Comparing Micro- and Macro-Level Loss Reserving Models

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Outline

1. Introduction
2. Motivation
3. Model Specification
4. Simulation Procedure
5. Results
6. Concluding Remarks
Definition of Loss Reserve

A loss reserve represents the insurer’s estimate of its outstanding liabilities for claims that occurred on or before a valuation date.

Figure: Development of a Property and Casualty Claim.
### Loss Reserving Methods

<table>
<thead>
<tr>
<th>Model</th>
<th>Characteristic</th>
<th>Output</th>
<th>Popularity</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-stochastic macro-level</td>
<td>Deterministic computation algorithms using aggregate claims data</td>
<td>Point estimate of the outstanding liability</td>
<td>Widely used by practitioners</td>
<td>Friedland (2010)</td>
</tr>
<tr>
<td>models</td>
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<tr>
<td>Stochastic macro-level</td>
<td>Stochastic models using aggregate claims data</td>
<td>First two moments or predictive distribution of the reserve estimate</td>
<td>Extensively studied by researchers, but not widely used by practitioners</td>
<td>England &amp; Verrall (2002), Wüthrich &amp; Merz (2008)</td>
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<tr>
<td>Stochastic micro-level</td>
<td>Stochastic models using individual claim level data</td>
<td>Predictive distribution of the reserve estimate</td>
<td>Emerged in a small steam of academic literature, not used by practitioners</td>
<td>Norberg (1993, 1999), Antonio &amp; Plat (2012)</td>
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</table>
Features of a typical micro-level reserving model

- Has a hierarchical structure with several blocks.
- Each block models a type of event during claim development process.
- Different covarites can be incorporated in each block of the model.
Motivation

- Accurate Reserves are Important
- Actuaries’ professional responsibilities
- Limitations of macro-level models / Advantages of micro-level models
- Extensions to the literature on micro-level reserving
Accurate Reserves are Important

Industry Facts

- U.S. P&C Industry statutory reserve as of EOY 2011 is near $600 billion.
- 40% of actuaries work in the reserving field.

- It is a Liability
  - Under-reserving may result in failure to meet the claim liabilities and even insolvency of the insurer.

- It is a Cost
  - A reference for insurance pricing, profitability, and capital allocation.

- It is a Requirement
  - Largest liability on insurers’ balance sheets and financial statements.
  - Over-reserving makes the insurers appear to be financially weaker than they are.
Greg Taylor (1985):

“... Each actuary involved in the estimation of outstanding claims is under a professional obligation to provide his client with the best quality estimate of which he is capable. It is this obligation, ..., which will provide the stimulus for further refinements of claims analysis techniques in the future.”
### Key Assumption
Claims development patterns do not vary substantially over accident years. Requires relatively stable internal and external environment. When the chain-ladder assumption is violated, material errors in the reserve estimates may appear.

### Basic Chain-Ladder Method

#### Accident Year

<table>
<thead>
<tr>
<th>Year</th>
<th>12</th>
<th>24</th>
<th>36</th>
<th>48</th>
<th>60</th>
<th>72</th>
<th>84</th>
<th>96</th>
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#### Key Assumption

Claims development patterns do not vary substantially over accident years.

- Requires relatively stable internal and external environment.
- When the chain-ladder assumption is violated, material errors in the reserve estimates may appear.
Extensions to Basic Chain-Ladder Method

Trending Techniques
- Treat the impact of environmental changes as a trend over accident years.
- Estimate the trend rate with the observed development and adjust the projection of future development with the trend rate.

Using actuarial judgments
- The projection of ultimate losses are totally or partially determined by a prior estimate.
Limitations of Macro-Level Models

Essential Limitation

Lots of useful micro-level information about the claims development cannot be incorporated in the reserving model.
Limitations of Macro-Level Models

Essential Limitation

Lots of useful micro-level information about the claims development cannot be incorporated in the reserving model.

- Unable to investigate the impact of insureds’ behavior on claims development
- Not suitable for a rapidly changing book of business
- Not suitable for long-tail lines of business with highly heterogenous claims.
- Based on a small dataset (cells in a run-off triangle)
The literature on micro-level reserving is in its infancy.

A “down-to-earth" micro-level model with less complicated specifications.

A side-by-side comparison of micro- and macro-level models under various scenarios with simulated data.

The target audience is not only academics but also practicing actuaries.
Hierarchical model with five blocks
Specification for the Micro-Level Model

- Hierarchical model with five blocks
  - Block 1: claim occurrence time – Uniform Distribution
Hierarchical model with five blocks

- Block 1: claim occurrence time – Uniform Distribution
- Block 2: reporting delay – 0 or Poisson distribution
Hierarchical model with five blocks

- **Block 1**: claim occurrence time – Uniform Distribution
- **Block 2**: reporting delay – 0 or Poisson distribution
- **Block 3**: transaction occurrence time – Survival model for recurrent events
Hierarchical model with five blocks

- Block 1: claim occurrence time – Uniform Distribution
- Block 2: reporting delay – 0 or Poisson distribution
- Block 3: transaction occurrence time – Survival model for recurrent events
- Block 4: transaction type – Multinomial logistic model
- Block 5: payment amount in each transaction – Log-normal model
Hierarchical model with five blocks

- **Block 1**: claim occurrence time – Uniform Distribution
- **Block 2**: reporting delay – 0 or Poisson distribution
- **Block 3**: transaction occurrence time – Survival model for recurrent events
- **Block 4**: transaction type – Multinomial logistic model
- **Block 5**: payment amount in each transaction – Log-normal model
Simulation Routine

**Generation**

\[ D(\theta) \rightarrow P/F \quad R = \sum \text{Payment on } F \]

**Estimation**

\[ P \rightarrow \hat{\theta} \]

**Prediction**

\[ D(\hat{\theta}) \rightarrow \hat{F}_1, \hat{F}_2, \ldots, \hat{F}_B \]

\[ \hat{R}_b = \sum \text{Payment on } \hat{F}_b \]

\[ \hat{R} = \frac{1}{B} \sum \hat{R}_b \quad RE = \frac{\hat{R} - R}{R} \times 100\% \]

**Evaluation**

\[ RE_1, RE_2, \ldots, RE_A \rightarrow \text{Distribution of } RE \]

A=number of samples; B=number of projections for each sample
Scenarios

- **Steady**

- **Changes in Product Mix**
  - Two types of claims: Type 1 ($X=0$), Type 2 ($X=1$)
  - Type 2 claims develop faster than Type 1 claims.
  - The proportion of Type 2 claims increases over accident years.

- **Changes in Regulation**
  - Claims occurred after the effective date of a new regulation develop faster than those occurred before the effective date.

- **Changes in Claims Processing**
  - Claims develop faster after a new claims processing scheme is launched.

- **Inflation**
  - Claim payments escalate with inflation.
  - Three inflation structures are used: stable, jump, increasing.

- **Mixed (changes in product mix under inflation)**
Methods under Consideration

- Basic chain-ladder
- Trended chain-ladder
  — Chain-ladder with trending techniques
- Micro-level model
- Micro-level model with omitted covariates
  — Intentionally omit covariates in the estimation and prediction routines
Results: Steady Environment

Figure: Percentage Reserve Error Distributions. Black: basic chain-ladder; blue: micro-level model.
Results: Steady Environment

Figure: Percentage Reserve Error Distributions. Black: basic chain-ladder; blue: micro-level model.

- Both distributions are centered around 0. No material errors are observed in either method.
Given the simplicity of the chain-ladder method, it is remarkable how close the two distributions are.
The reserve error given by the micro-level model appears to have smaller variation. This is likely to be a result of the much more extensive information used by the micro-level model.
Results: Changes in Product Mix

Figure: Black: basic chain-ladder; blue: micro-level; red: trended chain-ladder; green: micro-level with omitted covariates. The difference in the claims development speed becomes larger going from Case 1 to Case 3.
Results: Changes in Product Mix

Figure: Black: basic chain-ladder; blue: micro-level; red: trended chain-ladder; green: micro-level with omitted covariates. The difference in the claims development speed becomes larger going from Case 1 to Case 3.

- The chain-ladder reserve estimates are over-estimating the outstanding liability. The over-estimation increases from Case 1 to Case 3.
Results: Changes in Product Mix

Figure: Black: basic chain-ladder; blue: micro-level; red: trended chain-ladder; green: micro-level with omitted covariates. The difference in the claims development speed becomes larger going from Case 1 to Case 3.

- Reserve estimates given by the micro-level model do not appear to have material errors.
Figure: Black: basic chain-ladder; blue: micro-level; red: trended chain-ladder; green: micro-level with omitted covariates. The difference in the claims development speed becomes larger going from Case 1 to Case 3.

- Trending reduces reserve errors, but the variation becomes much larger.
Results: Changes in Product Mix

Figure: Black: basic chain-ladder; blue: micro-level; red: trended chain-ladder; green: micro-level with omitted covariates. The difference in the claims development speed becomes larger going from Case 1 to Case 3.

- When the covariate is omitted, the micro-level model also over-estimates the outstanding liability.
Summary of Simulation Results

- The basic chain-ladder forecasts are comparable to the micro-level forecasts under a stable environment.

- Under a changing environment, the chain-ladder assumption no longer holds, resulting in material errors in the reserve estimates.

- Micro-level models are able to efficiently identify and measure the impact of the environmental changes, and the use of extensive micro-level information reduces the reserve uncertainty, leading to reserve estimates with smaller errors and lower variation.

- The trending technique does help to reduce the material errors in the chain-ladder estimates, but it also introduces big additional uncertainties.
Concluding Remarks

- For actuaries responsible for setting reserves, this study highlights scenarios in which micro-level models might be desirable.

- Particular attention should be paid when setting reserves for a highly heterogeneous book of business under a changing product mix.

- The simulation study provides quantitative evidence to rationalize the further investigation of micro-level reserving with empirical data. The hierarchical model can be easily generalized to applications with empirical data.