# Individual claims reserving
Opportunity as a Challenge

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# Introduction to individual claims reserving

Introduction
From aggregate

Past

Future
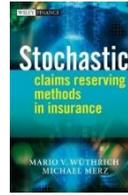
- The current reserving practice consists, in most cases, of using methods based on **claims development triangles** for point estimate projections as well as for capital requirement calculations.

- In the context of an increasing need within the reserving practice for more accurate models, taking advantage of the **information embedded in individual claims data** is a promising alternative compared with the traditional aggregate triangles.

- Traditional reserving methods (Chain-Ladder, Mack, Wüthrich,…) work well in relatively stable contexts and for standard business lines; today, however, the awareness of the insurance market about some possible limitations of traditional **aggregate models** to provide robust and realistic estimates in more variable contexts has reached a level which should be noted

- Several potential limits of aggregate models based on triangles have indeed already been highlighted both from a practical and a theoretical point of view:

  - **Huge estimation error** for the latest development periods due to use of limited information in observed aggregate amounts,

  - The **difficulty of these models in identifying and capturing** the **various sub-risks**,

  - **Over/under-estimation** of the distribution when back-testing realized amounts with forecasts

Introduction
… to individual-based modelling
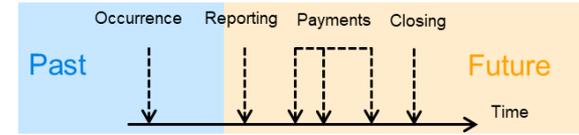
- As noted in the report on worldwide non-life reserving practices from the ASTIN Working Party on Non-Life Reserving (June, 2016), there is 'an increase in the need to move towards **individual claims reserving and big data**, **to better link the reserving process with the pricing process and to be able to** better value non-proportional reinsurance.'


- The first research papers on individual models are concomitant with the development of stochastic methods on aggregated triangles:

    - **Norberg (1983, 1993, 1999), Jewell (1987), Arjas (1989) et Hesselager (1994)** are among the earliest papers which introduced a proper probabilistic setting for individual claims reserving – current references are: **Larsen (2007), Antonio & Plat (2014), Boumezoued & Devineau (2017)**

    - To be compared with the stochastic models for triangles in **Mack (1993) and following contributions**

- In a context of increasing need for **more reliable quantification and management of reserve risk**, it appears promising **to take advantage of the information contained in detailed claims data**; this alternative requires models adapted to reveal the information inherent in these data.

Introduction
Zoom on the claim path and associated sub risks

- The claim development process is divided according to the following stages:

The joint modelling of occurrence and reporting allows to reprocess the observation biases caused by the underrepresentation in the database of claims with long reporting delay; this leads in particular to an *accurate quantification of the IBNR claims*.

The joint modeling of the occurrence, the reporting and the payments allows to characterize the payment trajectories *according to their date of occurrence and their reporting delay → improvement of the prediction of RBNS according to their development time.*

Why using individual reserving methods?
A better estimate of reserves and their components

- The primary objective of using individual models is **to improve the Best Estimate of reserves**, compared to the triangles-based methods.

  - The predictive capacity of these models relies on the fact that the **whole life** of each claim is taken into account (occurrence, reporting, payments, closing, …) as well as its **covariates**

- Beyond the quantification of reserves, these models allow a **separate estimation** of reserve amounts for **IBNR [Pure IBNR]**(*Incurred But Not Reported*) and **RBNS** (*Reported But Not Settled*)

  - Note that this distinction is, **by construction, more natural** in the context of individual models, whereas it is non-trivial (and less easy to justify) for methods based on triangles

- Adequate valuation of **non-proportional reinsurance**: due to the non-linearity of treaty valuation formulas, a **stochastic individual approach is needed** to produce an **unbiased pricing**

  - **The stochastic simulation of claims paths** beyond a basic frequency x severity model makes it possible to solve adequately this problem.

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Implementation process
Overview of the operational implementation process

- Individual reserving model is part of **an overall process** from data collection to monitoring of risk indicators over time:

Data collection & preparation

- Design a **rationalized collection strategy** focusing only on the claims data used by the individual model
- Perform the **data transformation** needed to feed the individual model
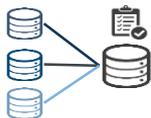
Model specification & calibration

- Specify the model components according to the **lines of business** to be addressed and the **available data**
- Estimate the parameters of the individual model using **smart parametrization** combined with **advanced optimization procedures**
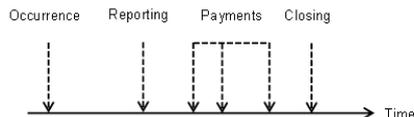
Simulation & model validation

- Forecast IBNyR and RBNS individual trajectories using **efficient simulation algorithms;** alternatively, rely on **closed-form formulas**
- Perform a **model validation process** based on goodness-of-fit analysis, back-testing procedures and comparisons with classical triangle-based methods
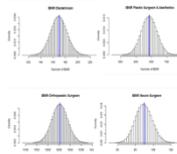

Reserve risk Dashboard

- Claim journey parameters are visualized through an **automated dashboard**
- Know why things happened: **identify the underlying risks** which caused changes in aggregate payments
- Monitor your key indicators periodically, and **leverage information to improve management actions**

Model specification & calibration
Claim path and associated sub-risks – specification details

- The individual claims paths are modelled with continuous time stochastic processes

Occurrence **Reporting** **Payments** **Settlement**

Time

u v

Claims occur at times T_n according to some **Poisson process** with intensity $\lambda(t)$

Claims are **reported** with a delay with distribution $p_{U|t}(du)$

Payments and settlement events are modelled using three types of events **(*)**:
(1) settlement without payment at settlement
(2) settlement with payment at settlement
(3) payment without settlement

Each type of event (1, 2, or 3) occurs according to its **specific intensity parameter** $h_1(v)$, $h_2(v)$ or $h_3(v)$.
→ If an event $i \in \{2,3\}$ occurs v time units after reporting, then random payments $Y_i(v)$ are generated

Occurrence and reporting distributions have to be estimated jointly as observation is biased due to hidden **Incurred But Not yet Reported claims (IBNyR)**

*Based on occurrence and reporting parameters, **stochastic IBNyR occurrences and reporting delays** can be simulated.*

*The payments and settlement model parameters allow simulation of **the stochastic future payments paths to closing for both IBNyR and RBNS claims**.*
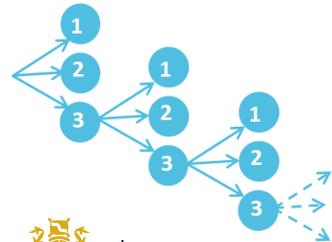
(*) *The corresponding interpretation is that over all event types in the claims pool, the **proportion of event** of type $i \in \{1,2,3\}$ is given by $\frac{h_i}{h_1+h_2+h_3}$. In addition, this gives **information on the timing** of these events, as for example, the time to wait between two intermediary payments (3) is $1/h_3$ in average, and the time to wait between two events (whatever their type) is $1/(h_1+h_2+h_3)$*

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Zoom on the implementation steps
Forecasting: closed-formulas and simulation algorithm
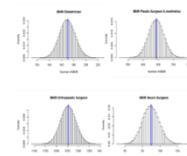
- **The total prediction error** for the future claim trajectories includes the following sub-components, as classical for reserve risk:

  - **Process error:** pure stochasticity due to the intrinsic randomness of future paths,

  - **Estimation error:** linked to the uncertainty on the value of the parameters estimated

- Both types of error can be quantified by **simulation** or alternatively by using **closed-formulas**, see Boumezoued & Devineau (2017):

|	Process error	Estimation error
Simulations	Algorithm called *thinning* for the simulation of all types of events involved in claim path	Simulation based on the **variance-covariance matrix of Maximum Likelihood Estimators** (asymptotic normality result)
Closed-formulas	**Closed-form formulas** established in Boumezoued & Devineau (2017)	Asymptotic normality result and the use of the **Delta method** for obtaining closed-forms

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Motor third party insurance case study

Motor third party case study
Database description

- The database used is made of **Motor third party claims** from 2010 to 2013. It comes from an emerging market with transactional data which reconciles to the financials.

- There are **238 747 observed claims** in the database, including 234 454 settled claims and 4 293 reported but not yet settled (RBNS).

- Data structure and cleaning:

  - For each claim, one observation per quarter, from its reporting until its settlement.

  - Negative payments have been deleted.

Table OS
Claims with no payments
9 068
(565 open, 8503 closed)

Claims with partial payments
35 095
(3 728 open, 31 367 closed)

Table payments
Payment but no OS: closed claims
194 584
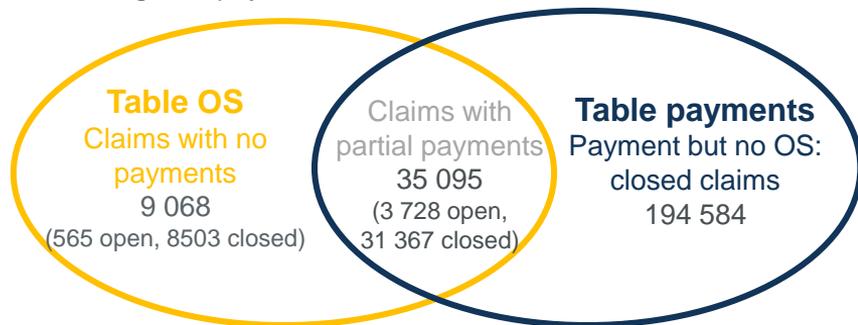
- Claims are classified into **5 groups of initial reserves**   →

Group	Signification
A	Initial reserve = 0
B	0<Initial reserve ≤1000
C	1000<Initial reserve ≤10 000
D	10 000<Initial reserve ≤100 000
E	Initial reserve >100 000

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Motor third party case study
## Database description

- For each claim, we potentially have the following **information**:
    - Occurrence date
    - Declaration date
   - Payment dates and associated amounts
    - Closing date

Reporting delays distribution (years) by the initial reserve

Observed occurrence dates
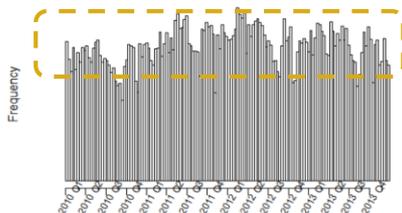
Relatively constant (but for seasonality) occurrence frequency

Observed reporting delays
(zoom on the first 6 months)

Line of business with longer reporting delays

Until 48 months of reporting
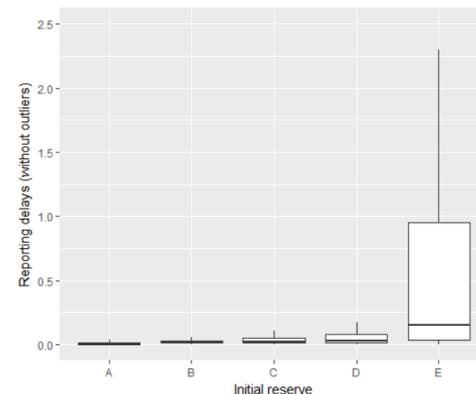
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Motor third party case study
Occurrence/reporting model calibration
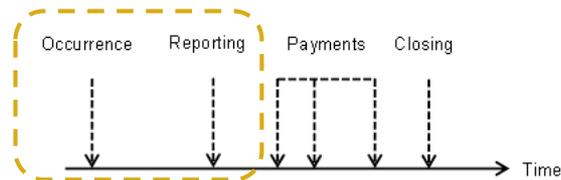
- Calibration of occurrence frequencies and reporting delays are given below for each of the 5 groups considered:

Occurrence frequency	Average reporting delay

Occurrence frequency

- The frequency of claims occurrence is captured (in red) by the model, **restoring the bias related to non-observation of IBNyR**.

- A calculation directly based on observation (in blue) would underestimate the frequency of claims occurrence.

- A joint estimation of the two parameters, which is more realistic, leads to higher parameters.
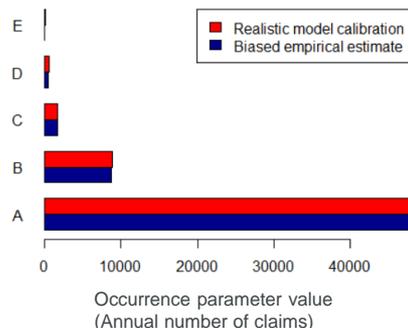
Average reporting delay

- The **reporting delays calibrated by the model** (in red) capture the specific reporting dynamics for each of the 5 groups

- A 'naive' estimate (in blue) would lead to an underestimation of the reporting delay (claims with a low reporting delay are over-represented in the sample).
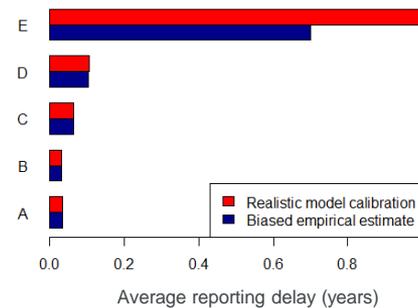
Motor third party case study
IBNR simulation, backtesting and comparison with Mack model

- In order to have a comparative dataset, the individual model and the Mack Chain Ladder model (1993) are calibrated on a **common history of 4 years**.

Results per group

Group	Individual Model	Mack Chain Ladder
A	1671	2854
B	244	2
C	94	18
D	51	20
E	32	37
TOTAL	**2092**	**2667**

Prediction of IBNyR number with individual model

Prediction of IBNyR number with Mack Chain Ladder model

Lack of sub-additivity of the MCL approach here, to be compared with the "stability by summation" property of the Individual model

Total results
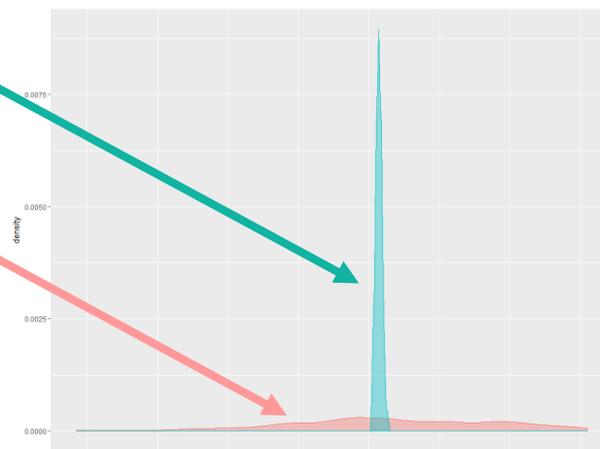
- Higher **predictive power** of the individual model in this context

- The Mack Chain Ladder approach seems to **overestimate** the number of IBNyR claims

- The Mack Chain Ladder approach results in **a much larger uncertainty estimate**

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Motor third party case study
Calibration of payments and settlement frequencies (1/3)

- **Recall of the methodology**

  Payments and settlement events are modelled using three types of events (*):
  (1) settlement without payment at settlement
  (2) settlement with payment at settlement
  (3) payment without settlement

  Each type of event (1, 2, or 3) occurs according to its specific intensity parameter $h_1(v)$, $h_2(v)$ or $h_3(v)$.

  $\rightarrow$ If an event $i \in \{2,3\}$ occurs v time units after reporting, then random payments $Y_i(v)$ are generated
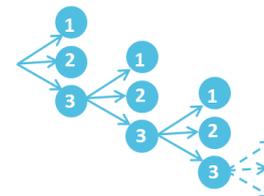
- **Interpretation**

  - Over all event types in the claims pool, the proportion of event of type $i \in \{1,2,3\}$ is given by $\frac{h_i}{h_1+h_2+h_3}$.

  - This gives information on the timing of these events, as for example, the time to wait between two intermediary payments (3) is $1/h_3$ in average, and the time to wait between two events (whatever their type) is $1/(h_1 + h_2 + h_3)$

- **Example**

  Let's take $h_1 = 0.5$, $h_2 = 3.5$, $h_3 = 1.0$.

  - There are 10% of settlement without payment at settlement , 70% of settlement with payment at settlement and 20% of payment without settlement.
  - The average time between two payments is 1/1=1 year.
 - The time to wait between two events is 1/(0.5+3.5+1.0)=0.2 years.

Motor third party case study
Calibration of payments and settlement frequencies (2/3)
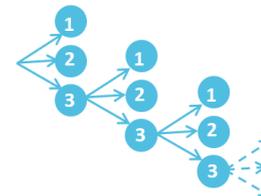
- Computation **of the frequency parameters** related to **payments** and **settlement**.

① Settlement without payment

Frequency - settlement without payment

h_1

② Settlement with payment

Frequency - settlement with payment

h_2

③ Payment without settlement

Frequency - payment without settlement

h_3
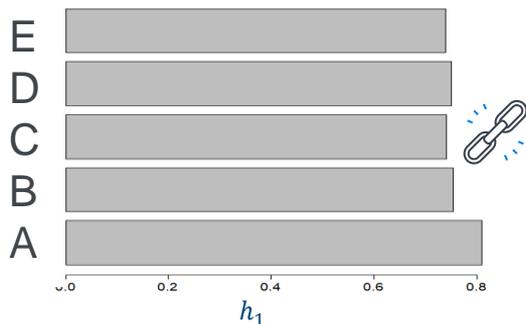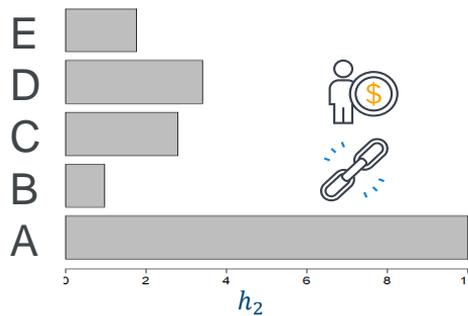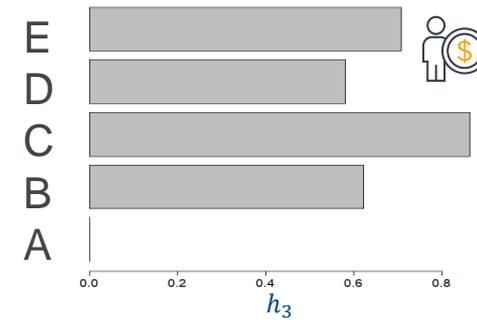
- Whereas settlement without payment frequencies (1) are relatively similar among all 5 groups, different Group frequencies for settlements with payment (2) and payments without settlement (3) allow the model **to reflect the claim history of each group.**

- For instance, one can identify that group A is characterized by **high frequency of settlement with (2) and without (1) payments** but **no payment without settlement (3)**. The data shows that claims with no initial reserve either close without a payment or close with a unique payment. This contrasts with claims of group B through E, which have **more frequent payments during the claims paths**

Motor third party case study
Calibration of payments and settlement frequencies (3/3)

- Refinement of the calibration to allow **for time-varying frequency parameters**: the frequencies are allowed **to vary from one claims development period to the next.**

  - This makes it possible to have a **more realistic model** and to anticipate the future dynamics of **claims according to their development time.**

① **Settlement without payment**

Frequency - settlement without payment

Frequency

Group →   A   B   C   D   E

② **Settlement with payment**

Frequency - settlement with payment

Frequency

Group →   A   B   C   D   E

③ **Payment without settlement**

Frequency - payment without settlement

Frequency

Group →   A   B   C   D   E
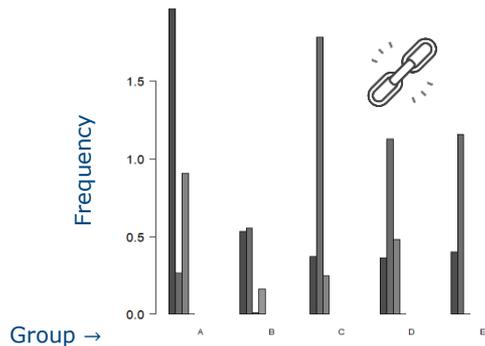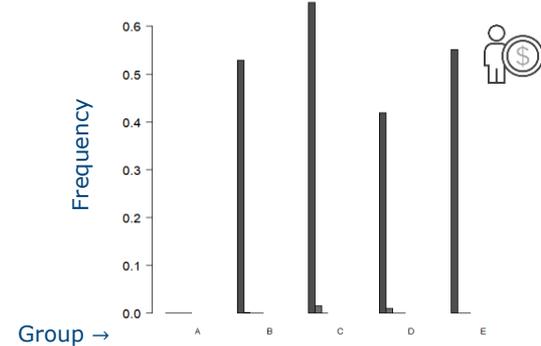
- **Closing frequencies** (1) clearly depend on the group: for groups C to E, they are maximum for claims of age around 2 years;
- **Settlement with payment** (2) are higher the first year for all claims.
- **Payments (without settlement) frequency** (3) show a very different pattern: here they indicate that an IBNR (zero age) claim has **potentially more future payments** in the short term than claims that have been developed for 2 to 3 years.

Motor third party case study
Computation of future payments for each type of claim

- The closed formulas that we have developed make it possible to instantaneously compute the **expected payment amount and the associated variance** (prediction error) for each type of claim (group) and according to its duration of development.

Expected future payments
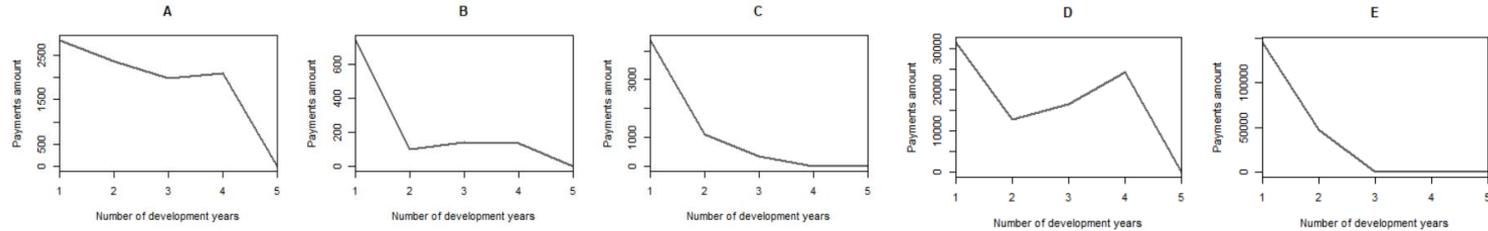
- For each group, the expected future aggregate payments **decrease over the first two years**, due to **a combination of a decrease in payment frequency and a growth in the settlement frequency** (see groups B to E in particular on the previous slides).
- Depending on the group, the expected payments increase or decrease as claims develop:
  - One can observe an increase in payments for group A, B and D, due to a lower settlement frequency without payment (1) and a higher frequency of settlement with payments (2).
  - One can observe a monotonic decrease in payments for group C and E because of the absence of payments with or without settlement.

- Based on the inherent CoVs, groups B and C are characterized by higher levels of uncertainty.
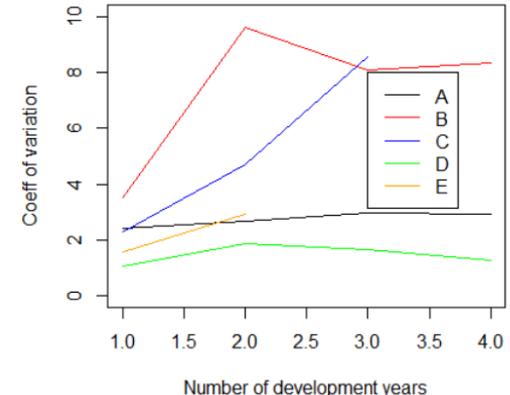
Motor third party case study
Computation of future payments for each type of claim

- We assess separately the IBNyR and RBNS reserves based on the individual model; this allows for computing the relative importance of the IBNyR both in number and amount:
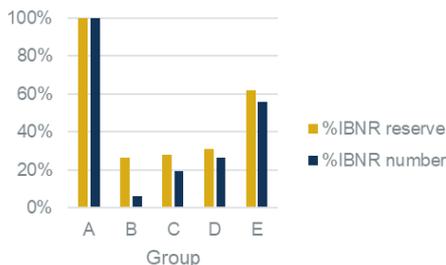
- The repartition between IBNyR and RBNS depends a lot on the group. In group B, for example, the expected number of IBNyR represents around 6% of the number of claims number to be paid (both RBNS and IBNyR), but up to 27% of the amount to be paid.

- The use of the individual model makes it possible to quantify the IBNR reserves in a coherent and appropriate way, in particular for the lines of business with high reporting delays.

- We compare the total reserve provided by the individual model with the Chain-Ladder prediction:
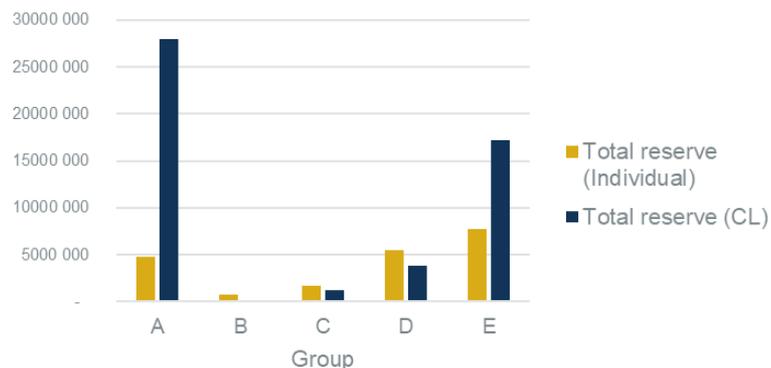
- The comparison shows that a Chain-Ladder approach produces a much higher reserve (for groups A and E) or a slightly lower reserve (for groups B, C, and D) compared to the individual model.

- The differentiated estimation makes the individual model particularly attractive for LOBs with complex and/or atypical development.

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Motor third party case study
Prediction error and comparison with Mack model

- The graph below represents the coefficient of variation (standard deviation divided by expectation) for the estimation error and the process error. It also makes the comparison between the individual model the Mack model.

Coefficients of variation

Legend:
- □ CV Mack Model (Process error)
- ▨ CV Individual Model (Process error)
- ▦ CV Mack Model (Estimation error)
- ■ CV Individual Model (Estimation error)

Group: E, D, C, B, A
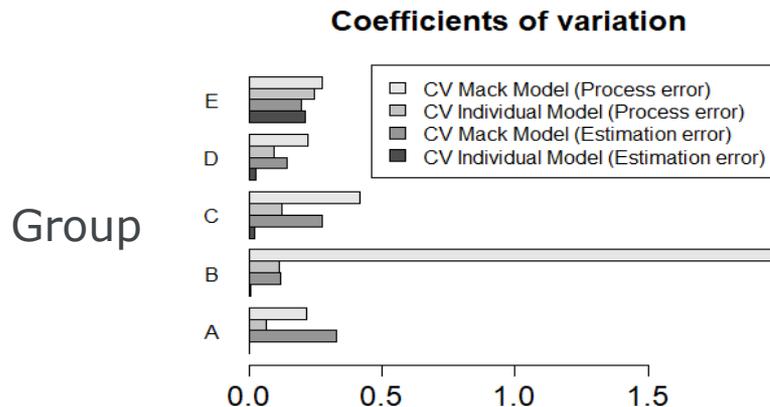
- The estimation error is clearly reduced with the individual model, which is a fundamental property. The individual model takes advantage of the detailed claims information ('line-by-line') in order to calibrate more reliably, and relies on a more 'natural' specification of the model into several sub-blocks (occurrence, reporting, payment, flow, …) which avoids errors of parametrization at the aggregated level.

- The process error is also reduced in the individual model, thanks to its specification. In this case study, use of the Poisson is intrinsically less dispersed compared to distribution free Mack model.

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Medical malpractice case study

Medical malpractice case study
Database description
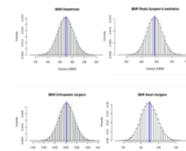
- The database used is made of **Medical malpractice claims of several origins** (classified into 8 groups).

- There are **19870 observed claims** in the database, including 6121 settled claims and 13749 reported but not yet settled (RBNS).

- For each claim, we potentially have the following **information**:

  - Occurrence date

 - Declaration date

  - Payment dates and associated amounts

  - Closing date

Observed occurrence dates

Observed reporting delays
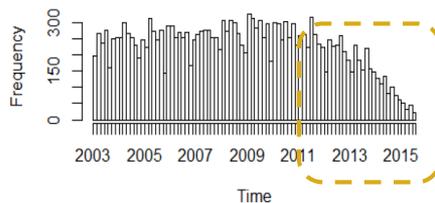
IBNyR-related observation bias
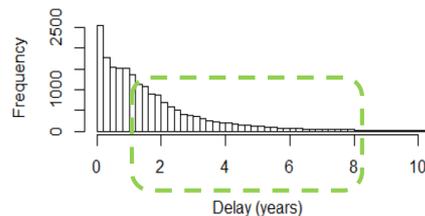
Line of business with particularly long reporting delays

Medical malpractice case study
Occurrence/reporting model calibration
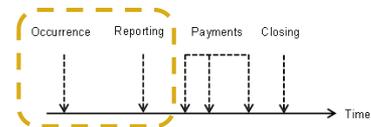
- Calibration of occurrence frequencies and reporting delays are given below for each of the 8 groups considered:

Occurrence frequency	Average reporting delay

Occurrence frequency

- The frequency of claims occurrence is captured (in red) by the model, **restoring the bias related to non-observation of IBNyR**.

- A calculation directly based on observation (in blue) would underestimate the frequency of claims occurrence.
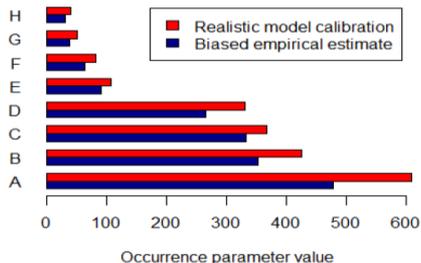
Average reporting delay

- The **reporting delays calibrated by the model** (in red) capture the specific reporting dynamics for each of the 8 groups

- A 'naive' estimate (in blue) would lead to an underestimation of the reporting delay (claims with a low reporting delay are over-represented in the sample).
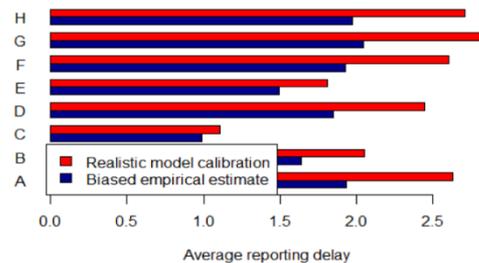
Medical malpractice case study
IBNR simulation, backtesting and comparison with Mack model

- In order to have a comparative dataset, the individual model and the Mack Chain Ladder model (1993) are calibrated on a **common history of 5 years**.

  – Predicted values are then compared to real observed values of IBNyR (backtesting)
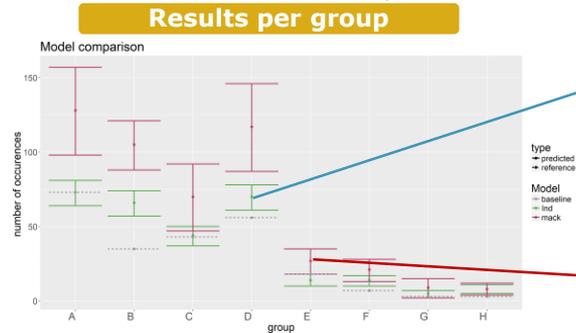
Prediction of IBNyR number with individual model

Prediction of IBNyR number with Mack Chain Ladder model

- Higher **predictive power** of the individual model in this context

- The Mack Chain Ladder approach seems to **overestimate** the number of IBNyR claims

- The Mack Chain Ladder approach involves relatively huge **uncertainty around the prediction**

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Medical malpractice case study
Calibration of payments and settlement frequencies (1/2)
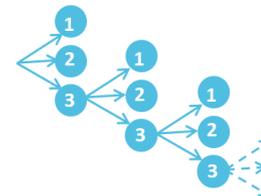
- Computation **of the frequency parameters** related to **payments** and **settlement**.
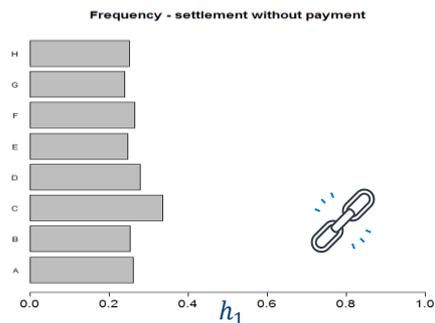
1 **Settlement without payment**   **2** **Settlement with payment**   **3** **Payment without settlement**
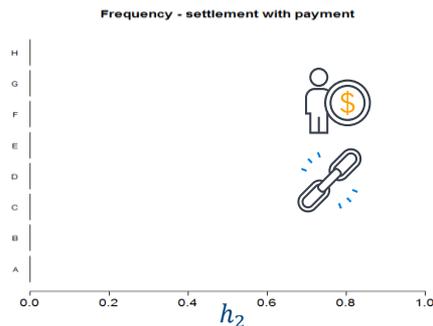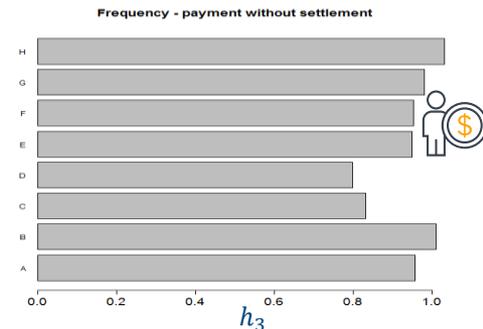
- Both settlement frequencies (1) and payments without settlement (3) are of the **same order of magnitude** (note that this database contains a negligible number of settlements with payment (2)).

- One can identify that group C is characterized by both **a shorter claims history** (1) and a **low payment frequency** (3). This contrasts with group B, with a larger time to settlement, and more frequent payments during the claims paths.

Medical malpractice case study
Calibration of payments and settlement frequencies (2/2)

- Refinement of the calibration to allow **for time-varying frequency parameters**: the frequencies are allowed **to vary from one claims development period to the next.**

    - This makes it possible to have a **more realistic model** and to anticipate the future dynamics of **claims according to their development time.**

1 **Settlement without payment**
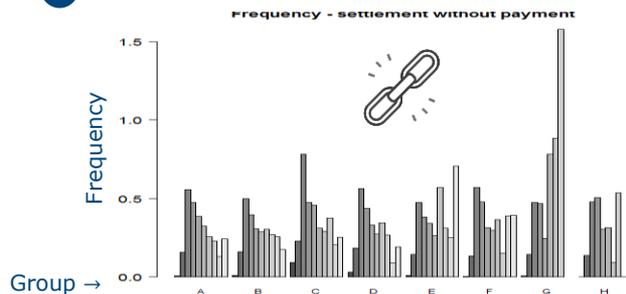
2 **Payment without settlement**
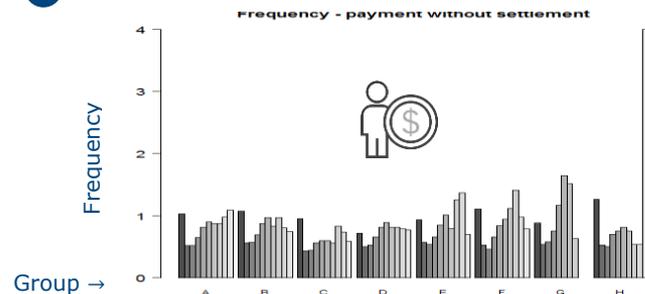
- **Closing frequencies** (1) are maximum for the majority of groups for claims of age around 3 years; these estimates **characterize claims with a high potential for long-term development**: these are rather 8-9 years old and belong to groups A to D (low frequencies)

- **Payments (without settlement) frequency** (3) show a very different pattern: here they indicate that an IBNR (zero age) claim has **potentially more future payments** in the short term than claims that have been developed for 2 to 3 years

Medical malpractice case study
Computation of future payments for each type of claim

- The closed formulas that we have developed make it possible to instantly compute the **expected payments and the associated variance** (prediction error) for each type of claim (group) and according to its duration of development.


Expected future payments

Variance of future payments
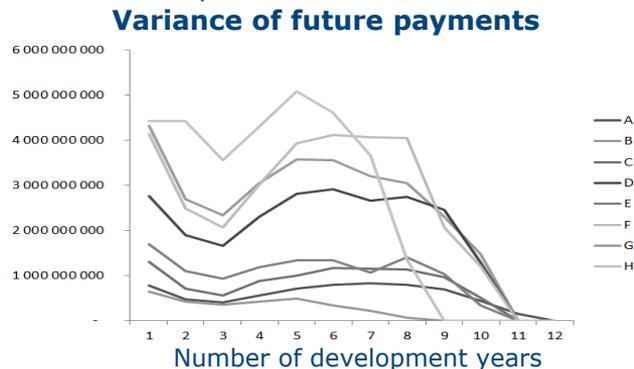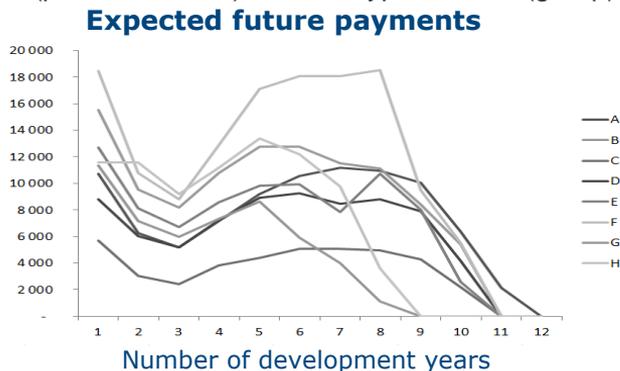
- Depending on the duration of development, the expected future payments decrease aver the first 3 years, due to the combination of a decrease in payment frequency and a growth in the settlement frequency (see previous slides).
- Expected payments then increase for more developed claims, due to a reduction in the settlement frequency after the 3-year barrier.
- This example illustrates the benefit of an analysis of development times, and in particular the bias due to the use of standard frequency x severity models (notably for the evaluation of reinsurance).

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Medical malpractice case study
Computation of future payments for each type of claim

- We assess separately the IBNyR and RBNS reserves based on the individual model; this allows for computing the relative importance of the IBNyR both in number and amount:
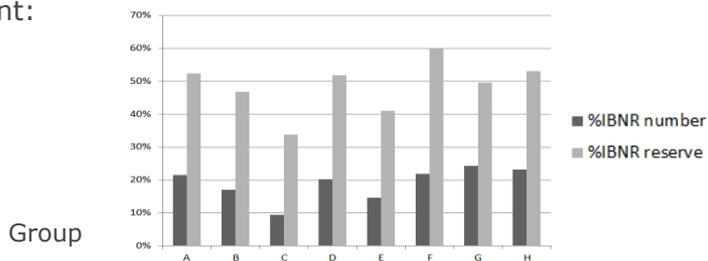
- Although the expected number of IBNyR represents around 20% of the claims number to be paid (both RBNS and IBNyR), in terms of amounts this represents here around 50%.

- The use of the individual model makes it possible to quantify the IBNR reserves in a coherent and appropriate way, in particular for the lines of business with high reporting delays.

- We compare the total reserve provided by the individual model with the Chain-Ladder prediction:
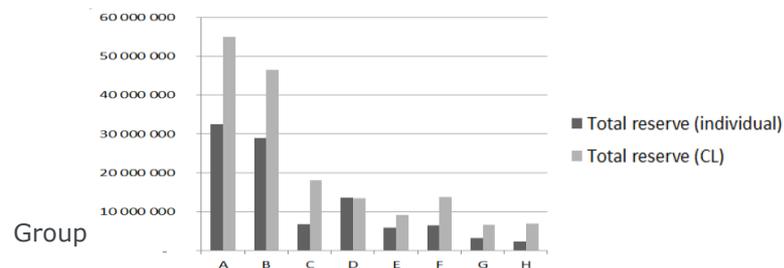
- The comparison between methods shows that Chain-Ladder provides higher reserves compared to the individual model.

- The differentiated estimation makes the individual model particularly adapted to the lines of business with complex and/or atypical development.

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Medical malpractice case study
Prediction error and comparison with Mack model

- The graph below represents the coefficient of variation (standard deviation divided by expectation) for the estimation error and the process error. It also makes the comparison between the individual model the Mack model.

Coefficients of variation

Group

Legend:
- CV Mack Model (Process error)
- CV Individual Model (Process error)
- CV Mack Model (Estimation error)
- CV Individual Model (Estimation error)
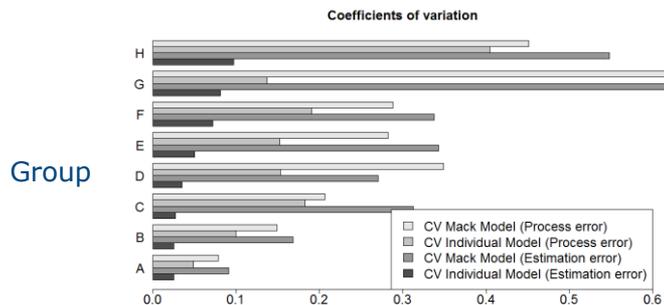
- The estimation error is clearly reduced with the individual model, which is a fundamental property : the model takes advantage from detailed claims information ('line-by-line') to make calibration more reliable, and relies on a more 'natural' specification of the model into several sub-blocks (occurrence, reporting, payment, flow, …) which avoids errors of parametrization at the aggregated level.
- The process error is also reduced in the individual model, thanks to its specification: Poisson modeling is intrinsically less dispersed compared to Mack's Markov chain model.
  Current modeling can easily be extended to more dispersed stochastic frameworks, depending on the calculation objectives and the risk indicators to be considered.

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Questions

Comments

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