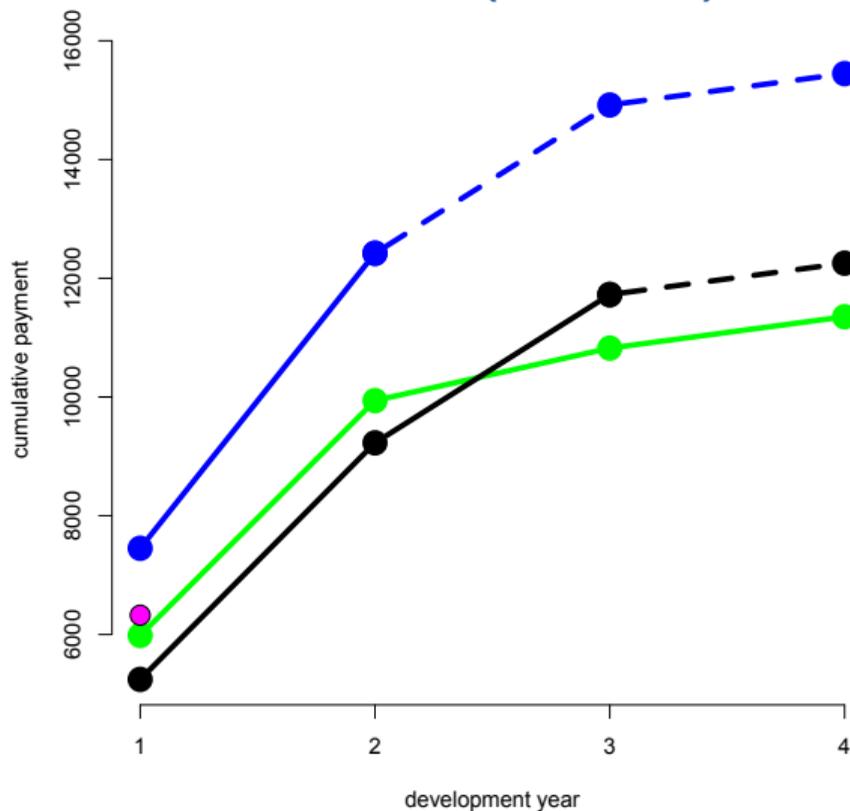
## And now: the second method (REACT)



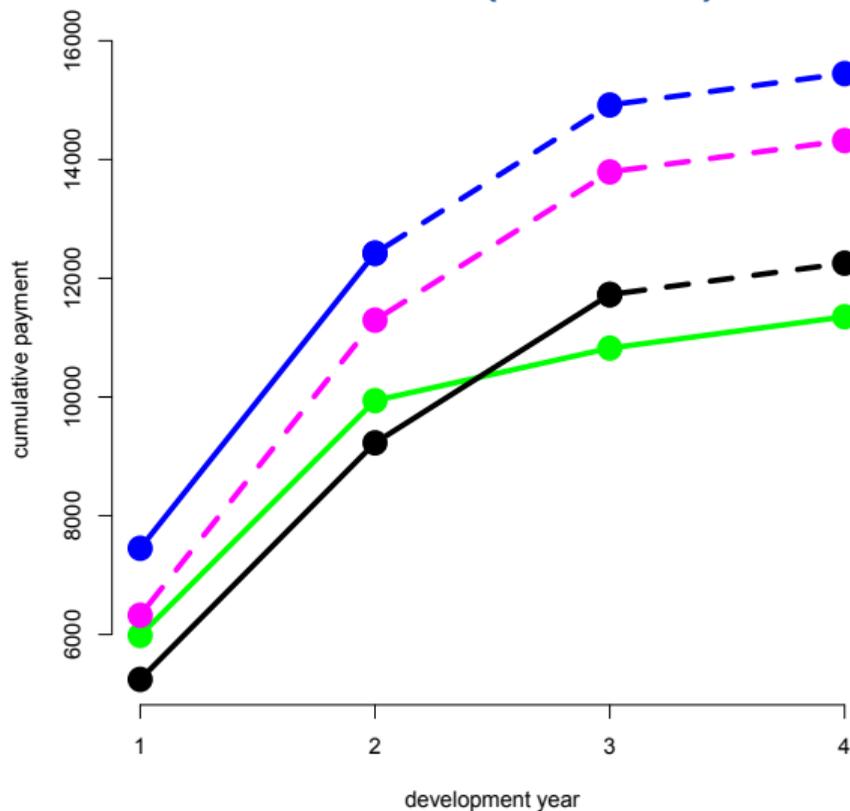
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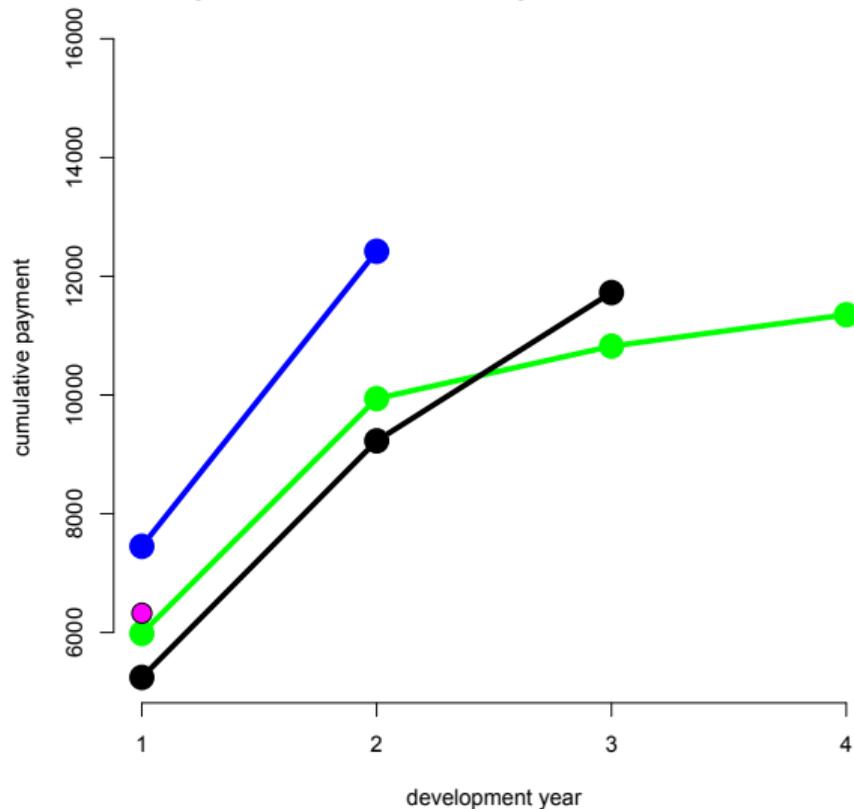
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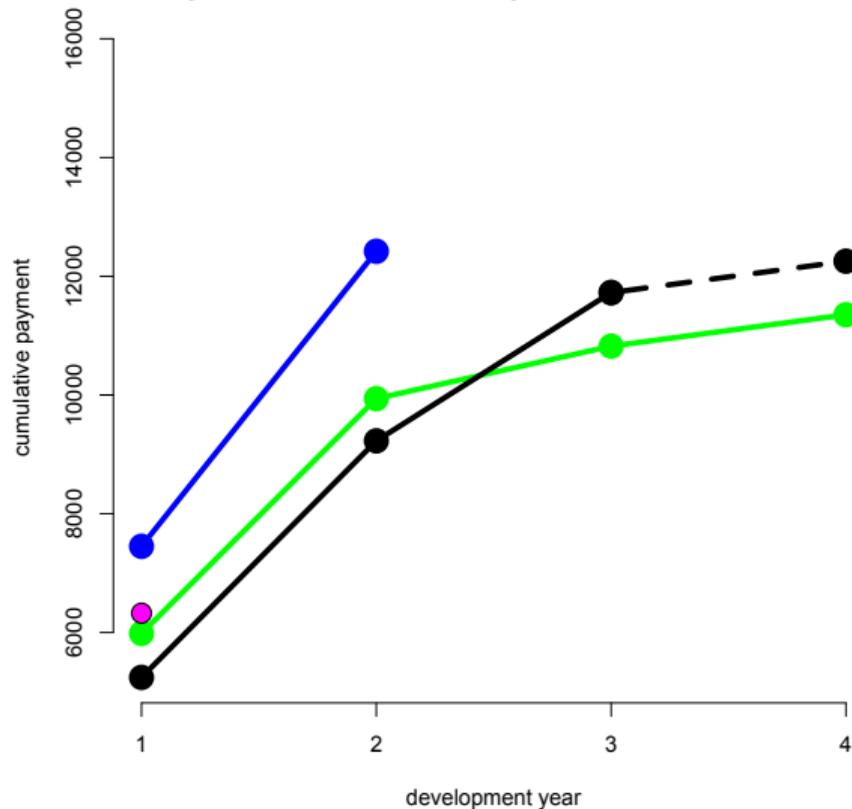
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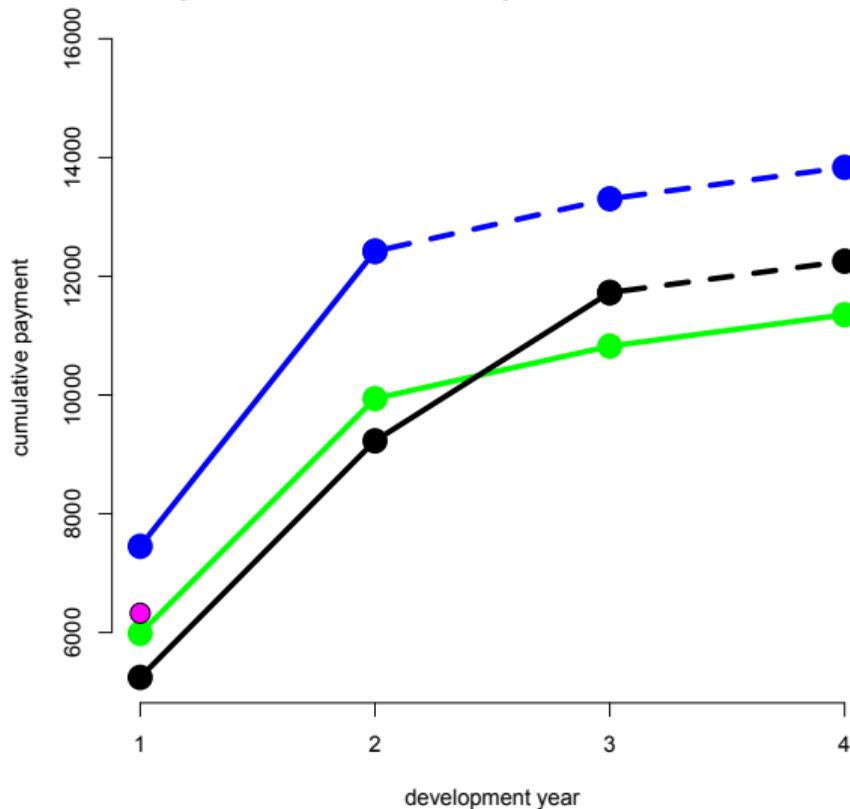
## The first method: (PARALLAX)



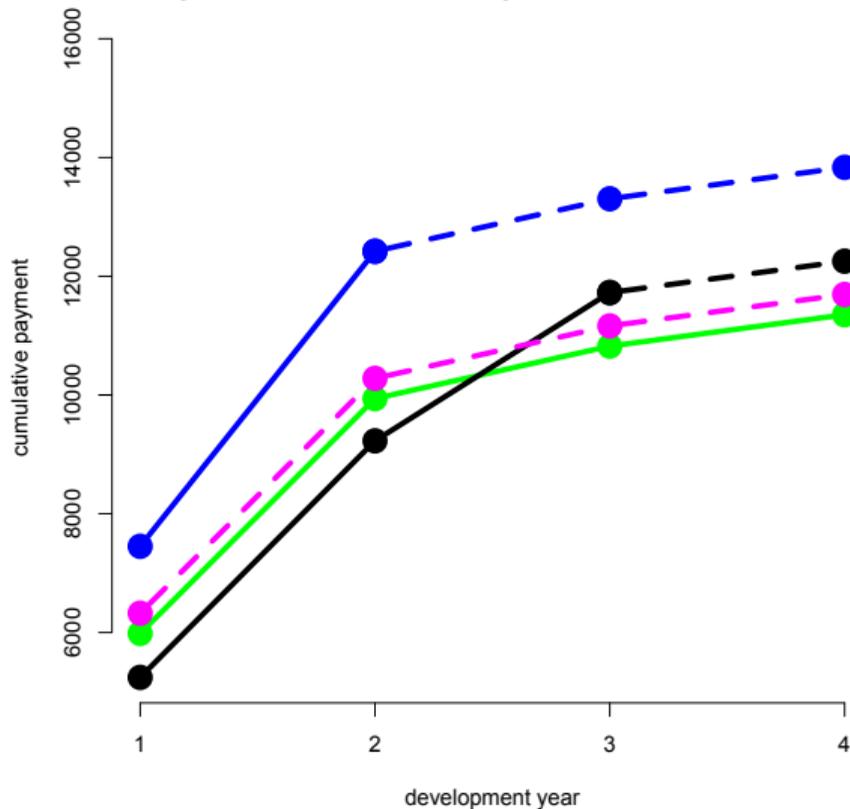
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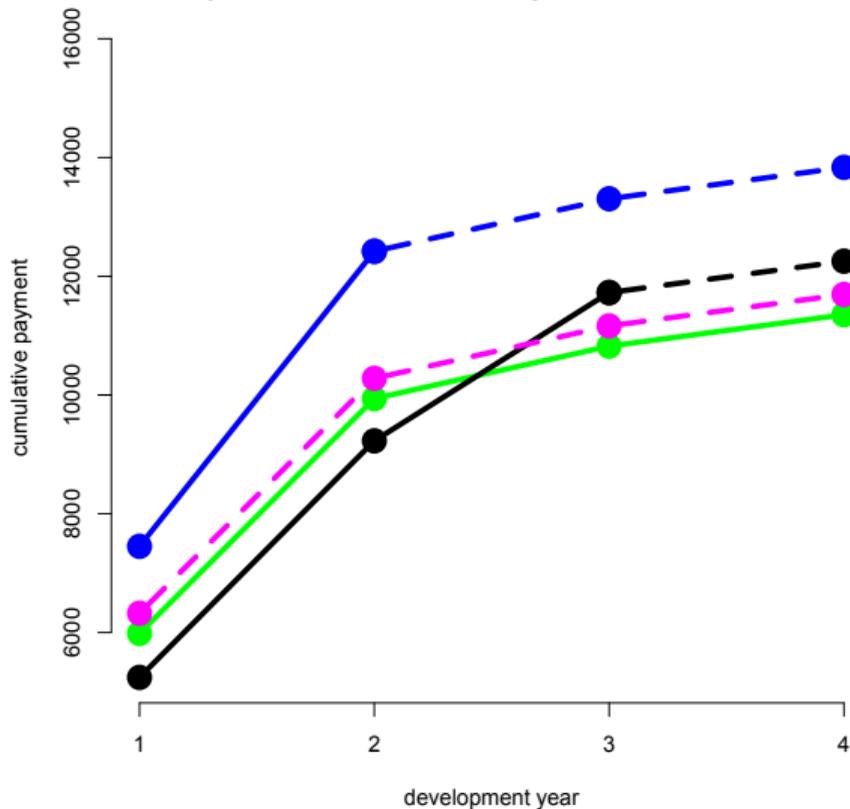
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## The third method: (MACRAME)



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- ❑ relatively complex mathematical model (a homogeneous Markov Chain) that drives the overall prediction (advantage and disadvantage at the same time)
- ❑ allows for various user-based modifications and specific adjustments (the set of Markov chain states or their over number... and way more)
- ❑ additional software tools are needed to make appropriate user-based decisions (various exploratory and confirmatory analytic tools)

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- ❑ allows for various user-based modifications and specific adjustments (the set of Markov chain states or their over number... and way more)
- ❑ additional software tools are needed to make appropriate user-based decisions (various exploratory and confirmatory analytic tools)
  
- ❑ However, the best results still obtained with the [apriori data-driven approach](#) (the algorithm originally proposed and proved in Maciak, Mizera, and Pešta, 2022)
- ❑ [Additional modifications and adjustments also in progress for the new package update...](#) (requirements of the reviewers for Maciak, Matúš, Mizera, and Pešta, 2025?)

## Bootstrap resampled reserve

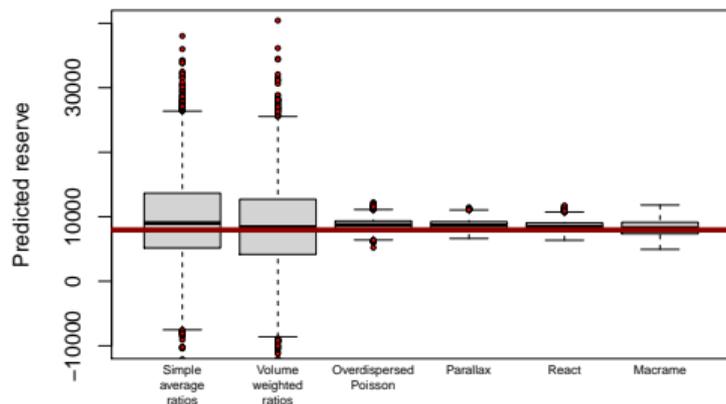
Instead of the point prediction the regulator/company is typically interested in the overall distributional prediction of the reserve (typically the 0.995 quantile of the reserve distribution)...

⇒ imposing some distributional assumptions or using resampling methods...

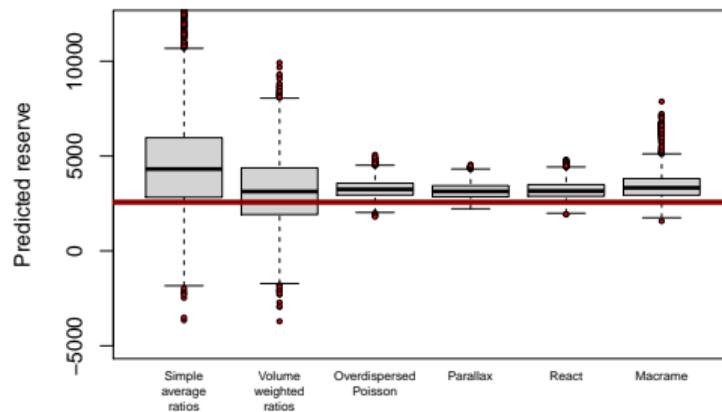
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(k) Portfolio 1



(l) Portfolio 2

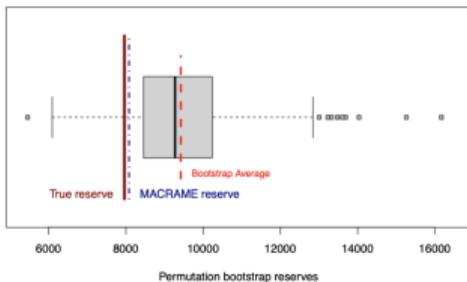
## ProfileLadder package: Permutation bootstrap

```
R> permuteReserve(...)
```

# ProfileLadder package: Permutation bootstrap

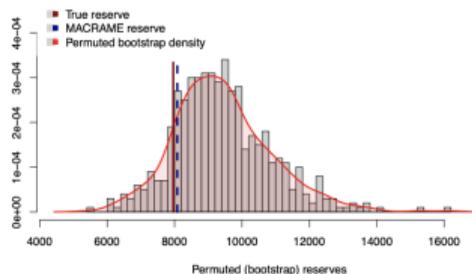
```
R> permuteReserve(...)
```

Permutation bootstrap for MACRAME (B = 500)



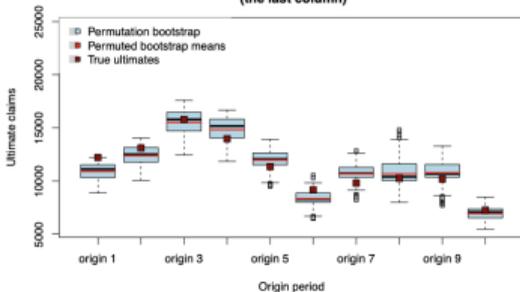
(a) Boxplot of  $\{\hat{\mathcal{R}}^{(b)}\}_{b=1}^{100}$  values

Permutation reserve distribution (B = 500)



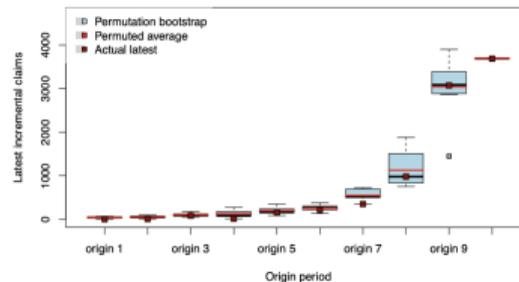
(b) Histogram and the estimated density

Permuted ultimate claims  
(the last column)



(c) Simulated ultimate claims

Latest incremental claims  
(actual vs. simulated)



(d) Simulated run-off diagonals

## Additional material in the R package ProfileLadder

- ❑ chainladder exploratory and inference tools...  
(`increxplor()`, `observe()`, ...)
- ❑ completed data triangles for back-fitting purposes  
(existing datasets – Meyers and Shi (2011))
- ❑ data illustrations from various practical areas  
(covid19 pandemic, start-up progress, exclusive data from the Czech Insurers' Bureau)
- ❑ and some more...  
(see the package documentation)

## Empirical comparisons – real data

- ❑ 518 run-off triangles from the National Association of Insurance Commissioners (NAIC) database (Meyers and Shi, 2011)
- ❑ Triangles with only zero observed claim amounts in the last four accident periods and also those triangles having 8 or more development profiles identically equal to zero are removed

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- 
- (i) 130 run-off triangles that were ODP compliant (with non-negative increments only, but profiles being entirely zero not allowed)
  - (ii) 299 not ODP compliant triangles (negative increments exists, but still no entirely zero profiles)
  - (iii) 89 remaining triangles that could be considered “rather atypical”, but are still not uncommon in the actuarial practice

## Out-of-sample bootstrap performance measures

**Reserve%** gives an absolute relative difference of the predicted reserve and the true reserve defined for each triangle as  $100 \times \left| \frac{\text{predicted reserve}}{\text{true reserve}} - 1 \right|$  and averaged over all triangles in the given scenario (smaller values are better);

**BootCoV%** expresses a coefficient of variation for the bootstrapped reserve distribution relative to the bootstrap mean  $100 \times \frac{\text{Std.Dev}(\text{bootstrapped reserves})}{\text{Avg}(\text{bootstrapped reserves})}$  averaged, again, over all triangles in the given scenario (smaller values are better);

**BootVaR.<sub>995</sub>** denotes the 99.5% quantile of the bootstrap distribution relative to the bootstrapped mean  $\frac{\text{Quantile}_{0.995}(\text{bootstrapped reserves})}{\text{Avg}(\text{bootstrapped reserves})}$  and averaged over all triangles in the given scenario (smaller values are better);

**BootQnt.<sub>950</sub>** provides a percentage proportion of the triangles in the given scenario for which the true reserve is dominated by the 95% quantile of the bootstrapped distribution (values closest to 95% are preferred).

## Claims reserves evaluation I

Method	Reserve%	BootCoV%	BootVaR <sub>.995</sub>	BootQnt <sub>.950</sub>
<i>Average</i>	58.79 (186.00)	79.46 (144.67)	3.67 (3.57)	100.00%
<i>Weighted</i>	47.13 (130.91)	53.60 (61.46)	2.63 (1.81)	98.46%
<i>ODP Model</i>	47.10 (130.89)	<b>16.98</b> (10.16)	<b>1.54</b> (0.39)	86.92%
<i>PARALLAX</i>	57.85 (125.45)	<b>22.34</b> (16.13)	<b>1.59</b> (0.46)	<b>96.92%</b>
<i>REACT</i>	<b>43.19</b> (78.28)	24.08 (18.03)	1.64 (0.51)	97.69%
<i>MACRAME</i>	<b>45.32</b> (76.43)	23.93 (12.65)	1.73 (0.42)	<b>95.38%</b>

**Table:** Overall empirical performance of six claims reserving techniques when applied to the group (i), 130 ODP compliant run-off triangles from Meyers and Shi (2011). The corresponding standard deviations are given in parentheses; two best results are indicated by bold typeface.

## Claims reserves evaluation II

Method	Reserve%		BootCoV%		BootVaR <sub>.995</sub>		BootQnt <sub>.950</sub>
<i>Average</i>	215.95	(1128.77)	4045.61	(4.0e+04)	43.14	(461.41)	99.67%
<i>Weighted</i>	541.33	(6135.24)	-3e+03	(2.3e+04)	-7.43	(132.37)	97.99%
<i>Chainladder</i>	541.33	(6135.24)	<b>29.78</b>	(212.59)	<b>1.97</b>	(7.58)	83.28%
<i>PARALLAX</i>	<b>68.83</b>	(132.40)	<b>9.53</b>	(628.55)	<b>1.70</b>	(11.04)	<b>92.98%</b>
<i>REACT</i>	97.85	(334.97)	66.60	(182.67)	2.92	(4.99)	<b>94.31%</b>
<i>MACRAME</i>	<b>68.38</b>	(93.76)	51.26	(36.96)	2.75	(1.59)	91.97%

Table: Empirical performance of six claims reserving techniques applied to the group (ii), 299 “rather typical” but ODP non-compliant run-off triangles from Meyers and Shi (2011). The corresponding standard deviations are given in parentheses; two best results are indicated by bold typeface.

## Claims reserves evaluation III

Method	Reserve%		BootCoV%		BootVaR <sub>.995</sub>		BootQnt <sub>.950</sub>
<i>Average</i>	255.88	(654.91)	-2e+03	(2.1e+04)	-47.74	(505.00)	<b>91.01%</b>
<i>Weighted</i>	181.32	(526.35)	4.6e+04	(4.3e+05)	167.99	(1492.61)	<b>91.01%</b>
<i>Chainladder</i>	181.32	(526.35)	<b>177.17</b>	(472.73)	<b>6.02</b>	(11.65)	79.78%
<i>PARALLAX</i>	142.08	(567.07)	<b>69.77</b>	(75.02)	<b>3.09</b>	(4.63)	77.53%
<i>REACT</i>	<b>111.03</b>	(256.82)	240.60	(1294.93)	7.94	(35.34)	76.40%
<i>MACRAME</i>	<b>111.02</b>	(141.21)	256.41	(1175.31)	10.25	(52.48)	69.66%

**Table:** Empirical performance of six claims reserving techniques applied to the group (iii), 89 “atypical” run-off triangles from Meyers and Shi (2011). The corresponding standard deviations are given in parentheses; two best results are indicated by bold typeface.

## Some conclusions

Three unsupervised loss reserving techniques based on **non-parametric and distribution free approaches** offering the following advantages:

- (i) they are **simple, straightforward, and easily applicable**;
- (ii) they require **neither distributional nor parametric assumptions** and apply to all kinds of run-off triangles, including those with negative incremental cells or zero cumulative claim amounts over some development periods;
- (iii) various stochastic model assumptions can be postulated in order to derive **desirable statistical properties** serving as the methods' **justifications**;
- (iv) it is straightforward to obtain also the **overall reserve distributions via bootstrapping techniques**;
- (v) and the proposed methods are also **robust against outliers**.

## ProfileLadder package on R CRAN available here:



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

Maciak, M., Matúš, R., Mizera, I., and Pešta, M. (2025?). **ProfileLadder: Profile Chain-Ladder Reserving.** Journal of Statistical Software (in revision)