ABSTRACT

At the 7th Global Conference of Actuaries in New Delhi, India, in 2005, Swiss Re presented a paper entitled “Experience Studies and its Feedback into the Actuarial Control Cycle” following which the audience expressed interest in issues relating to the interpretation of the results of experience studies and to what extent this can be applied in pricing etc.

At this 8th Global Conference of Actuaries in Mumbai, India, we take a closer look at interpretation issues in our paper entitled “Experience Studies – Interpretation, Insights and Additional Techniques”. We ask what conclusions can be drawn from the analysis and what additional information can be gleaned from the findings of the study. The Paper also touches on industry benchmarking and performance monitoring.

Finally, the application of additional techniques, using the Cox Model in providing further insights is discussed.

KEYWORDS
Homogeniety; Credibility; Selection Effect; IBNR; Data Adequacy; Benchmarking; Performance Monitoring; Cox Proportional Hazard Ratios
Experience Studies – Interpretation, Insights and Additional Techniques

Agenda

- Interpretation
  - Review of Experience Analysis Results
  - Illustrations

- Insights
  - Industry Benchmarking
  - Performance Monitoring

- Additional Techniques
  - Cox Model
Review of Experience Analysis Results

Assess the Following:
- Homogeneity
- Credibility
- IBNR
- Selection Effect
- Data Adequacy
- Trends

Interpretation
- What Can Be Concluded?
- Further Investigations

Review of Experience Analysis Results - Homogeneity

Segregation by Homogenous Groups
- Male, Female, Age-banded Cells
- Duration 0, 1, 2+
- Mortgage vs. Non-mortgage
- Fully Underwritten Business Only
- Medical vs. Non-medical
- Treatment of Substandard Lives
- With or Without Acceleration Benefits
- Changes in Disability or Other Definitions
Review of Experience Analysis

Results - Credibility

Experience Rating involves the application of Bayesian Credibility Theory to pricing:

\[
\text{Rate Charged} = Z \times \text{Actual Experience} + (1 - Z) \times \text{Expected Experience}
\]

Where:

\[ Z = \sqrt{N_c / N_r} \]

- \( N_c \) = Expected number of claims
- \( N_r \) = Claims required for full credibility

\[ Z = 100 \quad \text{(for 95\% chance of being within 20\%)} \]
\[ 400 \quad \text{(for 95\% chance of being within 10\%)} \]

Review of Experience Analysis

Results - IBNR

- Errors Have Serious Pricing Implications
- New (Complex) Products -
  - Delayed Awareness of Ability to Claim!!

IBNR - Run-Off Pattern

- % Claims Reported

% Claims Reported vs. Months

0\% 20\% 40\% 60\% 80\% 100\% 120\%
**Review of Experience Analysis**

**Results – Selection Effect**

- Growing Life Office – Highly Select Portfolio?
- Uncertainty in Selection Effect
- Driven by Quality of Underwriting, Type of Risks

<table>
<thead>
<tr>
<th>Duration</th>
<th>ETR</th>
<th>Proportion</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>50,000</td>
<td>50%</td>
</tr>
<tr>
<td>2</td>
<td>30,000</td>
<td>30%</td>
</tr>
<tr>
<td>3</td>
<td>15,000</td>
<td>15%</td>
</tr>
<tr>
<td>4</td>
<td>5,000</td>
<td>5%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100,000</td>
<td>100%</td>
</tr>
</tbody>
</table>

*Weighted Average Duration = 1.75*

**Review of Experience Analysis**

**Results – Data Adequacy**

- Were the Data Checks Comprehensive?
  - Complete List of Standard Checks
  - Skills for Spotting “Unusual” Errors
- Lapses, Terminations
- Data Issues Highlighted in Report
  - Were They Resolved?
  - Limitations on Conclusions That Can Be Drawn
Review of Experience Analysis
Results – Data Adequacy

Were the Data Checks Comprehensive?
- Complete List of Standard Checks
- Skills for Spotting “Unusual” Errors

Lapses, Terminations

Data Issues Highlighted in Report
- Were They Resolved?
- Limitations on Conclusions That Can Be Drawn

Illustration 1
Accidental Deaths

<table>
<thead>
<tr>
<th>Age Last</th>
<th>Male Actual</th>
<th>Male Expected</th>
<th>A/E</th>
<th>Female Actual</th>
<th>Female Expected</th>
<th>A/E</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 18</td>
<td>13</td>
<td>31.8</td>
<td>41%</td>
<td>12</td>
<td>12.5</td>
<td>96%</td>
</tr>
<tr>
<td>19 to 28</td>
<td>151</td>
<td>117.9</td>
<td>128%</td>
<td>34</td>
<td>31.5</td>
<td>108%</td>
</tr>
<tr>
<td>29 to 38</td>
<td>103</td>
<td>130.6</td>
<td>79%</td>
<td>33</td>
<td>32.5</td>
<td>102%</td>
</tr>
<tr>
<td>39 to 48</td>
<td>81</td>
<td>90.6</td>
<td>89%</td>
<td>24</td>
<td>25.8</td>
<td>93%</td>
</tr>
<tr>
<td>49 to 58</td>
<td>38</td>
<td>28.2</td>
<td>135%</td>
<td>8</td>
<td>7.7</td>
<td>104%</td>
</tr>
<tr>
<td>59 to 68</td>
<td>9</td>
<td>7.3</td>
<td>123%</td>
<td>2</td>
<td>2</td>
<td>98%</td>
</tr>
<tr>
<td>69 to 78</td>
<td>3</td>
<td>1.3</td>
<td>227%</td>
<td>0</td>
<td>0.5</td>
<td>0%</td>
</tr>
<tr>
<td>79 to 88</td>
<td>0</td>
<td>0.2</td>
<td>0%</td>
<td>0</td>
<td>0.1</td>
<td>0%</td>
</tr>
<tr>
<td>All Ages</td>
<td>398</td>
<td>407.9</td>
<td>98%</td>
<td>113</td>
<td>112.5</td>
<td>100%</td>
</tr>
</tbody>
</table>

Understated Accident Hump
Insufficient Credibility at Higher Ages
Illustration 2
UK Critical Illness Experience

<table>
<thead>
<tr>
<th>Year</th>
<th>Duration 0</th>
<th>Duration 1</th>
<th>Duration 2</th>
<th>All Durations</th>
<th>No of Claims</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>52%</td>
<td>87%</td>
<td>71%</td>
<td>70%</td>
<td>115</td>
</tr>
<tr>
<td>1992</td>
<td>58%</td>
<td>53%</td>
<td>58%</td>
<td>57%</td>
<td>119</td>
</tr>
<tr>
<td>1993</td>
<td>29%</td>
<td>38%</td>
<td>54%</td>
<td>46%</td>
<td>119</td>
</tr>
<tr>
<td>1994</td>
<td>38%</td>
<td>59%</td>
<td>53%</td>
<td>52%</td>
<td>162</td>
</tr>
<tr>
<td>1995</td>
<td>28%</td>
<td>47%</td>
<td>46%</td>
<td>44%</td>
<td>160</td>
</tr>
<tr>
<td>1996</td>
<td>26%</td>
<td>42%</td>
<td>52%</td>
<td>47%</td>
<td>200</td>
</tr>
<tr>
<td>1997</td>
<td>27%</td>
<td>35%</td>
<td>55%</td>
<td>50%</td>
<td>240</td>
</tr>
<tr>
<td>1991-1997</td>
<td>37%</td>
<td>51%</td>
<td>54%</td>
<td>50%</td>
<td>1,115</td>
</tr>
</tbody>
</table>

Source: UK CI Experience Study 1991-1997

Decreasing Trend
- Portfolio Changes
- Improving Experience?
- IBNR understated

Increasing Trend
- Anti-selection?
- Increasing Duration

Industry Benchmarking

Basic Comparison with LIC 94-96

Additional Benchmarking Can Provide Further Insights:
- Portfolio Composition of Company vs. Industry
  - Male vs. Female
  - Age Profile
- Selection Effect of Company vs. Industry
- Rider Attachment Ratios of Company vs. Industry
- Cause of Claim Statistics of Company vs. Industry
Performance Monitoring

- Quality of Underwriting
- Policy Definitions
- Claims Management
- Agent Behaviour
- Loopholes Exploited
- Mis-pricing by Segment
- Operational/Data Issues
- Profitability

Experience Studies

Additional Techniques - Cox Proportional Hazard Model

- Statistical Technique to investigate the relationship between several explanatory variables on an outcome variable at the same time

\[ Y_i = b_0 + b_1 X_{1i} + b_2 X_{2i} + \cdots + b_p X_{pi} + e_i \]

- Modelling approach to the analysis of Survival data

- Assessing confounding bias
Additional Techniques – Cox Proportional Hazard Model

\[ h(t) = \frac{\text{Number of Individuals experiencing an event in interval beginning at } t}{\text{Number of Individuals surviving at time } t \times \text{Interval width}} \]

\[ h(t) = h_0(t) \cdot \exp(b_{\text{age}} \cdot \text{age} + b_{\text{duration}} \cdot \text{duration} + \ldots + b_{\text{location}} \cdot \text{location}) \]

- \( b_0(t) \) = Baseline/Underlying Hazard Function
- Probability of dying (or reaching an event) when all explanatory variables are zero
- Analogous to the Intercept in ordinary regression

Additional Techniques – Cox Model

Interpreting Results

Q: How might you compare each person’s risk to that of the “baseline individual”?

Average comparative risk

Low comparative risk

High comparative risk

<table>
<thead>
<tr>
<th>Covariates</th>
<th>HR</th>
<th>95% CI</th>
<th>Stat.</th>
<th>p</th>
<th>z</th>
<th>p*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product</td>
<td>P&amp;M, Mortgage</td>
<td>1.38</td>
<td>(1.14, 1.67)</td>
<td>0.17</td>
<td>0.770</td>
<td>0.443</td>
</tr>
<tr>
<td></td>
<td>Savings, Mortgage</td>
<td>1.01</td>
<td>(0.71, 1.43)</td>
<td>0.19</td>
<td>2.380</td>
<td>0.018</td>
</tr>
<tr>
<td></td>
<td>Term, Mortgage</td>
<td>1.08</td>
<td>(0.72, 1.61)</td>
<td>0.12</td>
<td>1.480</td>
<td>0.071</td>
</tr>
<tr>
<td>Gender</td>
<td>Female, Male</td>
<td>0.84</td>
<td>(0.44, 0.70)</td>
<td>0.07</td>
<td>4.970</td>
<td>0.000</td>
</tr>
<tr>
<td>Rating</td>
<td>05 : 87</td>
<td>1.00</td>
<td>(0.61, 1.61)</td>
<td>1.15</td>
<td>1.540</td>
<td>0.124</td>
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<tr>
<td>Duration</td>
<td>01 : 06+</td>
<td>0.60</td>
<td>(0.44, 0.88)</td>
<td>0.10</td>
<td>2.980</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>02 : 06+</td>
<td>0.71</td>
<td>(0.43, 1.15)</td>
<td>0.06</td>
<td>3.380</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>03 : 06+</td>
<td>1.11</td>
<td>(0.62, 1.42)</td>
<td>0.26</td>
<td>3.240</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>04 : 06+</td>
<td>0.83</td>
<td>(0.50, 0.96)</td>
<td>0.10</td>
<td>2.380</td>
<td>0.017</td>
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<tr>
<td></td>
<td>05 : 06+</td>
<td>0.78</td>
<td>(0.53, 1.14)</td>
<td>0.10</td>
<td>1.060</td>
<td>0.298</td>
</tr>
<tr>
<td>Sum</td>
<td>&gt; 150000 : &lt;= 150000</td>
<td>0.96</td>
<td>(0.66, 1.40)</td>
<td>0.14</td>
<td>0.600</td>
<td>0.255</td>
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<tr>
<td></td>
<td>Joint</td>
<td>0.99</td>
<td>(0.71, 0.87)</td>
<td>0.12</td>
<td>2.980</td>
<td>0.003</td>
</tr>
</tbody>
</table>

Interaction terms for joint life:

- Male x Joint
- Female x Joint
- Term x Joint
- Selection (duration 1-6) x Joint

* see explanation in text

What’s the best estimate level for a standard female policy holder issued under a joint life term policy with SA > 150000?
Additional Techniques - Cox Model

Using Results

**Caution:** Only make comparative statements about hazard.

- You can say that the hazard for one group is three times higher than that of another, but you cannot say how high, or low, either function is.

- This is the compromise associated with Cox regression.

### Best estimate =

\[
0.73 \times 0.56 \times 0.88 \times 2.6 \times 1.39 = 68.5\%
\]

---

**Sample Data**

<table>
<thead>
<tr>
<th>id</th>
<th>time0</th>
<th>time1</th>
<th>fracture</th>
<th>protect</th>
<th>age</th>
<th>calcium</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>10</td>
<td>15</td>
<td>0</td>
<td>0</td>
<td>72</td>
<td>9.46</td>
</tr>
<tr>
<td>19</td>
<td>15</td>
<td>22</td>
<td>1</td>
<td>0</td>
<td>72</td>
<td>9</td>
</tr>
<tr>
<td>20</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>67</td>
<td>11.19</td>
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<tr>
<td>20</td>
<td>5</td>
<td>15</td>
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<td>0</td>
<td>67</td>
<td>10.68</td>
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<td>20</td>
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<td>10.46</td>
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<td>21</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>82</td>
<td>8.97</td>
</tr>
<tr>
<td>21</td>
<td>5</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>82</td>
<td>7.25</td>
</tr>
<tr>
<td>22</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>80</td>
<td>7.98</td>
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<tr>
<td>22</td>
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<td>73</td>
<td>7.67</td>
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<tr>
<td>23</td>
<td>5</td>
<td>7</td>
<td>1</td>
<td>1</td>
<td>73</td>
<td>9.29</td>
</tr>
</tbody>
</table>
Slide 19

Additional Techniques - Cox Model
Estimating baseline cumulative hazard function

Slide 20

Additional Techniques - Cox Model
Estimating the baseline hazard function

Written for and presented at 8th GCA, Mumbai 10-11 March, 2006
### Additional Techniques - Cox Model Diagnostics

<table>
<thead>
<tr>
<th>Product</th>
<th>Occupation class</th>
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</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Graph" /></td>
<td><img src="image2.png" alt="Graph" /></td>
</tr>
</tbody>
</table>

If the proportionality assumption is violated for a predictor, then there is an interaction between the predictor and TIME.

<table>
<thead>
<tr>
<th>Sex</th>
<th>S4 bands</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3.png" alt="Graph" /></td>
<td><img src="image4.png" alt="Graph" /></td>
</tr>
</tbody>
</table>

### Issues to Consider

- Credibility
- Actuarial Judgement
- Modelling Interaction Factors
- Confounding Bias
- Stratification
**Slide 23**

### Additional Techniques - The Cox Model

#### Appendix

- **Likelihood function:**
  \[ L(\beta) = \prod_{i=1}^{n} \left\{ \frac{f(t_i, \beta, x_i)}{S(t_i, \beta, x_i)^{\delta_i}} \right\} \]

- **Survivorship function:** probability that a subject with covariate value \(x\) survives at least \(t\) time units

- **Hazard Rate:**
  \[ h(t) = h_0(t) \cdot \exp(\beta_1 x_1 + \ldots + \beta_k x_k) \]

- **Hazard Ratio:**
  \[ HR(t, x_1, x_2) = \frac{h(t, x_1)}{h(t, x_2)} = \frac{h_0(t) \cdot \exp(\beta x_1)}{h_0(t) \cdot \exp(\beta x_2)} = \frac{\exp(\beta x_1)}{\exp(\beta x_2)} = \exp^{\beta(x_1 - x_2)} \]

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**Slide 24**

### Thank You
About the Authors:

**Rani Rajasingham**
Rani Rajasingham graduated with a degree in Physics from Oxford University, UK and qualified as a Fellow of the Institute of Actuaries, UK in 2001. She also has a post-graduate diploma in Actuarial Science from the University of Cape Town, South Africa.

Rani joined Swiss Re in Singapore in May 2004, and is currently with Swiss Re Services India Private Limited, Mumbai, India on International Assignment. Prior to joining Swiss Re, she worked with Life Insurance Companies in Malaysia and Singapore for 10 years and earlier, with a UK Actuarial Consultancy.

She represents the Singapore Actuarial Society (SAS) in the Insurance Accounting Committee of the International Actuarial Association and was on the SAS Guidance Note sub-committee.

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**Ramesh Baluswamy**
Ramesh is a student actuary from the Actuarial Society of India and the Institute of Actuaries, UK. Besides he is also a qualified management accountant from the Institute of Cost and Work Accountants, India and holds a post-graduate diploma in Actuarial Science from the Bharathidasan University, India.

Ramesh joined the SwissRe Shared Services Unit at Bangalore in May 2005 to lead the Experience Studies team. Prior to joining SwissRe he had worked with GE Capital International Services for close to 5 years and earlier to that was with a Management Consultant Firm.

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