The Marginal Value of Individual Rating Factors in Pricing

11-14 October 2011

Agenda

• Introduction
• Previous analysis
• Modelling options
• Further thoughts and game theory
• Conclusion

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Introduction

• There may soon be more restriction on factors that can be used in pricing
  – Gender Directive
  – Postcode discrimination – Jack Straw’s bill
  – Age?
  – Credit score?
• How will one single factor affect pricing model?
• Any solutions to reduce the impact?
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Previous Analysis

- There are several papers thoroughly analyse the impact of excluding one single factor, from view of
  - Consumer
  - Insurer/shareholder
  - Whole society
- ABI report
- CEA report
- Also study from USA where similar restriction is applied in some states
Previous Analysis

- First order impact
  - Redistribution
    - Low-risk overpays to subsidise high-risk
  - GLM
- Second order impact
  - Market wide
    - High-risk tend to buy more insurance
    - Mixture of risk will change overall
  - Company wide
    - Similar change, but depends on company strategy
- A single factor could have significant impact on rating structure

Focus of this workshop

- How to build a better rating structure when a single factor is excluded from model?
- Focus on modelling technique

- There are other considerations to this issue
  - Other source of information/data
    - On-going
    - Expense
  - Interpretation of rules
    - Renewal
    - Indirect discrimination
Focus of this workshop

- Other considerations
  - Telematics
    - Technique
    - Practice
    - Privacy
  - Strategy

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Option 1: Drop the single factor out of rate table

• Method
  – Drop the single factor out of all rating tables without refreshing model.
  – Need to make assumption on mixture when drop it from multi-way tables
    – The assumption could be made from historical data as well as judgement
  – Example: Gender & Age
    – Assumption of gender distribution by age

Option 1: Drop the single factor out of rate table

• Advantage
  – Simple to implement

• Issue
  – Parameters of other factors in the model might change
  – The assumption of distribution of the single factor in multi-way table might be difficult to make
    – Table is more than two ways
      • Smoothing
    – Distribution might change before and after excluding the single factor
Option 2: Refresh GLM

- Method
  - Exclude the single factor from the model setting
  - Train a GLM on historical available data
- Advantage
  - GLM is a standard practice in industry
  - Simple to explain/implement
  - Parameters of other factors in the model will adjust automatically.

Option 2: Refresh GLM - Issue

- It assumes that the correlation between factors won’t change in the future
  - Might not be true when rating structure is changing significantly
    - Age & Car age
    - Age & Car Value
- Output of GLM depends on the mixture of book/correlation between factors if the true model structure underlying the data is not linear.
Option 2: Refresh GLM - Issue

• If the true model structure underlying the data is linear, GLM result is independent of mixture of book.
• Example 1: true structure is multiplicatively linear

<table>
<thead>
<tr>
<th>Relativity</th>
<th>Factor 1 - A</th>
<th>Factor 1 - B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor 2 - 1</td>
<td>1</td>
<td>1.2</td>
</tr>
<tr>
<td>Factor 2 - 2</td>
<td>1.7</td>
<td>2.04 (=1.2*1.7)</td>
</tr>
</tbody>
</table>

Option 2: Refresh GLM - Issue

• Standardized mixture of book

<table>
<thead>
<tr>
<th>Standardized Exposure</th>
<th>Factor 1 - A</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Factor 2 - 1</td>
<td>20</td>
<td>36</td>
</tr>
<tr>
<td>Factor 2 - 2</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

• Log link and Gamma distribution

<table>
<thead>
<tr>
<th></th>
<th>Parameter Estimation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.7129</td>
</tr>
<tr>
<td>Factor 1 - A</td>
<td>- 0.1823</td>
</tr>
<tr>
<td>Factor 2 - 1</td>
<td>- 0.5306</td>
</tr>
</tbody>
</table>
Option 2: Refresh GLM - Issue

- Different standardised mixture of book

<table>
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<th>Standardized Exposure</th>
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<td>36</td>
</tr>
<tr>
<td>Factor 2 - 2</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

- no matter what mixture of book is assumed, the output will be exactly same!

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Option 2: Refresh GLM - Issue

- Example 2: true structure is *not* multiplicatively linear

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</thead>
<tbody>
<tr>
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<td>1</td>
<td>1.2</td>
</tr>
<tr>
<td>Factor 2 - 2</td>
<td>1.7</td>
<td>2.55 (=1.5*1.7)</td>
</tr>
</tbody>
</table>

- Same Log link and Gamma distribution
- Apply the different assumption on the mixture of book
### Option 2: Refresh GLM - Issue

#### Standardized Exposure

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<tr>
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</thead>
<tbody>
<tr>
<td>Factor 1 - A</td>
<td>-0.1936</td>
</tr>
<tr>
<td>Factor 2 - 1</td>
<td>-0.6136</td>
</tr>
</tbody>
</table>

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</thead>
<tbody>
<tr>
<td>Factor 1 - A</td>
<td>0.8379</td>
</tr>
<tr>
<td>Factor 2 - 1</td>
<td>0.6498</td>
</tr>
</tbody>
</table>

#### Standardized Exposure

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</thead>
<tbody>
<tr>
<td>Factor 1 - A</td>
<td>0.8729</td>
</tr>
<tr>
<td>Factor 2 - 1</td>
<td>0.6833</td>
</tr>
</tbody>
</table>

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### Option 2: Refresh GLM - Issue

- High exposure segment have very limited impact
- Low exposure segment could change as much as 7%
Option 2: Refresh GLM - Issue

- This shows that for data with a non-linear underlying structure, the GLM estimation depends on the mixture of book
- A practical solution to this is to add interactive term into GLM to make it linear
- However, it is hard to check all factors to make sure the model is linear
- Need to be careful in using this approach

Option 3: Non-linear models

- When there is no evidence that the underlying data structure is linear, non-linear models could be used
- General benefit
  - Non-standard: competitive edge
  - Understand the risk better
  - Develop new rating factors
  - Identify profitable niche segment
- More software is available and become more standard
  - R
  - SAS
Option 3: Non-linear models: Decision tree

• Advantage
  – Simpler than other types of non-linear model
    – Much easier to understand
  – No assumption to make on distribution or function between response and explanatory variables
  – Model interactive term naturally
• Disadvantage
  – Result is normally worse than other non-linear models

Option 3: Non-linear models: GAM/GAMLSS

• Generalized additive model (1986)
  – Nonlinear/non-parametric estimation
  – But more parameters/method to choose when setting up the model than GLM
  – Difficult to model interactive term
  – The additive structure is less intuitive in insurance rating structure
  – Much less used than GLM
• Generalized additive model for Location, Scale and Shape GAM (2001)
  – Limited research on how it is compared to GLM
Option 3: Non-linear models : Neural Network

- Advantage
  - ‘Generalised’ GLM
  - Non-linear
  - Usually gives better result than GLM when set up properly

- Issue
  - Over-fit
    - Lack of statistical testing theory
  - Black-box
    - Lack of understand and difficult for communication

Option 4: Better model of other existing factors

- Other existing factors will become more important
  - More complicated structure

- NCD system
  - Markov chain
  - But treated as a normal rating factor within GLM.
- Claim history
- Conviction history
What if one company find another predictive factor?

- Consider a very simple scenario
  - Market consists of high-risk and low-risk only; High-risk need £600 to achieve required ROE and low-risk need £400
  - Company A – one rating factor, with premium £400 and £600, respectively
  - Company B – no rating factor, flat premium £500
- B will be selected against – write all high-risk and make loss
- A will write all low-risk and break even
What if one company find another predictive factor?

- However, B will realize its loss and, based on the claim experience, increase premium to £600
- B will write half of the high-risk, make even
- A will write all low-risk plus half of the high-risk, make even
- This state is stable…
- until A realise its advantage and increase premium for low-risk
  - A will then make profit

What if one company find another predictive factor?

- The advantage of extra rating factor need to be combined with acute market awareness to get real benefit
  - Mixture of book
  - Conversion
- Company with less rating factor can still run business in the high-risk segment
  - Volume will be limited
  - But not a problem for small/niche market player
- Pricing strategy and game theory
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### Conclusion

- Single factor could have a significant factor in pricing
- GLM might not work proper when the mixture of book change significantly;
- There are other options to improve model:
  - Non-linear models
  - Existing rating factor/system, such as NCD
- Strategic pricing become more important: game theory could be used in analysis.
Questions or comments?

Expressions of individual views by members of The Actuarial Profession and its staff are encouraged.

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