Risk Based Capital (RBC) Reserve Risk Charges—Standard Formula vs. Individual Company Assessments

Report 10 of the CAS RBC Dependencies and Calibration Working Party (DCWP)

Abstract: This paper compares the results of measuring reserve risk factors (RRFs) (a) from the standard formula approach described in DCWP Report 7 against (b) three types of individual company reserve risk assessments, Mack,[1] stochastic loss development[2] and the newer Correlated Chain Ladder method.[3]

For 10-year Schedule P lines of business (LOBs) that we analyzed, we find that:

For personal LOBs, the two different calibration approaches produce similar RRFs, with the standard formula calibrations slightly lower;

For the larger commercial LOBs, the individual company RRFs are lower, often much lower, than the standard formula RRFs;

With any of the calibration approaches, RRFs nearly always decrease as LOB-size increases, measured either in terms of reserves or premium; and

Among the three types of individual company RRFs measurement approaches,

The Feldblum normal chain ladder (Normal CL) and normal Bornhuetter-Ferguson (Normal BF) simulation methods tend to produce the highest RRFs.

The Meyers correlated chain ladder, the Feldblum log-normal chain ladder method and Mack analytical method are similar and lower than the first two methods.

Our analysis did not allow us to conclude that the observed ordering of the five stochastic methods is statistically significant

The comparisons identify areas of similarity and areas of difference that warrant further research to more fully understand the implications of the different approaches in practice.

These results are based on a particular sample of companies and the robustness of these results needs testing with future research.

This is one of several papers being issued by the RBC DCWP.

Keywords: Risk-Based Capital, Capital Requirements, Analyzing/Quantifying Risks, Assess/Prioritizing Risks, Integrating Risks

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[1] Mack, Thomas "Distribution-Free Calculation of the Standard Error of Chain Ladder Reserve Estimates," ASTIN Bulletin 23, 1993, pp. 213–225.

[2] Feldblum, Sholom, Stochastic Chain Ladder and related Stochastic Bornhuetter-Ferguson "Workers Compensation Reserve Uncertainty" CAS Forum 1996.

[3] Meyers, Glen "The Leveled Chain Ladder Model for Stochastic Loss" Reserving Casualty Actuarial Society E-Forum, Summer 2012.

1. Introduction and Findings

1.1 Introduction

DCWP Report 7[4] described a method for using Annual Statement data in calibrating NAIC RBC reserve risk factors (RRFs). We will refer to that method as the Improved Calibration Method (ICM). ICM indicated RRFs by LOB are defined as the 87.5th percentile reserve[5] runoff ratio over time and across companies. Two features of that calibration are worth noting. First, the reserve runoff ratio compares the carried reserve at the initial reserve date to the hindsight value of the reserve after some number of years of development. Second, the calibration uses industry data, i.e., all companies across all years, rather than the individual company data. Therefore, in this paper we refer to these calibrations as "hindsight/industry" calibrations. Other standard formulas, like the Solvency II standard formula, are also generally calibrated using a hindsight test and are partially, if not completely, based on industry data[6].

An alternative method of calibrating RRFs is to use individual company data and methods such as Mack. In that case the calibration is based on variation inherent in the data, rather than a hindsight test. Also, the calibration uses individual company data rather than industry data. Therefore, in this paper we refer to these as "inherent variability/individual company" calibrations or "stochastic" calibrations. Inherent variability/individual company calibrations are common in economic capital models and Solvency II internal models.

The purpose of this paper is to compare RRF indications from the ICM, as an example of a hindsight/industry data calibration, to several possible inherent variability/individual company calibrations.

For the ICM indications we used the baseline calibration process described in DCWP Report 7, ("baseline ICM" or "ICM"). We also use two tailored versions of the ICM. First, use the baseline method but applied only to companies with 23 years of net earned premium (NEP) greater than zero ("23-year-ICM" or "ICM-23-years). Second, we use the 23-year-ICM normalized to a zero average redundancy/deficiency by LOB and LOB-size ("ICM 23

[4] Casualty Actuarial Society E-Forum, CAS Research Working Party on Risk-Based Capital Dependencies and Calibration (DCWP), "Risk Based Capital (RBC) Reserve Risk Charges – Improvements to Current Calibration Method, Report 7."

[5] Reserve refers to unpaid loss and defense and containment costs (also known as allocated loss adjustment expenses) net of reinsurance, including case reserves, IBNR reserves and any other management reserves.

[6] "Calibration of the Premium and Reserve Risk Factors in the Standard Formula of Solvency II" report issued by the Joint Working Group on Non-Life and Health NSLT Calibration, 12 December 2011 (JWG Paper).

Year Mean Adjusted" or "ICM-Adjusted").[7]

For the inherent variability/individual company indications we selected 167 incurred loss development triangles spread by company, LOB and LOB-size as described in Section 2.2 below. For each of those LOB-company data triangles, we applied the following methods to the incurred loss data:

- The Mack (1993) distribution-free analytical stochastic model ("Mack").
- The Feldblum (1996) Monte-Carlo simulation stochastic model – Normal Chain Ladder ("Normal CL"), Normal Bornhuetter Ferguson ("Normal BF"), and Lognormal Chain Ladder ("LogN CL").
- The Meyers (2012) Bayesian stochastic model ("Correlated Chain Ladder" or "CCL").

For each of those 167 company-LOB combinations we selected the ICM, 23-year ICM and ICM-adjusted RRFs indicated for the appropriate LOB and LOB-size from the risk database.

1.2 Findings

There are many variations by LOB and LOB-size, but on average, comparing the results from the methods we observe the following:

1. Among the stochastic methods
   - The Normal CL and Normal BF methods tend to produce the highest RRFs.
   - The CCL, LogN CL and Mack methods produce results lower than the other two stochastic methods.
   - Our analysis did not allow us to conclude that the observed ordering of the methods is statistically significant.
2. RRFs from the ICM methods are generally higher than the RRFs indicated from the stochastic methods, although the stochastic and ICM results are similar, or slightly lower, for personal lines.
3. The LOB-size, measured either based on premium or reserve volume is inversely related (negatively correlated) to RRFs for each method.

Table 1.1 below shows the unweighted average results by method for the 167 company-LOB data points.

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[7] Calculated as the 23-year-ICM minus the average deficiency (or plus the average redundancy) by LOB and LOB-size.

Table 1.2 below shows the unweighted average results by LOB-size for the 167 company-LOB data points.

Table 1.1
Summary of RRFs by Method
All Data Points Combined

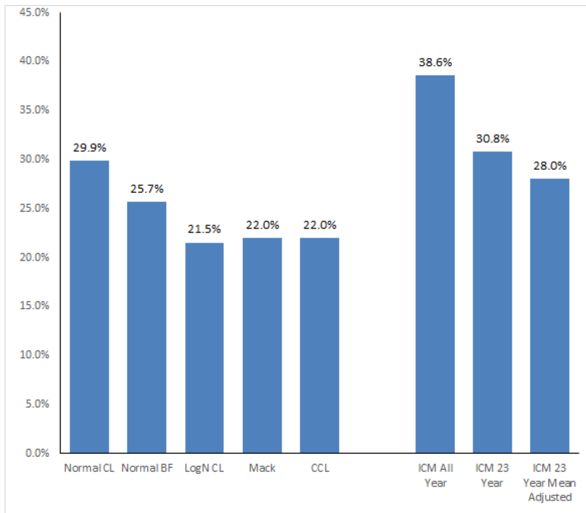
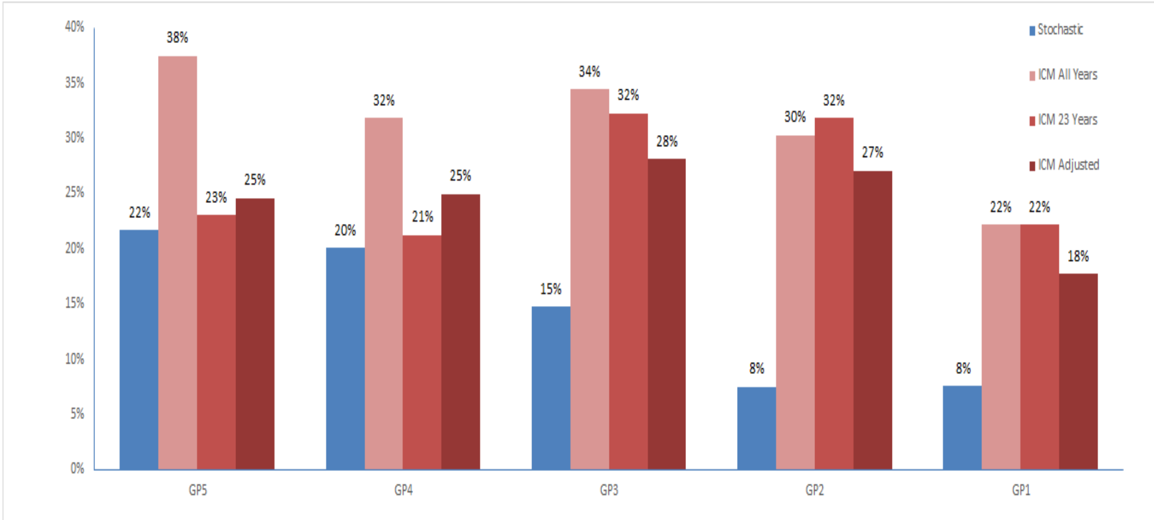


Table 1.2
Summary of RRFs by LOB-Size
(GP5 is smallest; GP1 is largest)[8]
All Data Points Combined

[8] See section 2 for definition of GP1-GP5.



In interpreting the results of this work, the following differences in the ICM data and the stochastic data should be considered.

4. All of the 167 LOB-companies in the stochastic data have 'well behaved' data, as described in section 2.2.
5. The ICM includes all data.
6. As such, the stochastic RRFs might be viewed as (a) a minimum or and/or (b) the RRFs appropriate to the line without "operational" risk associated with market share growth, fewer years of data, etc.
7. In the stochastic analysis, the RRF is the 87.5th percentile around the modeled expected value, transformed to represent the 87.5th percentile around the booked reserve. These methods do not reflect the extent to which booked reserves might tend to be over/under the expected value.
8. In the ICM and ICM-23 year analysis, other hand, the RRF is the 87.5th percentile observed in the data and therefore does reflect the extent to which booked reserves might tend to be over/under the expected value. As a test of the significance of that effect, the ICM-Adjusted analysis is normalized to a zero average redundancy/deficiency by LOB and LOB-size, which removes the historical redundancy/deficiency that is observed in the runoff data.
9. The stochastic analyses do not include accident periods prior to 1988.
10. The ICM uses Schedule P "all prior" data. Thus the runoff ratio, while limited to 10 calendar years of development, includes all accident years, no matter how old.
11. This might be important in some cases such as:

12. liability - asbestos emergence
13. workers compensation - tabular reserve emergence

This work is intended as an initial step in understanding the extent and nature of differences between the standard formula assessment of RRFs and the individual company assessment of RRFs that would typically enter ORSA, economic capital or internal model assessments.

In some cases the differences seem small enough. From Table 1.1 we see that the ICM-adjusted RRF falls within about 10% of both the Normal and BF Chain Ladder methods 28.0% vs. 29.9% and 25.7%). From Table 1.2, for the smallest size group, the ICM-adjusted RRF is within 12% of the average stochastic method.

In other cases the differences are large. From Table 1.1 the CCL, Mack or Lognormal Chain Ladder approaches are more than 20% below the ICM-adjusted and stochastic Normal CL and BF CL approaches. From Table 1.2 for the largest companies, groups 1 and 2 the average stochastic methods is less than 1/2 or 1/3, respectively, of the ICM-adjusted RRF. The comparison varies by LOB, as discussed in the paper.

The differences might arise from differences in the underlying risk by type of company or by differences in assumptions, methods or type of data used to measure risk, rather than differences in the underlying risk. It was beyond the scope of this report to explore all the factors that might have created the observed differences. It was also beyond the scope of this work to examine the stability over time of results from different methods. A more in-depth analysis is worthy of future research.

In the remainder of this report:

- Section 2 provides more detail regarding the data we used.
- Section 3 provides more detail regarding our analysis.

1.3 Terminology, Assumed Reader Background and Disclaimer

This paper assumes the reader is generally familiar with the property/casualty RBC formula[9] and has a working knowledge of DCWP Report 7.

In this paper, references to "we," "our," refer to the principal authors of this paper. The "working party" and "DCWP" refer to the CAS RBC Dependencies and Calibration

[9] For a detailed description of the formula and its basis, see Feldblum, Sholom, NAIC Property/Casualty Insurance Company Risk-Based Capital Requirements, Proceedings of the Casualty Actuarial Society, 1996 and NAIC, Risk-Based Capital Forecasting & Instructions, Property Casualty, 2010.

Working Party.

The analysis and opinions expressed in this report are solely those of the authors, and in particular are not those of the members' employers, the CAS, or the American Academy of Actuaries.

DCWP makes no recommendations to the NAIC or any other body. This DCWP material is for the information of CAS members, policy makers, actuaries and others who might make recommendations regarding the future of the P&C RBC formula. In particular, we expect that the material will be used by the American Academy of Actuaries.

This paper is one of a series of articles prepared under the direction of the CAS RBC DCWP.

2. Data

In our analysis we use two types of data:

- Information to assess indicated ICM RRFs as described in Report 7 (ICM Risk Data).
- Individual company data triangles to assess inherent reserve uncertainty (Individual Company Data).

The sections below discuss data used to assess ICM RRFs (2.1) and data by individual company (2.2).

2.1 ICM Risk Data

The key statistic in the calibration of RRFs is the Reserve Runoff Ratio. This is calculated as follows:

- The numerator of the Reserve Runoff Ratio is the reserve movement, i.e., the change in the company's estimated ultimate incurred losses[10] from the initial reserve date to the latest available valuation date, ten years of development for initial reserve dates 2000 and prior.
- The denominator is the total initial reserve, i.e., the case reserve plus the Incurred But Not Reported (IBNR) reserve, at the initial reserve date, i.e., the end of each calendar year, for all AYs through that year-end.

We calculate reserve runoff ratios for initial reserve dates from December 31, 1988 to

[10] Loss and DCC, excluding A&O. Net of reinsurance. As presented in Schedule P Part 2

December 31, 2009.[11]

As described in DCWP Report 7 we filter the data as follows:

- We exclude data points with unexpected zero or negative values.
- We include companies of any LOB-size, but we calculate RRFs by LOB-size
- Companies that are part of pools have been consolidated into a single combined pool data point.
- The runoff includes incurred movement in the "all prior" row of Schedule P. Thus the runoff ratio, while limited to 10 calendar years, includes all accident years, no matter how old.[12]
- We exclude "minor lines[13]" data points.

2.2 Individual Company Data– Selection Approach

We selected 167 LOB-companies spread among LOBs[14] and LOB-size categories. We aimed to have 19 companies for each LOB, 4 of the largest 10 companies and 5 in each of the three smaller size groups. The data was selected based on the considerations described below:

Years

All the selected LOB-companies have 23 accident years of data, 1988-2010, no negative reserves, and no negative paid or ultimate claims in any AY.

Size

The companies were selected from up to 5 size groups, with size based on 23 year average annual premium for the LOB, as follows:

- Two from the top five companies (rank 1 – 5 by premium) – Called GP1
- Two from the companies with premium LOB-size rank 6-10– Called GP2
- Five from near of the middle of each of the next 3 quintiles of companies by size

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[11] The runoff ratio for December 2010 is not useful as the initial and developed values are the same.

[12] The all prior row would include development in calendar years 1988-2010 for AYs 1987 and prior. This means, for example, that the other liability and reinsurance liability LOBs would include AYs 1988-2010 development from asbestos claims from AYs 1986 and prior.

[13] As described in DCWP report 7, a "minor lines" data point is one in which the all-year premium for the LOB is less than 5% of the all year premium for all lines for the company. Minor lines data points show much higher RRFs than other data points. DCWP Report 7 shows the effect of excluding minor lines data points.

[14] We only analyzed 10-year Schedule P lines.

– Called GP3-GP5.[15]

In selecting companies we aimed at groups of companies of similar sizes within each size group, rather than spreading evenly through the size group. We did not select any LOB-companies with average NEP under $1 million. The selections are labeled GP1, GP2 ...GP5, but that labeling does not exactly follow rules 2 above, as getting the proper balance of all the criteria in this section sometimes meant taking company rank 11-15 as a GP2 or putting some GP3 companies into GP4.

Premium Growth

We selected companies that had more stable size over time. For that purpose we measured size based on market share by LOB for each company for each of the 23 years. We examined the ratio of (a) maximum market share to (b) minimum market share for each company. Where possible, we selected companies with Max/Min ratios of 1.5 or less. This was often practical for GP1 and G2. That was not always possible, and we selected companies with higher ratios, up to 10+ when needed.

Reinsurance Levels

When possible, we selected companies with ceded reinsurance levels typical for the LOB and LOB-size of the group.

Pooling

The data does not include any companies identified as part of "Pooled Groups", except for GP1 and GP2, when (a) most companies in the size group were pooled and (b) the ceded premium from the entity was less than 15%.

Selection Comments

[15] For workers compensation there were not enough suitable companies in the middle groups, GP2-GP5. Therefore we selected two additional large companies, one from GP1 and one from GP2. We also selected four additional small companies, called GP6, composed of companies smaller than GP5. Our summaries of data by LOB-size include GP6 with GP5.

The selected companies are not intended to be a sample of typical companies.[16] Rather, they are a sample of companies with long term well-behaved data, relative to the LOB and size group. As such, the resulting RRFs might be viewed as (a) a minimum or and/or (b) the RRF appropriate to the line without "operational" risk associated with market share growth, fewer years of data, etc.

Because of the various constraints we applied, we did not always have the targeted number of LOB-companies in total or in each size group.

LOB-Company Data triangles

For each LOB-company combination we compiled the Schedule P paid, case incurred, recorded ultimate losses, and IBNR. This produced a 23 x 10 trapezoid for each LOB-company. In addition we compiled NEP by year.

3. Analysis

This section contains the following:

- In subsections 3.1 – 3.3 we discuss the different methods we used to determine RRFs.
- In subsection 3.4 we discuss the results by LOB for each of the 167 LOB-company data points.
- In subsection 3.5 we discuss the results by size group for each LOB, summarized across companies.
- In subsection 3.6 we discuss the results summarized by LOB, for all size groups, and also summarized across size and LOBs, by method.
- In subsection 3.7 we compare the stochastic methods to the ICM methods.

3.1 The Improved Calibration Method

As described in DCWP report 7, the ICM reserve runoff ratios (see section 2.1) are calculated for each company and LOB. For each LOB the reserve runoff ratios are segmented into LOB-reserve size bands. The first band is the 0th to 15th percentile by LOB-reserve size; the next band is the 15th to 25th percentile by LOB-reserve size, with each additional percentile increasing at 10% increments until the final band, starting at the 95th

[16] This was purposeful to help assure that the data was suitable for the individual company methods. Future research can examine the extent to which this constraint biased the results.

percentile by LOB-reserve size.[17] The RRF for each LOB reserve-size band equals the 87.5th percentile of the reserve runoff ratios within the size-band.

For this analysis we present three ICM results. The first result is from the baseline method presented in report 7 (ICM). The second is the baseline method applied to companies with 23 years of NEP greater than zero (23-year RRFs).[18] The third is the ICM-23 Year Mean Adjusted approach that is normalized to a zero average redundancy/deficiency by LOB and LOB-size.[19] The RRF for any desired size level is determined by selecting the value of the size band where the company-LOB data point falls.

3.2 Five Stochastic Methods

We used five stochastic reserve methods for determining alternative RRFs. Three of these methods use the procedures presented by Hodes, Feldblum and Blumsohn (1996). The Feldblum methods simulate future loss payments based on a Monte-Carlo simulation approach applied to Chain Ladder loss development factors (LDF). In the first approach, the LDFs are assumed to be randomly distributed based on a normal distribution with mean and variance derived from the empirical LDF by age. In the second, the LDFs are assumed to be randomly distributed based on a log-normal distribution with mean and variance derived from the empirical LDF by age[20]. In addition, a Bornhuetter-Ferguson (BF) simulation method is employed with normal distributional assumptions for the LDFs.[21]

The fourth method is the Mack (1993) method. In the Mack method the cumulative losses at subsequent evaluation dates are assumed to relate through a linear regression model where the error structure is a function of the cumulative losses at the original evaluation period.

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[17] If the largest 5th-percentile of companies includes more than 200 data points, it is further divided into the largest 100 data points and all other data points. If the largest 5-percentile includes less than 200 data points it is divided into two equal groups.

[18] In DCWP Report 7, baselines RRFs are based on data from companies with at least 5 years of non-zero NEP. In this report, we also show ICM RRFs based on data from companies with 23 years of experience, to better match the individual company experience (ICM-23-year). Appendix I of this paper and DCWP Report 7 show the difference in RRFs based on number of years of experience.

[19] Calculated as the ICM-23 year minus the average deficiency (or plus the average redundancy).

[20] We incorporated parameter risk in the methods using normal distribution however we did not incorporate parameter risk in the log-normal case, because the log-normal distribution of the LDFs with parameter risk produced unreasonably volatile results.

[21] We did not use a BF lognormal method due to the large volatility of the results even without incorporating parameter risk

The fifth method is Glenn Meyers' Bayesian method (2012) which is based on a Bayesian framework implemented by employing Markov Chain Monte Carlo techniques. We will refer to this method as the Correlated Chain Ladder.

We applied each of the above methods to the incurred loss data triangles.

For each of those 167 company-LOB combinations we selected the ICM, 23-year ICM and ICM-adjusted RRFs indicated for the appropriate LOB and LOB-size from the risk database.

3.3 Calculating RRF for Stochastic Methods

As usual for stochastic reserve analysis, the mean of the stochastic process does not equal the booked reserve. Therefore, to scale the modeled variability to the booked reserve we multiplied (a) the 87.5th percentile of modeled ultimate loss by (b) the ratio of (i) the booked ultimate loss (Schedule P Part 2 column 10) to (ii) the mean modeled ultimate.

This produces a scaled version of the modeled 87.5th percentile around the booked ultimate loss.[22] This approach preserves the coefficient of variation (CV) of the distribution while substituting the indicated mean ultimate loss with the selected ultimate runoff value.

We then calculated the RRF as follows:

$$\frac{87.5^{\text{th}}\text{ percentile around the Booked Ultimate} - \text{Booked Ultimate}}{\text{Booked Reserve}}$$

Appendix I illustrates the "scaling" approach.

3.4 Comparison of RRFs by Method

The following tables show the RRFs resulting from the five stochastic methods and two ICM methods, for each LOB, up to 19 companies per LOB. Each point on the table represents a method applied to a LOB-size data point. The horizontal axis shows the company reserve as of the 2010 evaluation date from Schedule P excluding the prior row[23] on a log scale. The vertical axis shows the indicated RRF. The vertical and horizontal axes scales vary from chart to chart to show the maximum amount of detail.

[22] Appendix I shows that scaling the stochastic result to the book reserve rather than scaling to the ultimate incurred does not change the results

[23] The stochastic results are based on 23 AYs. The ICM is based on the same 23 AYs plus the Schedule P "all prior" row. The graphs are based on the reserve size excluding reserves on the "all-prior" row.

The legend in the upper right corner of the charts identifies the methods. To the right of each method's name is the slope of the linear regression of the RRF versus the log transformed reserve. Each company for which we have results in a given LOB is represented by seven points—one for each of the five stochastic methods the baseline ICM RRF and the 23-year ICM RRF.

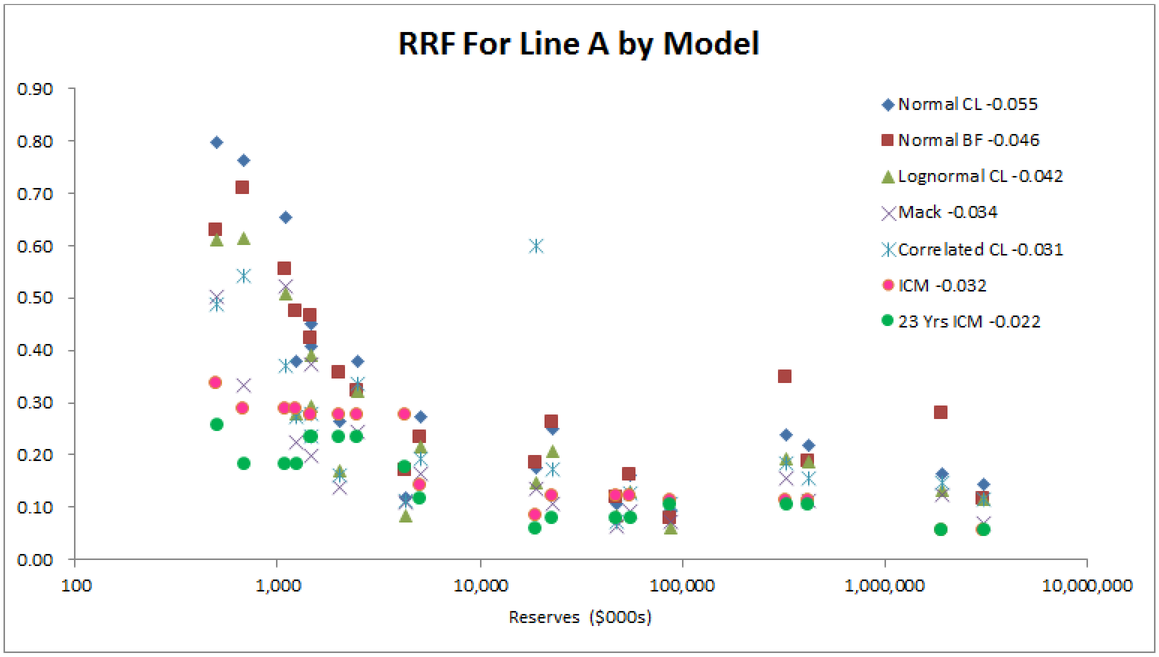
The discussion below discusses the results separately for personal lines, major commercial lines and all other.

As we observe differences among the methods, we comment on possible contributing factors. Those comments are hypotheses for further analysis. It is beyond the scope of this paper to fully explore those differences.

<u>Personal Lines</u>

Tables 3.4.1 and 3.4.2, homeowners/farmowners and private passenger automobile (PPA), respectively, show that the ICM RRFs are similar to the stochastic methods RRFs. We also see that the RRFs decrease as the reserves increase. Although there are slight rebounds, the data generally suggests a negative correlation between RRF and LOB-reserve size.

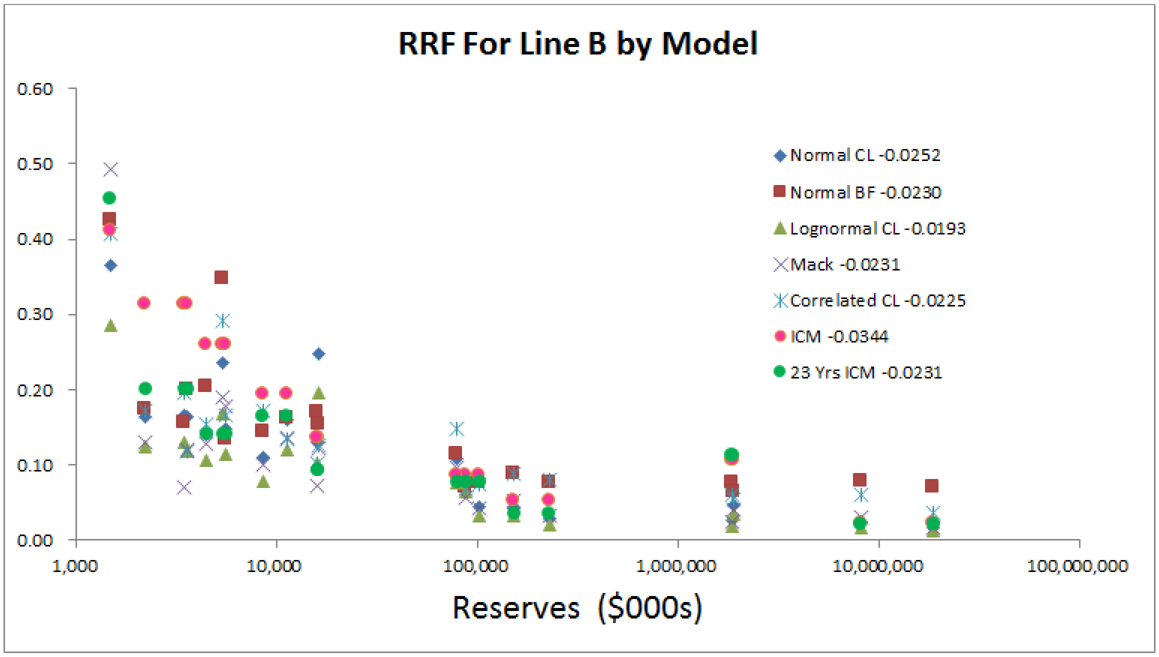
Table 3.4.1
Homeowners/Farm owners RRF by Company and Method



One interesting feature of the homeowners/farmowners is that the baseline ICM RRFs appears to be among the middle of the range of values for reserves less than $100 million but drops below the stochastic methods when reserves are greater than $100 million. It will be seen that the opposite is more often the case for the commercial LOBs where the ICM RRFs are generally larger than the stochastic methods RRFs, especially when reserve size is high.

What is consistent with most other lines is that the 23-year ICM RRFs are generally less than the baseline ICM RRFs. This is consistent with the view companies with fewer years of experience might exhibit more variable reserve runoffs.

Table 3.4.2
Private Passenger Auto RRF by Company and Method



For personal auto, the ICM RRFs are similarly displayed among the stochastic methods; however, it continues to be generally within the range of stochastic methods' results for large reserve sizes. Also the 23-year ICM RRFs stay within the range of other results.

<u>Major Commercial Lines</u>

The following tables 3.4.3, 3.4.4 and 3.4.5 show the results in the same format for commercial automobile, workers compensation and commercial multi-peril (CMP) LOBs, the large non-specialist commercial lines.

Unlike the situation for personal lines, for these three lines we see that the ICM RRFs are generally the highest or among the highest of the RRFs produced by the various stochastic methods.

The two ICM results tend to converge as the reserves increase. The convergence for large LOB-sizes was also seen in the personal lines. We believe convergence for large LOB-sizes may due to the fact that the top-10 companies in groups 1 and 2 disproportionately, if not universally, have 23 years of reserve data.

Similar to the situation for personal lines we see that the RRF decline with LOB-size is flatter as reserves increase, especially for companies with reserves greater than $100 million. Some of this flattening of the RRF with size for larger companies might be driven by more risky exposures underwritten by larger companies, so the RRF magnitude might be driven by factors other than just size.

A possible explanation for the higher RRFs from the industry hindsight calibrations relates to the nature of the data being used. The stochastic Mack and Correlated Chain Later Methods do not use any data more than 120 months mature, and therefore would not measure the extent to which there was volatility on reserves at the oldest development periods. The ICM, on the other hand, incorporates runoff from the prior year row in Schedule P and therefore does reflect the effect of development beyond 120 months.

Table 3.4.3
Commercial Auto Liability RRF by Company and Method

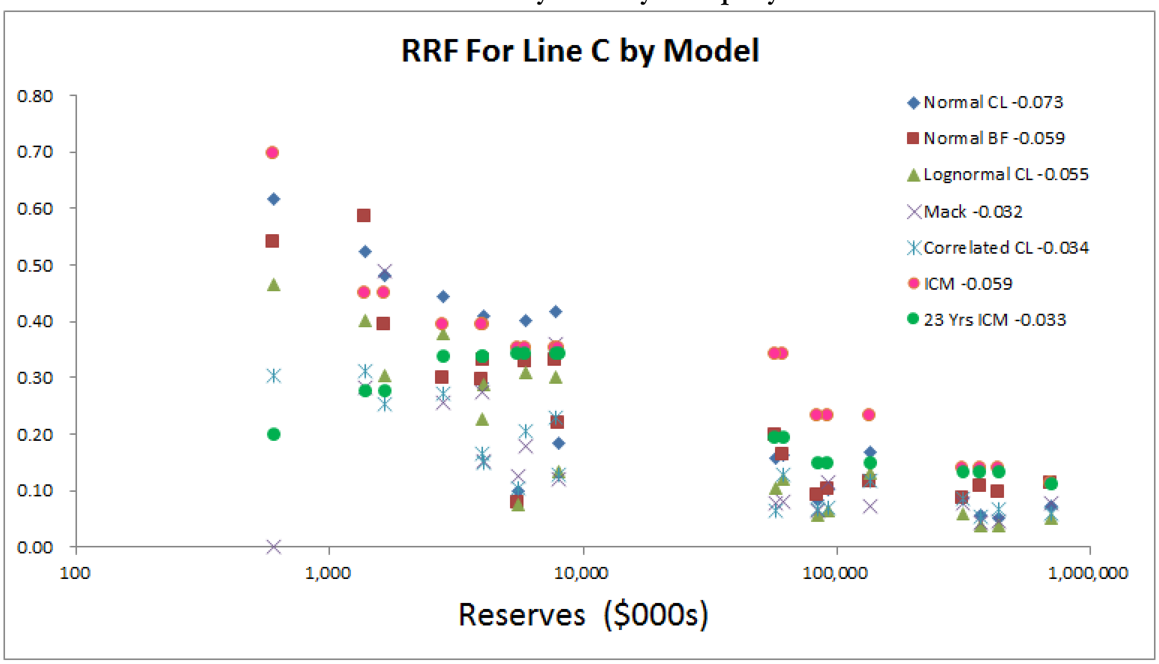
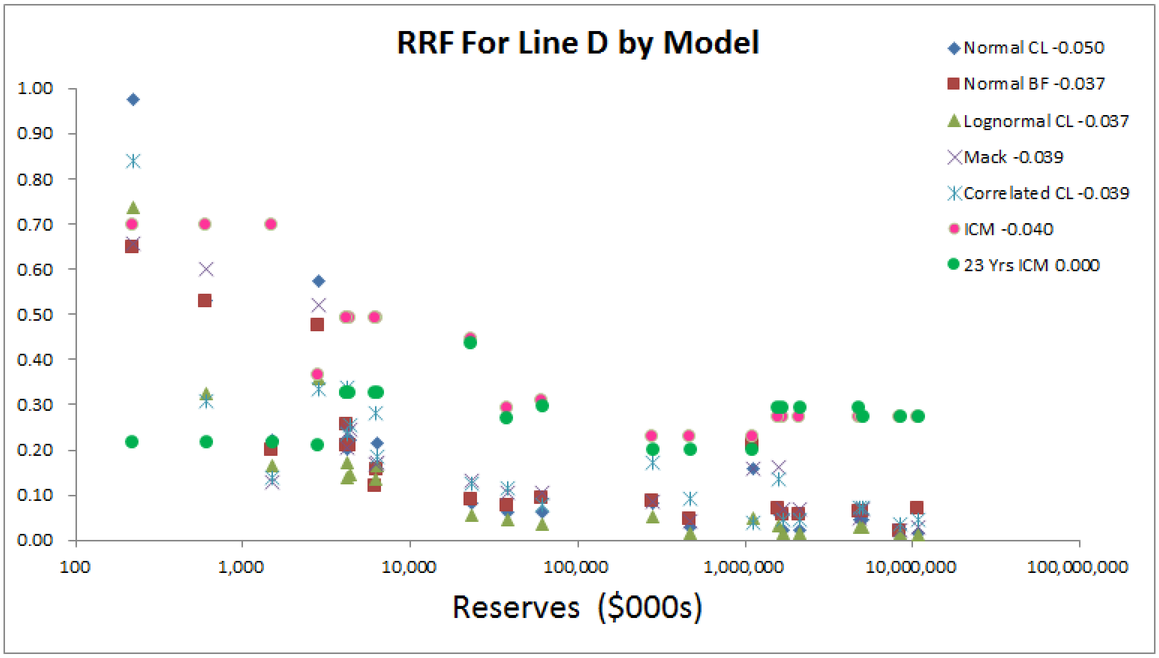


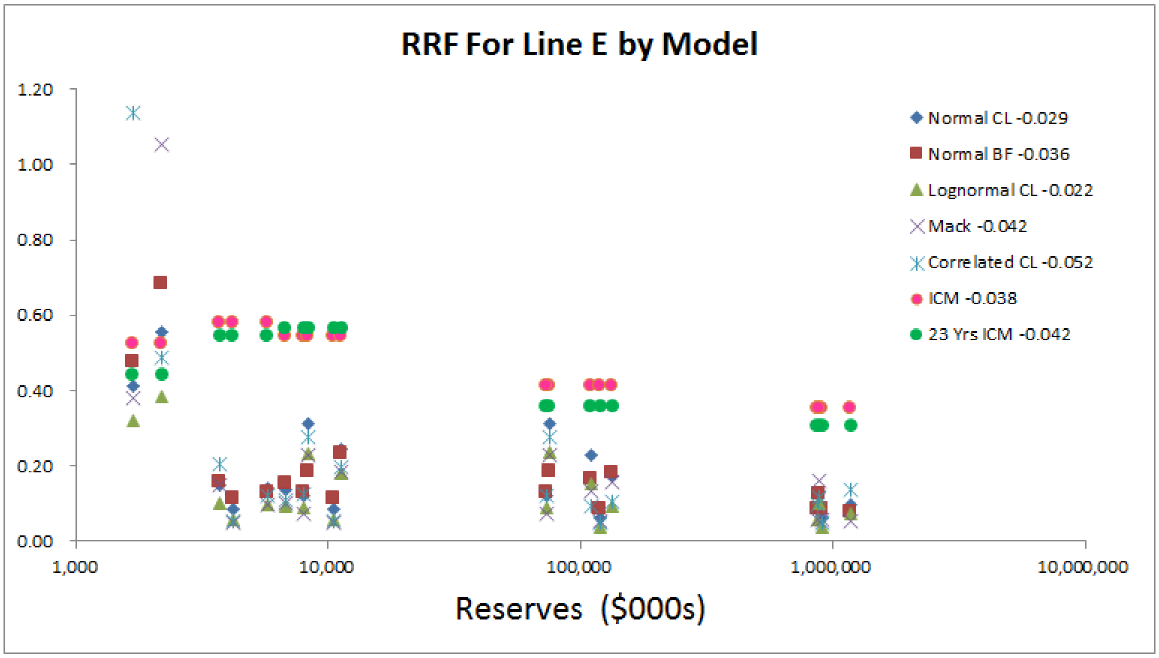
Table 3.4.4
Workers Compensation RRF by Company and Method



Workers compensation, in Table 3.4.4 above, shows RRFs for stochastic methods that are generally lower than the stochastic RRFs from other long tail lines. We attribute this at least in part to the influence of less uncertain statutory indemnity benefits which compensates for the uncertainty of the medical component.

As seen in other LOBs discussed above, the RRFs are clearly negatively correlated to reserve volume for workers compensation for reserves less than $100 million. The relationship for larger reserve sizes is not apparent, maybe due to the risky exposures underwritten by the larger companies. However we see that the 23-year ICM RRFs are to be unusually high for the second largest cohort of reserves.

Table 3.4.5
Commercial Multi-Peril RRF by Company and Method



Commercial Multi-Peril RRFs, in Table 3.4.5 above, show ICM RRFs that are generally much higher than for stochastic methods except for companies with the smallest reserve sizes.

<u>All Other Lines</u>

Table 3.4.6 and 3.4.7 shows the results applied to medical malpractice occurrence and claims-made polices.

For the medical malpractice occurrence LOB there were only four companies in our LOB-company data set and patterns are hard to discern.

The medical malpractice claims-made LOB differs from other LOBs in two respects. First there is little indication among the stochastic methods that the RRF decreases with increasing reserve volume. We employed a 2 tail test at the 10% level of significance and determined that the regression slope was not significant for medical malpractice occurrence. More details are included in Appendix II.

However there does appear to be a decrease in the ICM RRF as reserves increase. Secondly, we see the ICM results in negative ratios for most observed companies. We believe this is due to the general historical pattern of favorable reserve development for this line.

Table 3.4.6
Med Mal Occurrence RRF by Company and Method

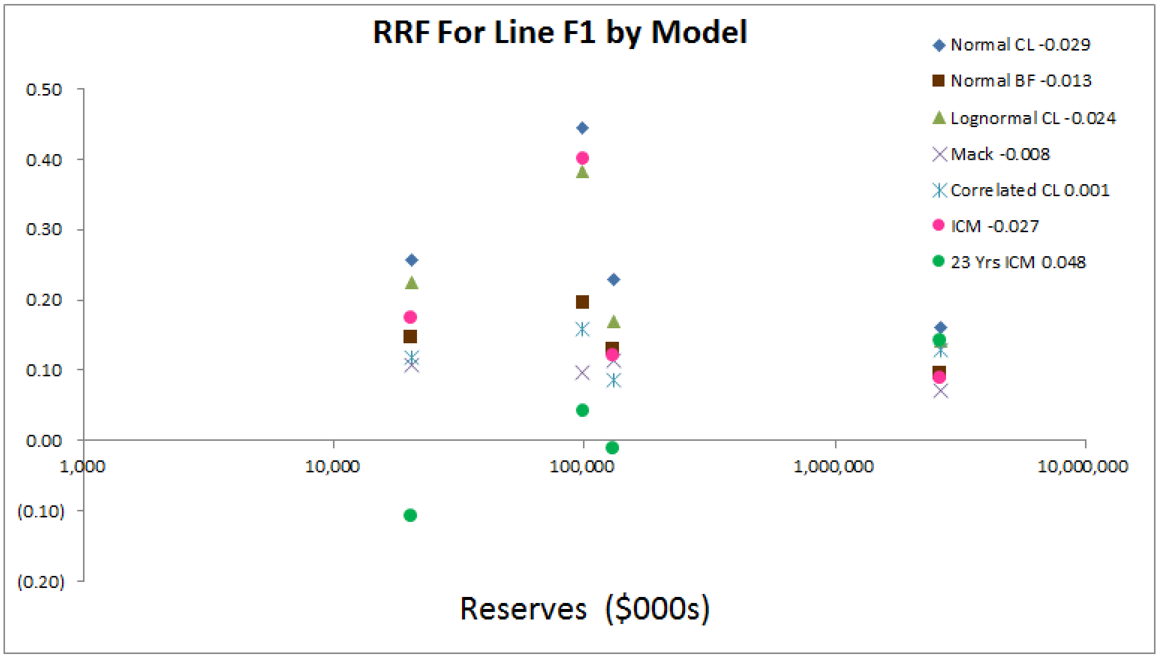
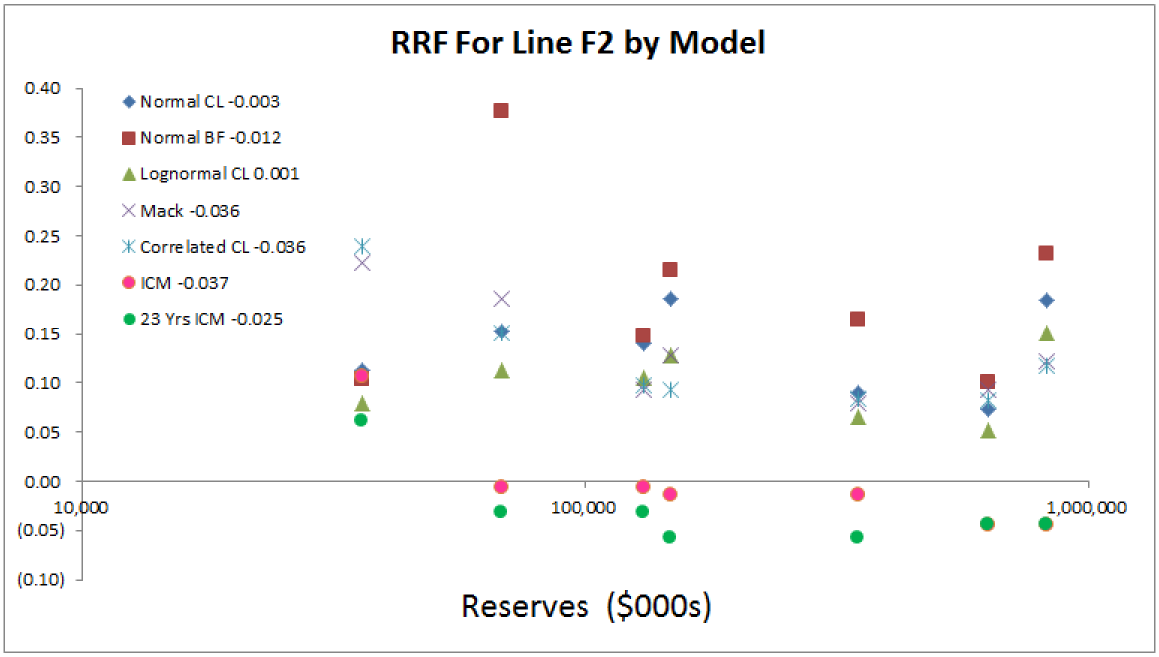


Table 3.4.7
Med Mal Claims Made RRF by Company and Method



Tables 3.4.8, 3.4.9 and 3.4.10 below show RRFs for special liability, other liability,[24] and products liability[25] LOBs.

We see that for the special liability and product liability LOBs the resulting slope suggests a significant negative correlation between the baseline ICM RRF and the size of the reserve. For other liability on the other hand, there is a small positive correlation between reserve size and the resulting ICM RRF. As mentioned earlier the 23-year ICM RRFs tend to be lower for small reserves and the two methods converge for large reserves. This generally causes the 23-year ICM RRFs decreasing trends to be less steep compared to the baseline ICM RRFs. For other liability the effect is a steeper trend when the slope is positive for the 23-year ICM RRFs.

Other liability is the only LOB where the linear regression indicates a positive slope for both ICM methods. This is driven by the high RRFs for companies with excess of $100 million of reserves. Also, for the other liability LOB, the stochastic RRFs are generally lower.

For the reinsurance liability LOB (Table 3.4.12) the results are similar to other liability, results in that the 23-year ICM, the linear regression indicates a positive slope by size, and both ICM methods are considerably higher than the stochastic methods.

Both the upward trend by size in the ICM RRFs and the observed lower RRFs for the stochastic results may be due to the fact that the "all prior" experience is included in the ICMs. For other liability and reinsurance liability (Tables 3.4.9 and 3.4.12), asbestos development in the last 20 years for accident years 1987 and prior may be affecting the ICM RRFs for companies with larger reserves to a larger extent than is the case for companies with smaller reserves. This asbestos development would not be included in the data entering the stochastic analyses.

[24] Other liability is presented in Schedule P split between occurrence and claims made. However here it is shown on a combined basis.

[25] Products liability is presented in Schedule P split between occurrence and claims made. However here it is shown on a combined basis.

Table 3.4.8
Special Liability RRF by Company and Method

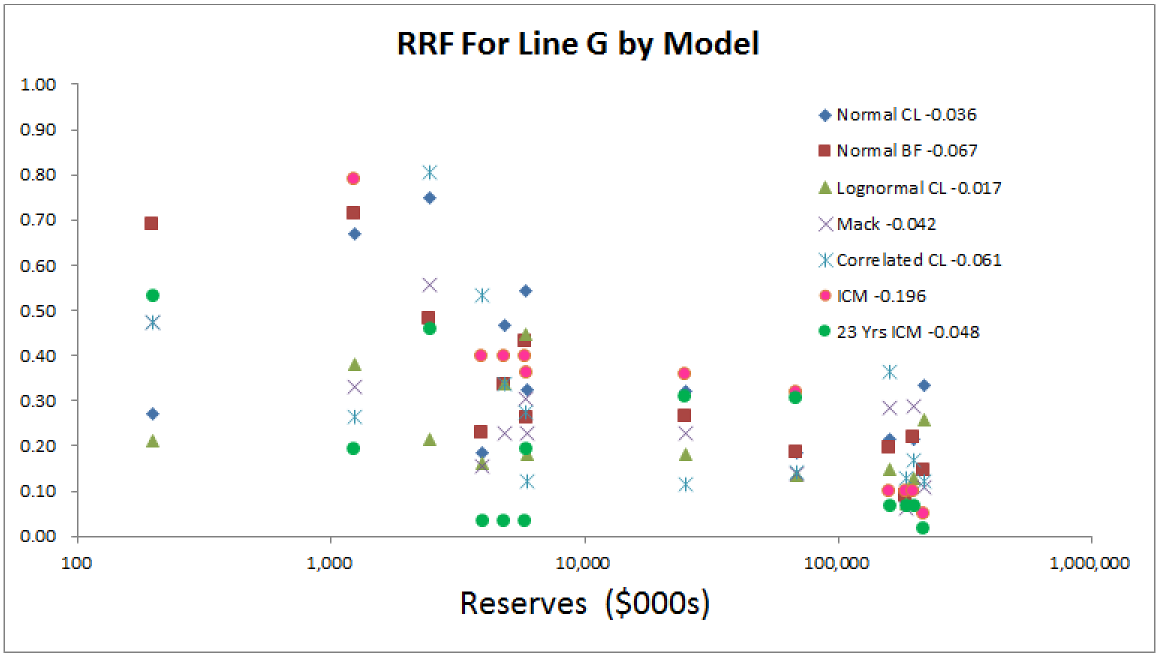


Table 3.4.9
Other Liability RRF by Company and Method

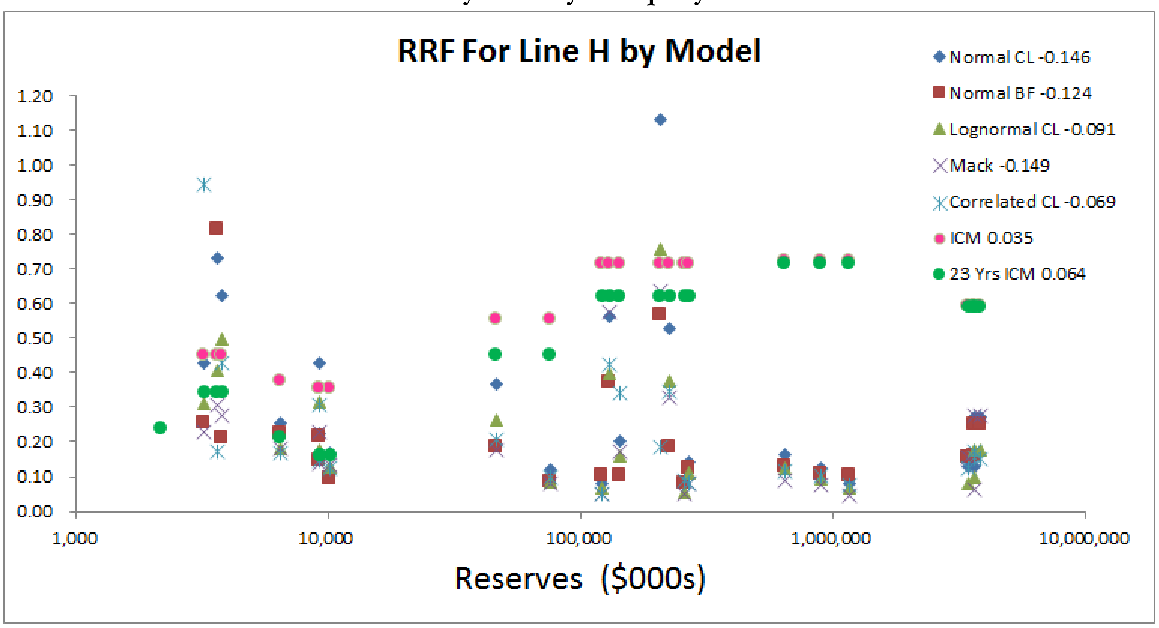
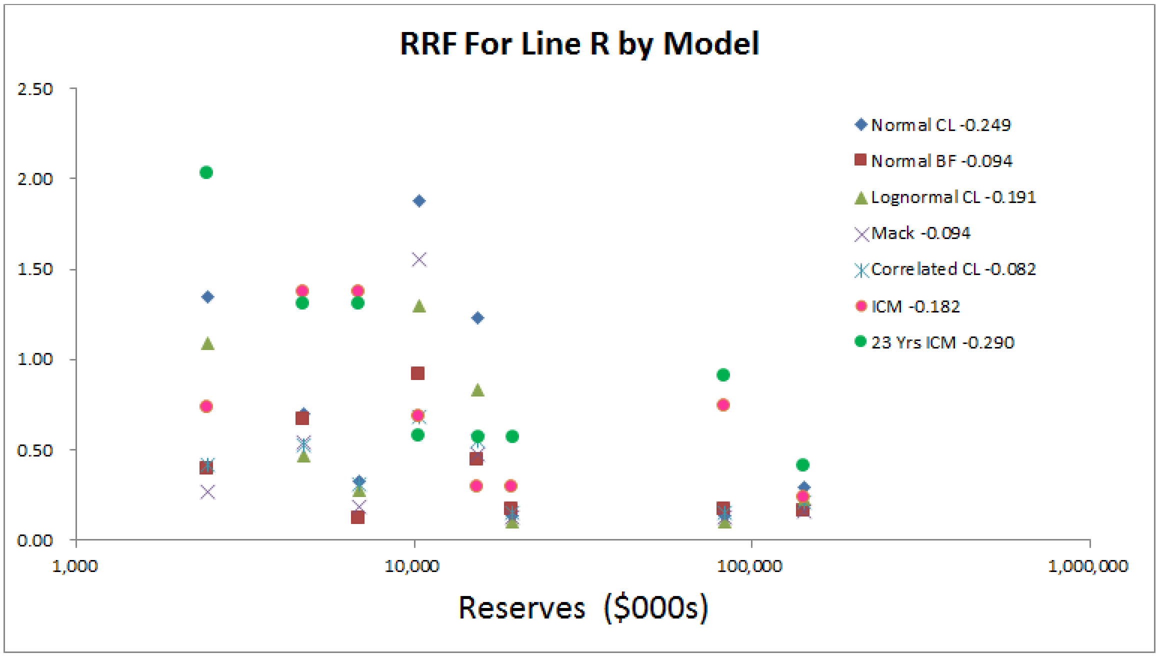


Table 3.4.10
Products Liability RRF by Company and Method



Finally, tables 3.4.11 and 3.4.12 show the reinsurance assumed LOBs. There are a limited number of companies in the data, and the limited data makes discerning patterns less reliable. Nonetheless, it appears that stochastic RRFs decrease with reserve size for both LOBs.

As discussed with the other liability LOB, the reinsurance liability ICM RRFs are much higher than the corresponding RRFs from the stochastic methods. The lower RRFs for the stochastic methods might be reflective of more stable companies selected for the stochastic analysis, and also be the effect of the not including "all prior" development.

Table 3.4.11
Reinsurance Property RRF by Company and Method

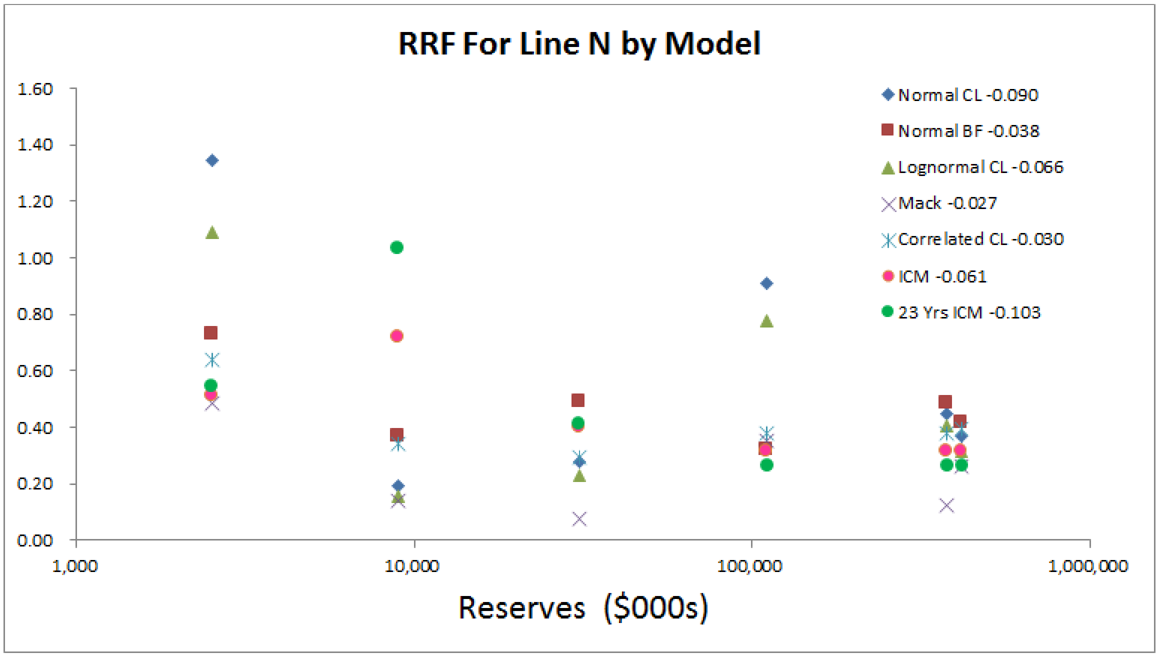
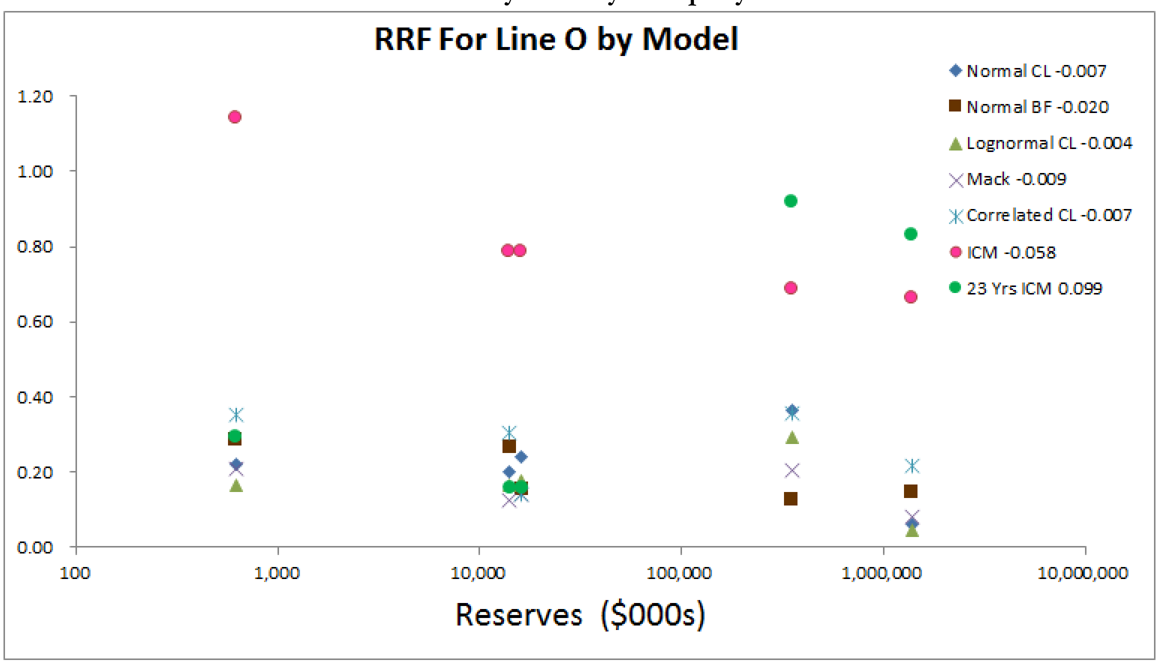


Table 3.4.12
Reinsurance Liability RRF by Company and Method



3.5 Comparison of Reserve Risk Factors by Size Groups

In this section we look at the companies in premium LOB size groups 1-5 described previously in Section 2.2. The horizontal axis shows the size group name, GP5=smallest and GP1=largest and the simple average of sum of the NEP over the latest 10 years (in $millions) to indicate relative size of each group. The vertical axis shows the premium weighted average of the RRFs for the companies in the premium LOB size group. We use booked reserve as weight.

For each size group, the first three bars show RRFs from the Feldblum simulation techniques. The second set of two bars shows the RRFs from the Mack analytical and Meyer's Bayesian methods. The final two bars show the baseline ICM and 23-year ICM RRF results.

As seen in the scatter plots of section 3.4, the charts below show that:

14. The RRFs decrease as the LOB-premium increases.
15. For personal lines, the ICM RRF is comparable to the company modeled RRFs. For the three large commercial lines, and a number of the other commercial lines the ICM RRFs are noticeably larger than the stochastic RRFs.

We also see some patterns of RRFs from stochastic methods as follows:

16. The Normal CL and Normal BF methods often produce RRFs that are higher than the RRFs from the LogN CL, CCL and Mack methods. This may be partly due because stochastic methods based on Monte Carlo simulations are sensitive to data outliers that may have a leveraged effect on the final indicated reserve uncertainty. Also the Normal CL and Normal BF methods incorporate both process and parameter risk in the calculation of the uncertainty associated with the unpaid claim liability distribution, while the LogN method only incorporates process risk.
17. The Mack method RRFs tends to produce RRFs lower than any method other than LogN CL. The LogN CL method does reflect parameter risk. The analytical Mack method is believed by some to produce stochastic projections that are not very sensitive to data anomalies and outliers.

<u>Personal Lines</u>

For both of the personal LOBs, Tables 3.5.1 and 3.5.2 show the negative correlation between reserve size and RRF that we observed in the scatter plots. Also the data shows that ICM RRFs are generally within the range of the RRFs produced from the various stochastic methods, as we saw in the scatter plots.

We also observe that the RRFs from the Normal CL and Normal BF methods are often higher than the RRFs from LogN CL method. The RRFs from the Mack method are often the lowest of the stochastic results.

Table 3.5.1
Homeowners/Farm owners Average RRF by Premium Group

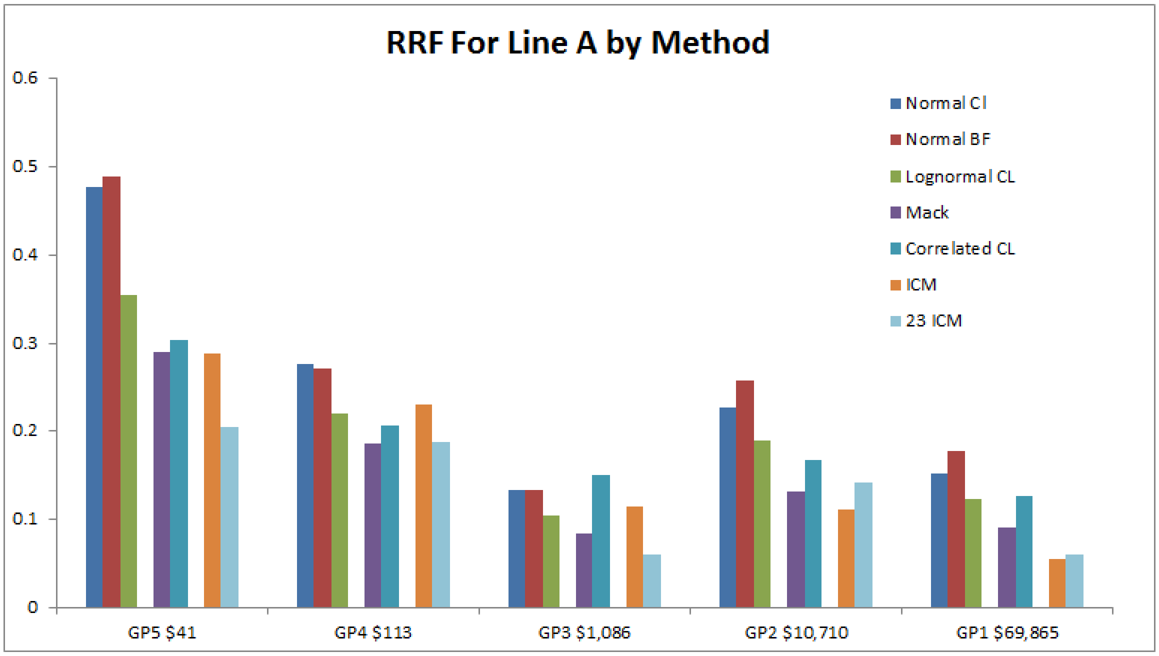
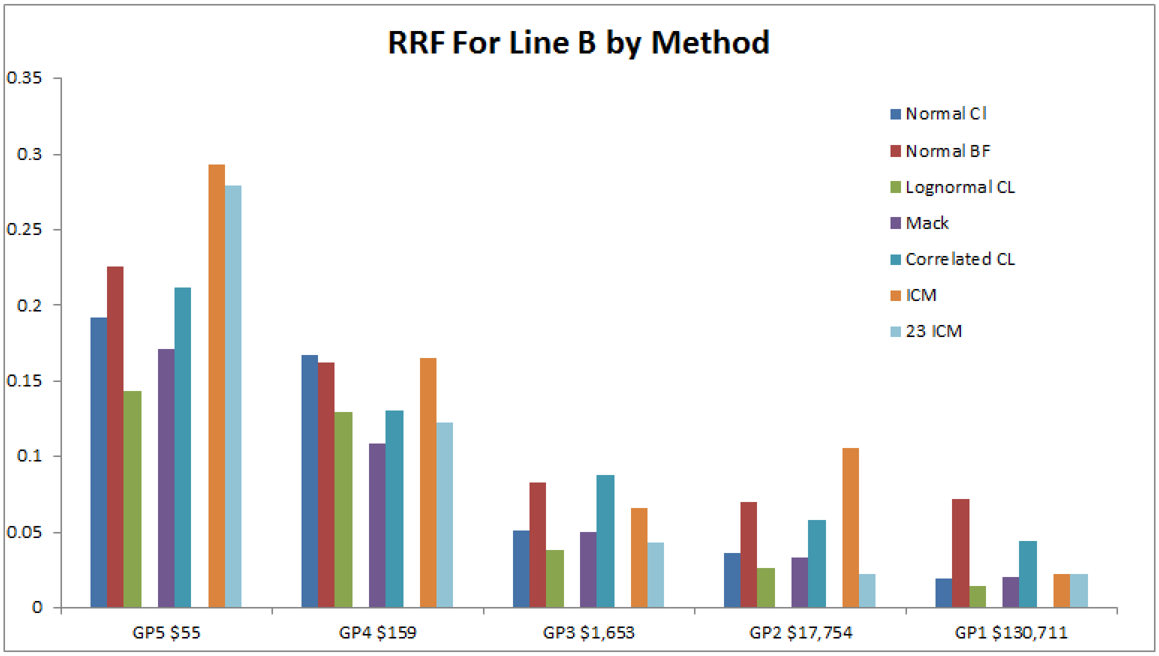


Table 3.5.2
Private Passenger Auto Average RRF by Premium Group



Major commercial lines

As observed in the scatter plots, Tables 3.4.3, 3.4.4 and 3.4.5, Tables 3.5.3, 3.5.4 and 3.5.5 show that the ICM RRFs for the large commercial LOBs are much higher than the corresponding RRFs from the stochastic projections, especially for the workers compensation and commercial-multi-peril LOBs.

We also observe that the RRFs from the LogN CL method are often lower than the RRFs Normal CL and the Normal BF.

Table 3.5.3
Commercial Auto Liability Average RRF by Premium Group

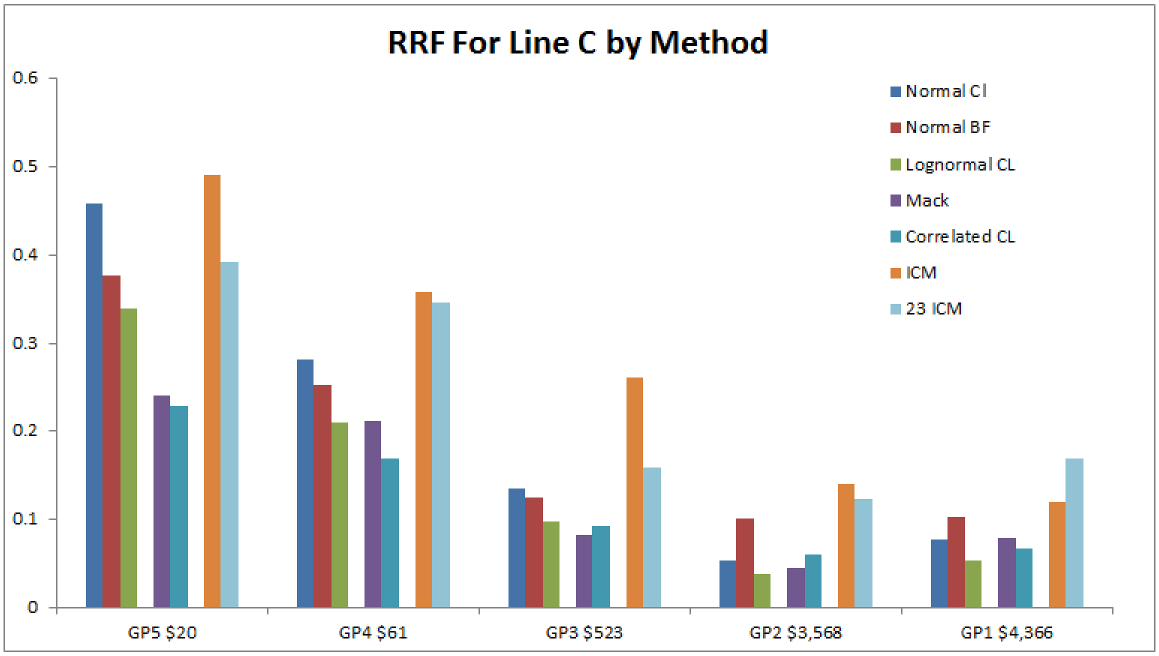


Table 3.5.4
Workers Compensation Average RRF by Premium Group

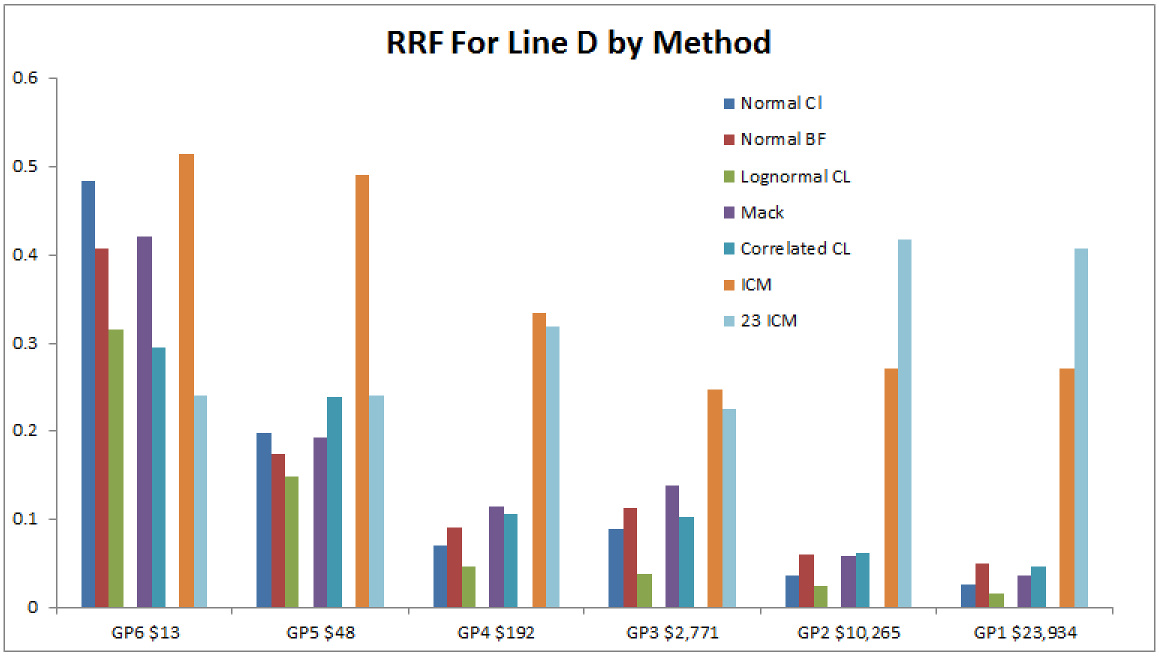
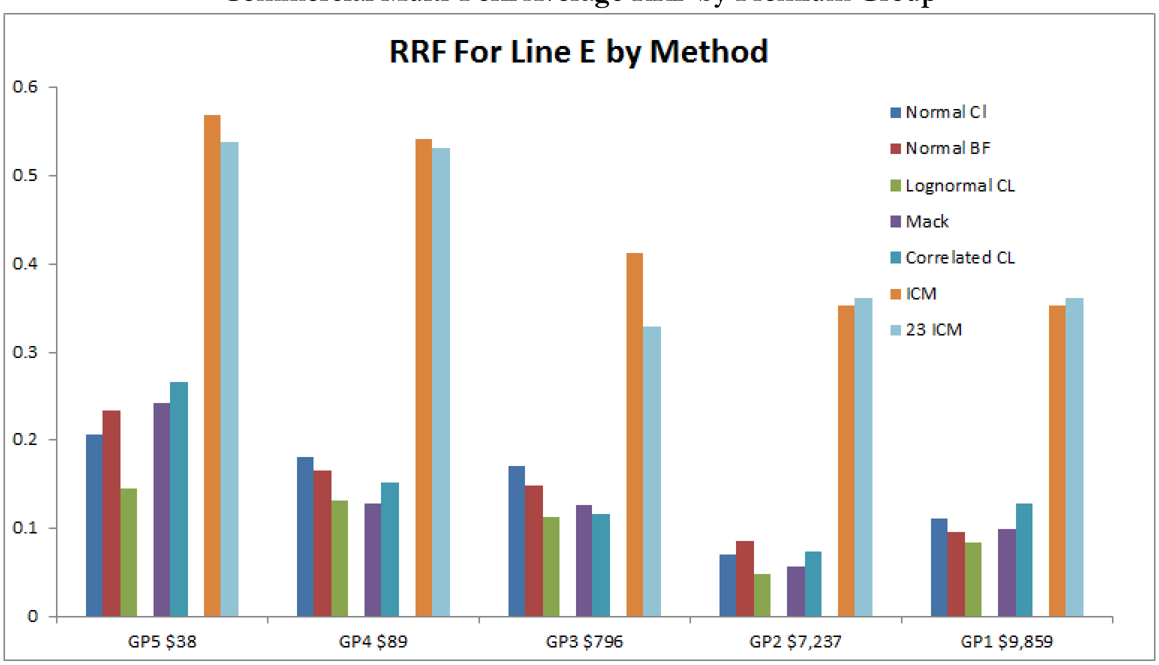


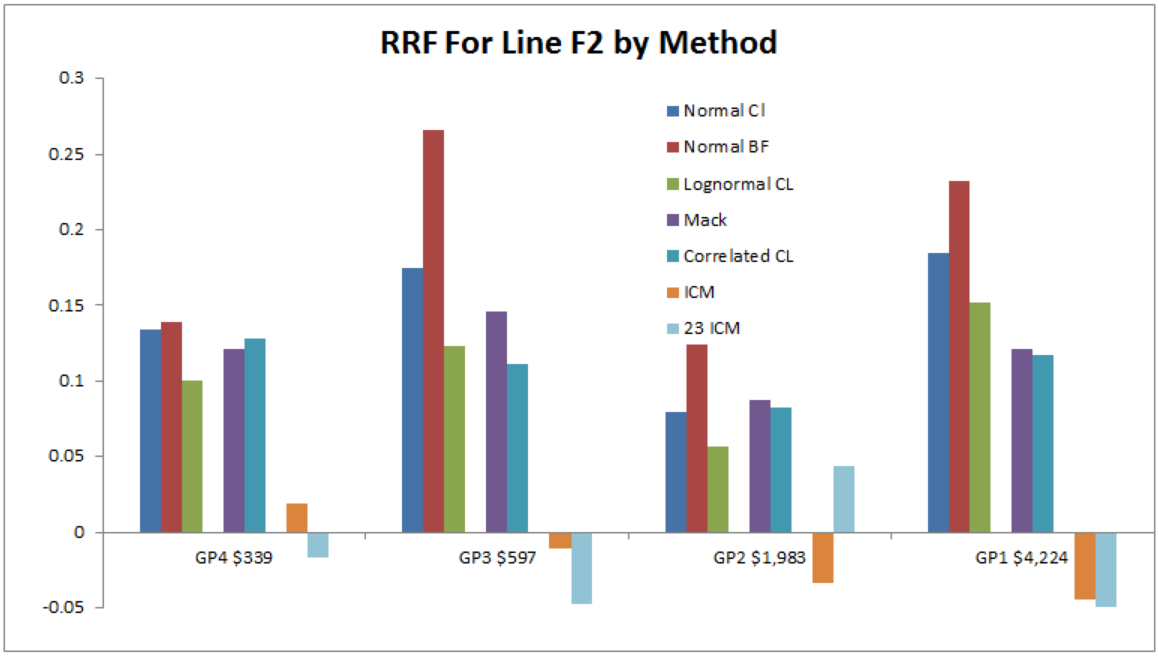
Table 3.5.5
Commercial Multi-Peril Average RRF by Premium Group



<u>Other lines</u>

The medical malpractice claims made LOB, Table 3.5.6, is the only LOB where the ICM indicated RRFs are negative for some of the large premium size groups, probably reflecting favorable reserve development experienced by these companies.

Table 3.5.6
Med Mal Claims Made Average RRF by Premium Group



Tables 3.5.7 and 3.5.8 show that, just as was seen in the scatter plot, the ICM RRFs are very high compared to the corresponding stochastic RRFs for some of the lower premium groups for special liability and some of the larger premium groups for other liability.

Table 3.5.7
Special Liability Average RRF by Premium Group

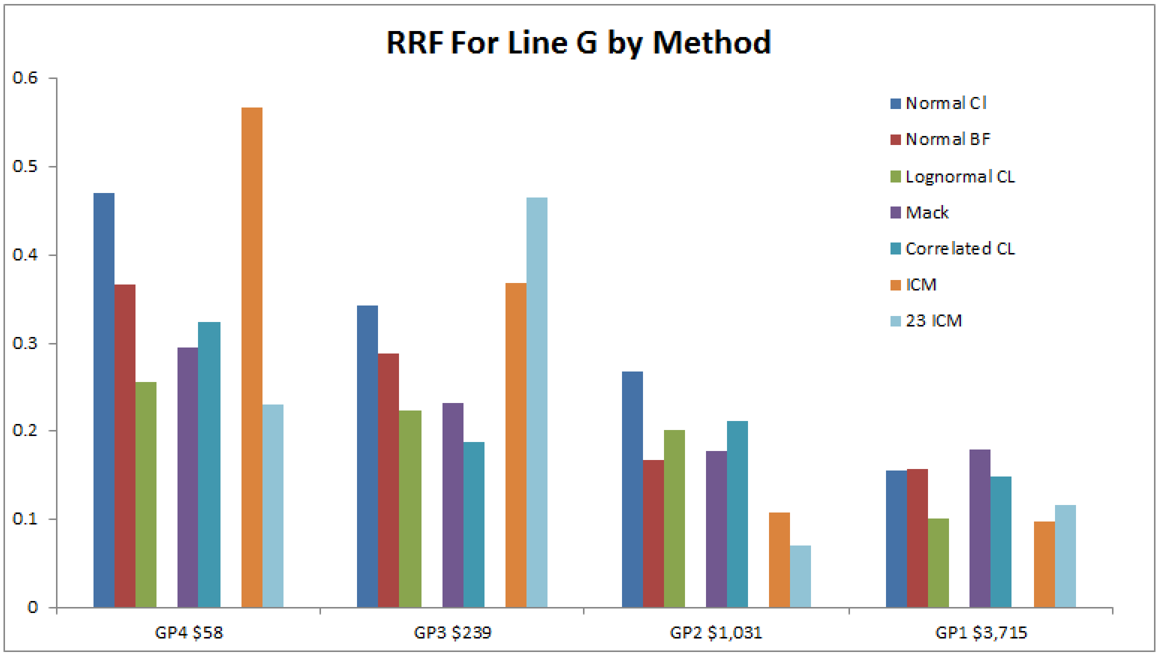
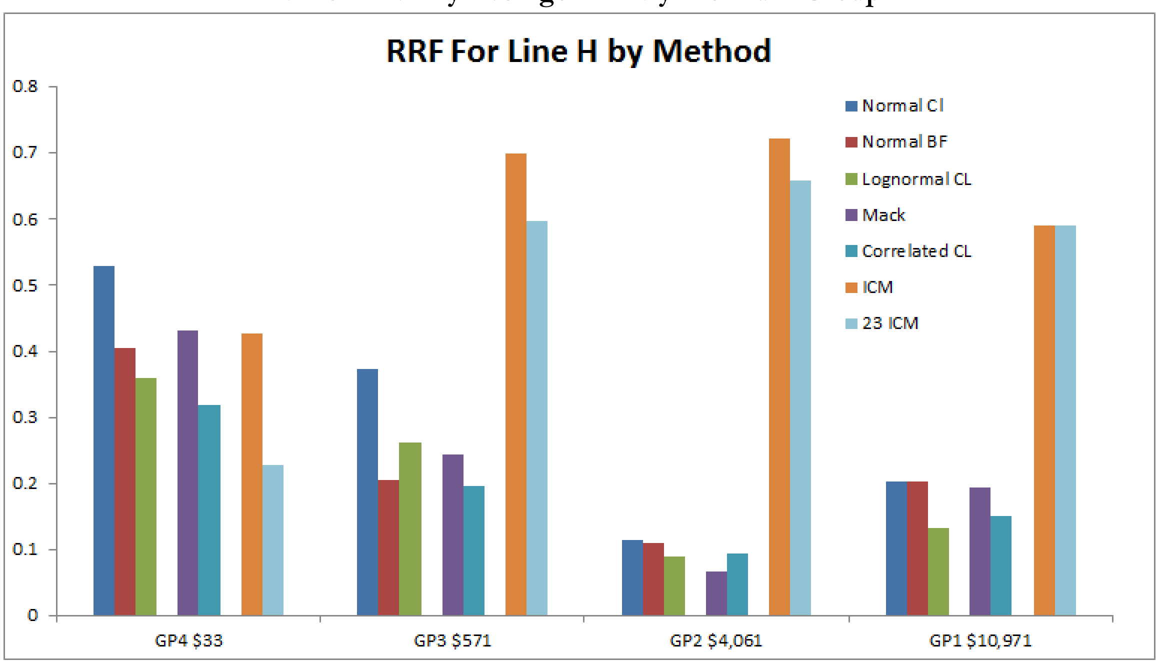
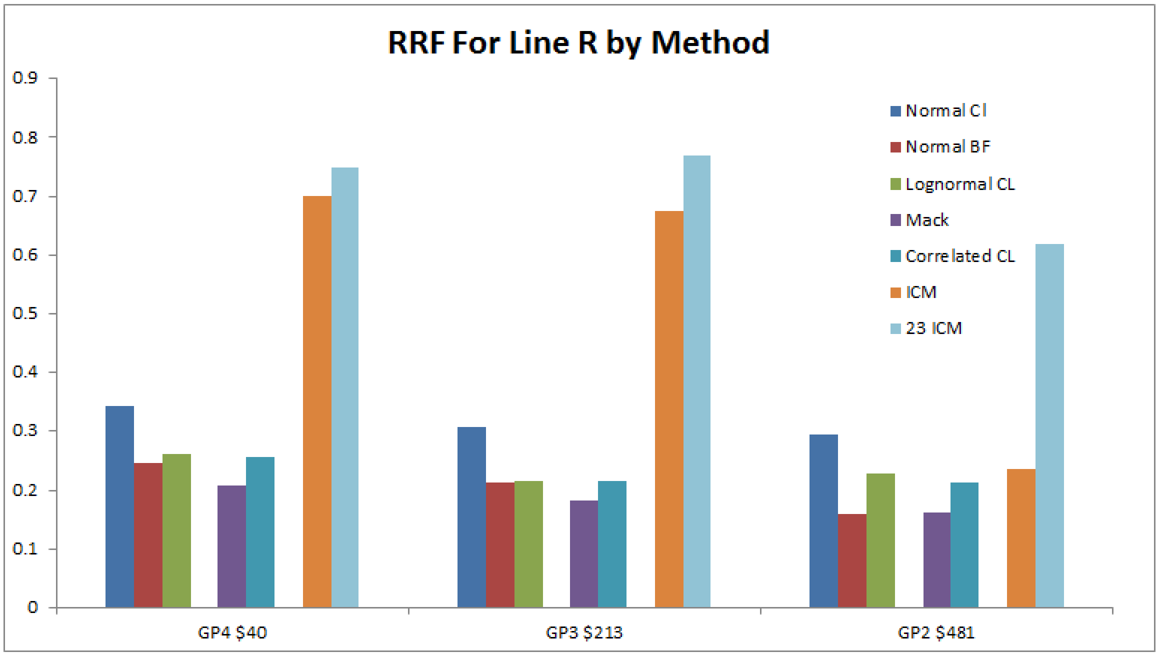


Table 3.5.8
Other Liability Average RRF by Premium Group



For product liability the RRFs for the stochastic methods are relatively close among each other, while the ICM RRFs are in general higher than the stochastic RRFs.

Table 3.5.9
Products Liability Average RRF by Premium Group



The reinsurance liability LOB produces some of the largest RRF across all LOBs reflective of the large uncertainty associated with this coverage.

Table 3.5.10
Reinsurance Property Average RRF by Premium Group

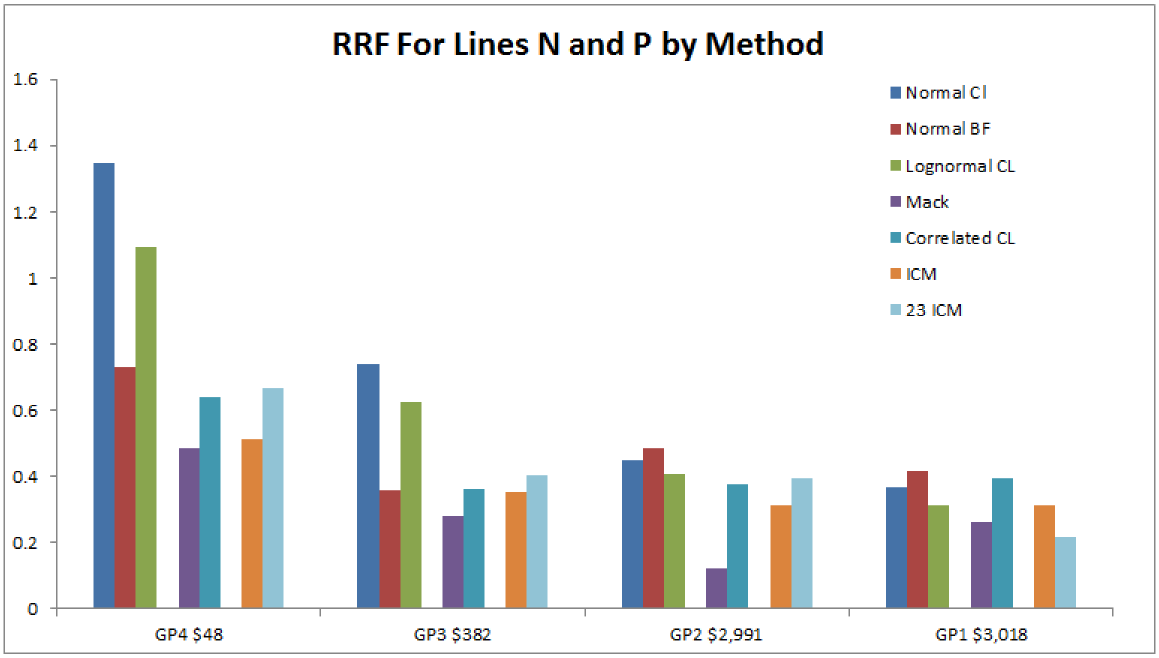
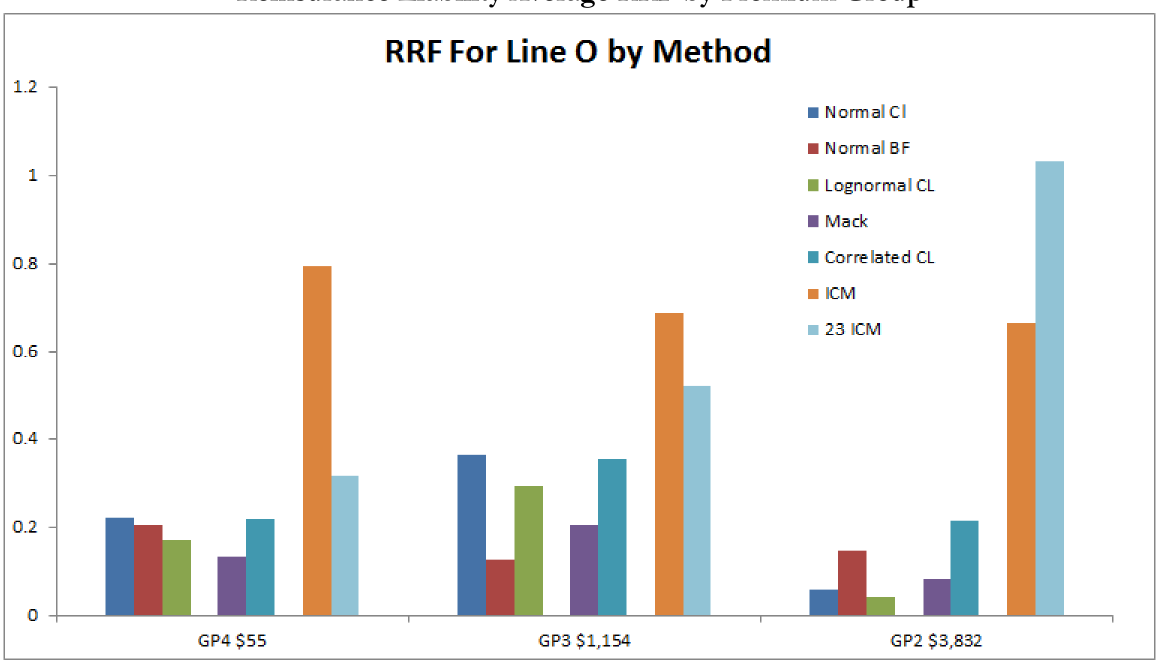


Table 3.5.11
Reinsurance Liability Average RRF by Premium Group



3.6 Comparison of Stochastic Reserve Risk Factors by Method

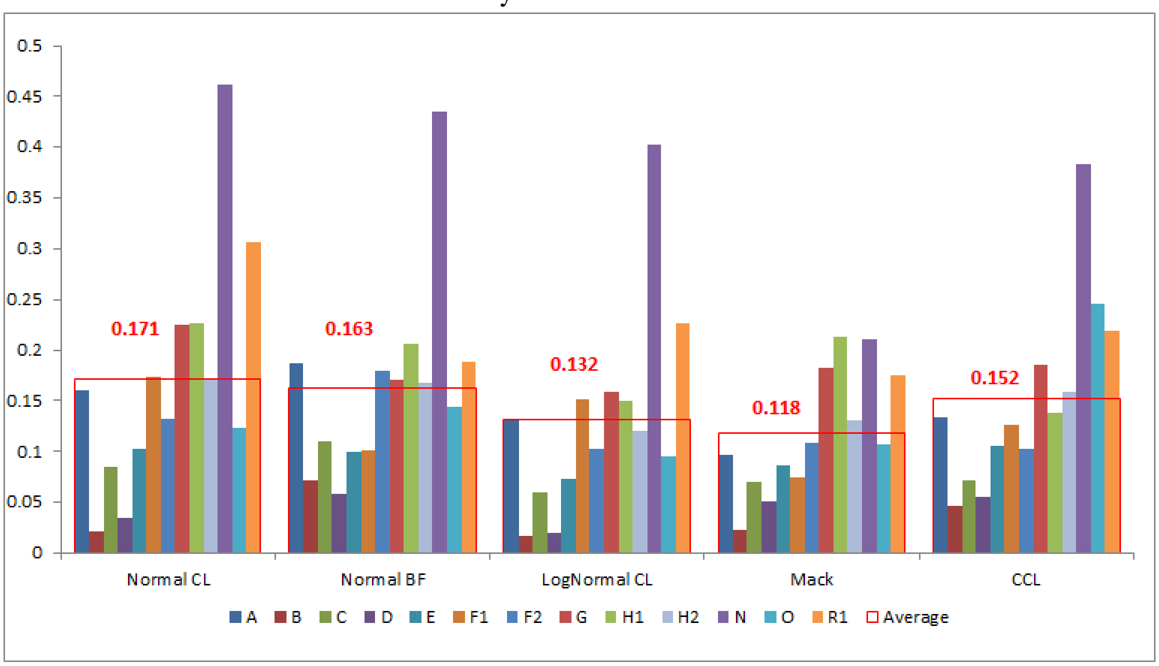
In this section we look at the stochastic methods across all LOBs.

Table 3.6.1 shows the RRF for each LOB and Method. The RRF values are the weighted average across LOB-sizes using booked reserves as weights. Using weighted averages across sizes means that the results are weighted heavily to the large LOBs in Groups 1 and 2 versus the smaller LOBs in Groups 3-5. Therefore the values are notably lower than the values in Table 1.2 where the values were simple averages across premium size groups.

The horizontal line in each set of LOBs by method shows the simple average of these RRF values across LOBs.

We see again that the Normal CL and Normal BF approaches generally produce larger RRFs than the Mack Method. These Normal CL and Normal BF approaches also have larger RRFs than the CCL RRFs. The LogN CL method produces RRFs generally between the Mack and Correlated Chain Ladder ones. The Mack method produces, almost uniformly, the lowest RRFs.

Table 3.6.1
RRF by LOB and Method



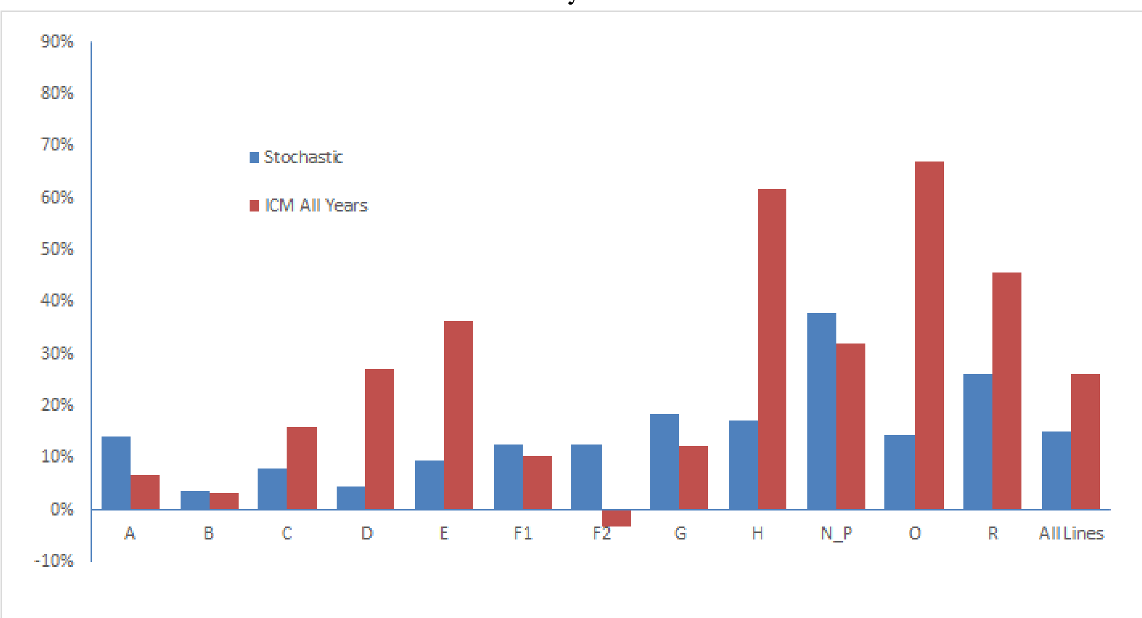
3.7 Comparison of ICM and Stochastic Methods

In this section we compare the results of the stochastic methods to those of the ICM methods, first by LOB and then by LOB-size.

<u>By LOB</u>

Table 3.7.1 shows that the ICM (all years) is lower than the average of the Stochastic Methods for personal lines (A and B) and higher for the large commercial lines (C, D, and E). The results are mixed for the specialty liability lines and reinsurance.

Table 3.7.1
RRF by LOB[26]

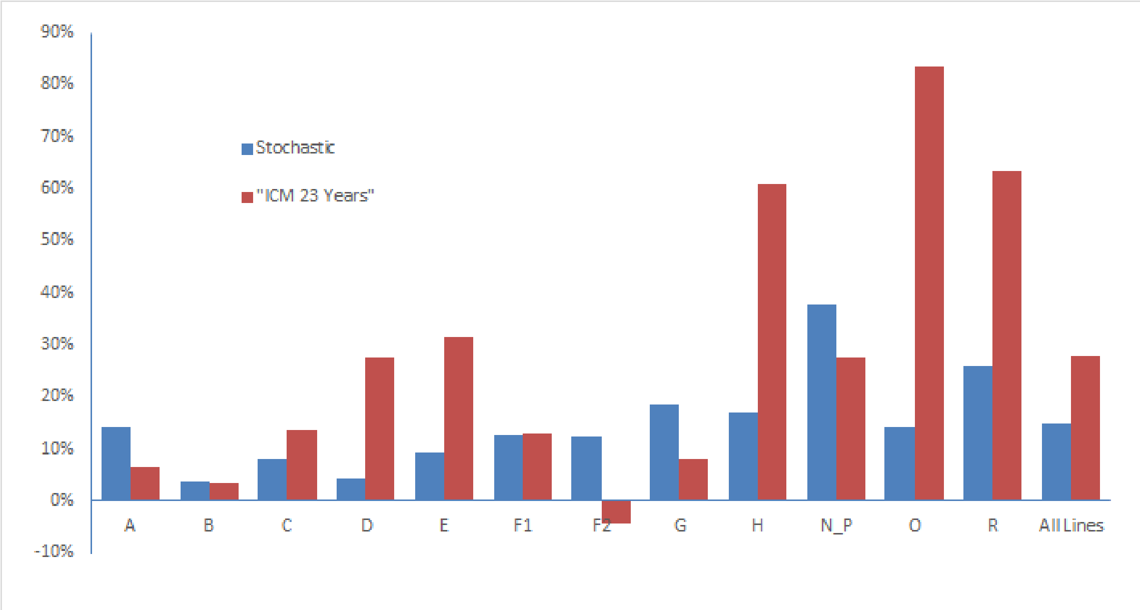


We observe large differences between the two values in several of the LOBs.

In Table 3.7.2 compare the average of stochastic RRFs to the 23 year ICM RRFs.

[26] For each LOB in Tables 3.7.1-3.7.3 the RRF is the weighted average of the RRFs by reserve size within that LOB.

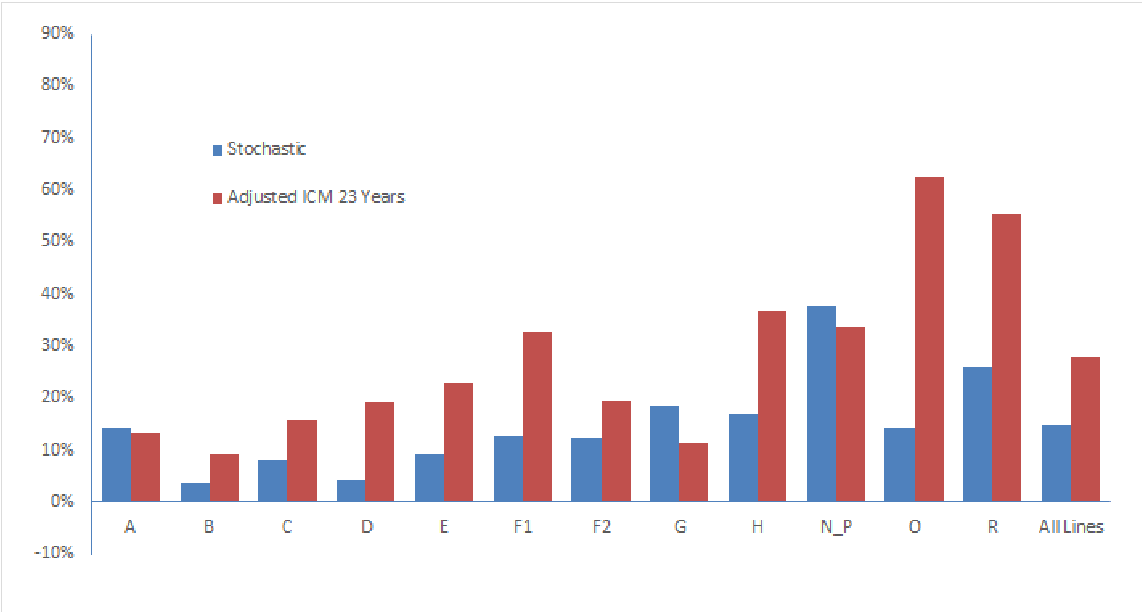
Table 3.7.2
RRF by LOB 23 Years of Data



Limiting the ICM data to those companies with 23 years of reserves available has a mild effect on the difference between methods. Most notably, for commercial auto (C), commercial multi-peril (E), and special liability (G), the ICM 23 years is closer to the stochastic result than was the ICM. However for products liability (R) and assumed liability (O) the difference between the methods increased. This may be attributable to the volatile nature of these lines.

Table 3.7.3, compares the stochastic methods RRFS to the ICM-23 year- Adjusted RRF. The most noticeable effect is a decrease in the difference between the methods for large commercial lines (C, D, and E) and products and other liability lines (H and R). For workers compensation the effect may be partly due to removing the adverse development due to emergence of tabular reserve. For products and other liability the effect may be partly due to removing the effect of adverse development from asbestos liability claims. Also interesting is that the medical malpractice claims made (F2) where the negative indicated ICM RRF becomes positive.

Table 3.7.3
RRF by LOB – Stochastic vs. ICM-23 Years-Adjusted



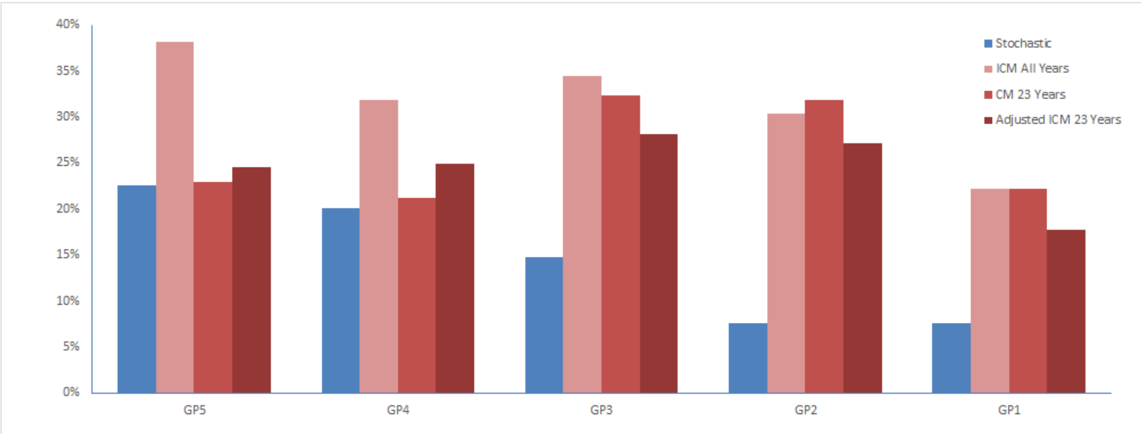
<u>By LOB-Size</u>

Next we consider the same sequence of modifications now grouping the data by premium size instead of LOB.

Table 3.7.4, which is the same as Table 1.2, shows the average of the stochastic methods compared the three ICM results, ICM, ICM-23 years, and ICM-adjusted. We show data by group size in order of increasing LOB-size by premium.

Initially, we see (again) that RRFs decrease as LOB-size increases.

Table 3.7.4
RRF by LOB-Size- Average Stochastic vs. ICM's

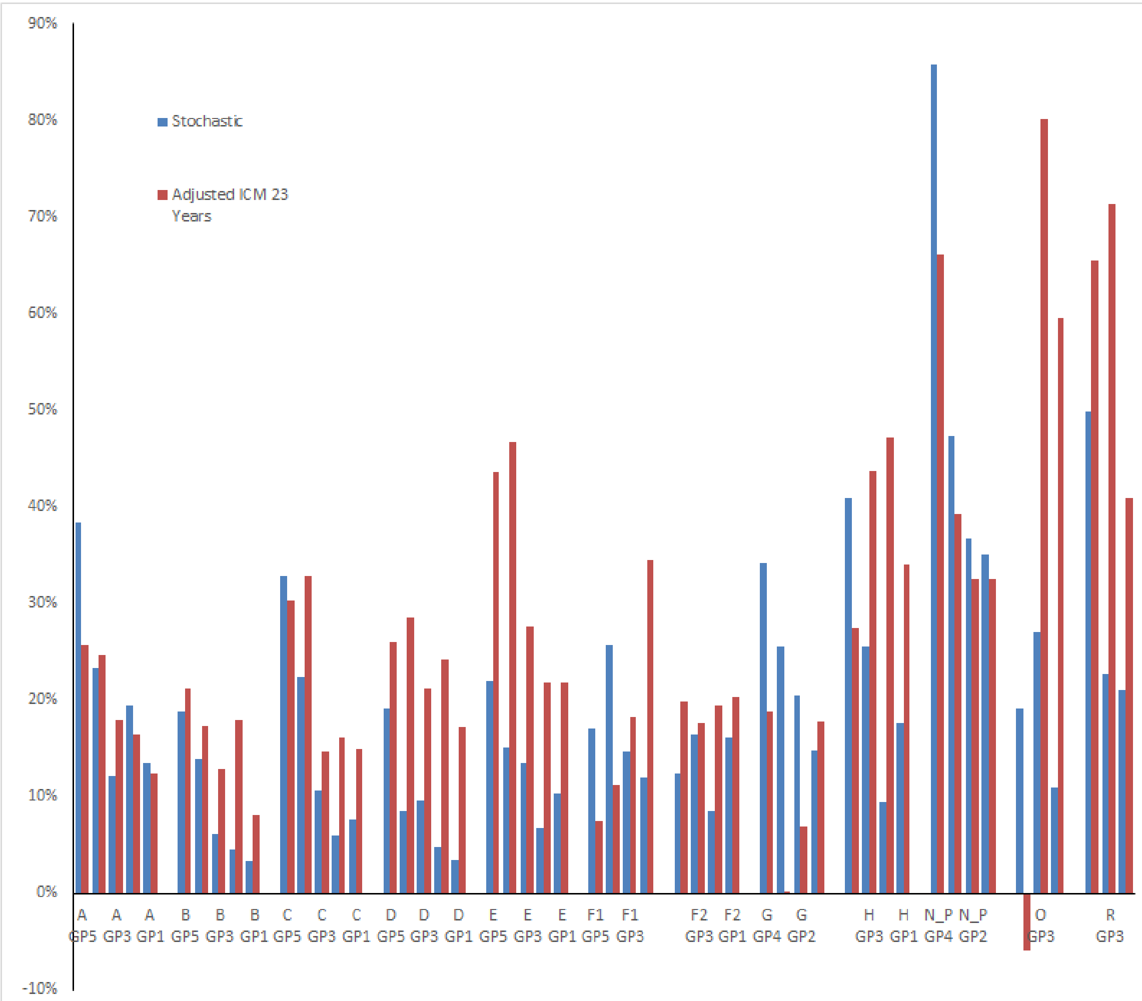


For all LOB-sizes ICM-23-years is closer to the average of the stochastic methods than is the baseline ICM. The remaining difference is larger for the smallest companies, GP4 and GP5. The observed effect for the smallest companies may be due in part the effect of more years of experience offsetting the variability due to small size. The small difference for the largest companies may be due, in part, to the fact that most of the larger companies have 23 years of reserves so there is little difference in the data sets.

The ICM-adjusted method, compared to the ICM-23 year method, reduces the difference for the larger companies but increases the difference for the smallest companies. The ICM-adjusted RRF is much higher than the average stochastic RRF for Groups 1, 2 and 3, the largest companies.

Table 3.7.5 shows more detail regarding stochastic and ICM-adjusted RRFs by LOB, size and method. The overall patterns in table 3.7.4 do not always apply by size band.

Table 3.7.5
RRF by Premium and Group Size



4. Further Research

Areas of further research suggested by this work include the following:

18. Wider sample of companies – Apply the tests in a larger group of companies, including those with less-well behaved data;
19. Other stochastic methods - Measure RRFs using other popular stochastic methods, e.g., bootstrapping;
20. "All Prior" data – examine the effect of industry data excluding the "all prior" experience to determine the effect that data has on the difference between stochastic RRFs and ICM RRFs, with respect to asbestos, non-tabular discount for workers compensation or other factors.
21. More Explanations - Generally better understanding of factors that "explain" the differences between the stochastic and standard formula approaches, by LOB and LOB-size.
22. Time Period – Examine whether the effects observed differ using different time periods, e.g., the first half of the 24 AYs vs. the second half of the 24 AYs.

5. Authors

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Sholom Feldblum	Douglas Robert Nation	Christina Tieyan Zhou
CAS Staff – Karen Sonnet		

6. References

[1] Casualty Actuarial Society E-Forum, CAS Research Working Party on Risk-Based Capital Dependencies and Calibration (DCWP), Report 7, Risk-based Capital (RBC) Reserve Risk Charges – Improvements to Current Calibration Method
http://www.casact.org/pubs/forum/12wforum/DCWP_Report.pdf

[2] Feldblum, Sholom, "NAIC Property/Casualty Risk-Based Capital Requirements," Proceedings of the Casualty Actuarial Society, 1996, pp. 297-435,
http://www.casact.org/pubs/forum/12wforum/DCWP_Report.pdf

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[4] Hodes, Douglas M., Sholom Feldblum, and Gary Blumsohn, Workers Compensation Reserve Uncertainty, CAS E-Forum, 1996, page 61-150
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https://eiopa.europa.eu/fileadmin/tx_dam/files/Press-Room/releases/EIOPA-11-163-A-Report_JWG_on_NL_and_Health_non-SLT_Calibration.pdf

[6] Mack "Distribution-Free Calculation of the Standard Error of Chain Ladder Reserve Estimates," *ASTIN Bulletin* 23, 1993, pp. 213–225.
http://www.actuaries.org/LIBRARY/ASTIN/vol23no2/213.pdf

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http://www.casact.org/pubs/forum/12sumforum/Meyers.pdf

Appendix I – Detailed Procedure for Stochastic RRFs and Comparison of Scaling Methods

In section 3.3 we discuss the conversion of the modeled ultimates from each of the stochastic methods to an RRF. We begin with an example. Consider the data for LOB A for a particular company using the Mack method:

(1)	Total Booked Ultimate (all AYs) from Schedule P Part 2:	$588,767
(2)	Total Paid to Date (all AYs) from Schedule P Part 3:	$541,378
(3)	Total Booked Reserves (1) – (2)	$47,389
(4)	Modeled Ultimate (Mack Mean)	$584,025
(5)	Modeled Reserves (4) – (2)	$42,647
(6)	87.5th Percentile of Modeled Ultimate (Mack)	$586,987
(7)	87.5th Percentile of Modeled Reserve (6) – (2)	$45,609
(8)	87.5th Percentile of Booked Ultimate Scaled by Ultimate (1) x (6) / (4)	$591,753
(9)	87.5th Percentile of Booked Reserves Scaled by Reserves (3) x (7) / (5)	$50,680
(10)	Reserve Risk Factor Based on Scaled Ultimate [(8) – (1)] / (3)	0.063
(11)	Reserve Risk Factor Based on Scaled Reserves [(9) – (3)] / (3)	0.069

We have shown the two methods of scaling discussed in the paper. As mentioned, we do not believe there would be a material difference in our conclusions if we had used the reserve scaling instead of the ultimate scaling. Tables I-1 through I-5 show a linear relationship for the RRFs calculated by the two scaling methods for each of the 5 stochastic methods. We include the 45 degrees slope line as well as an aid to compare the results from the two scaling methods.

Table I-1
Scatter Plot of RRFs by Scaling Method –
Normal Chain Ladder Method

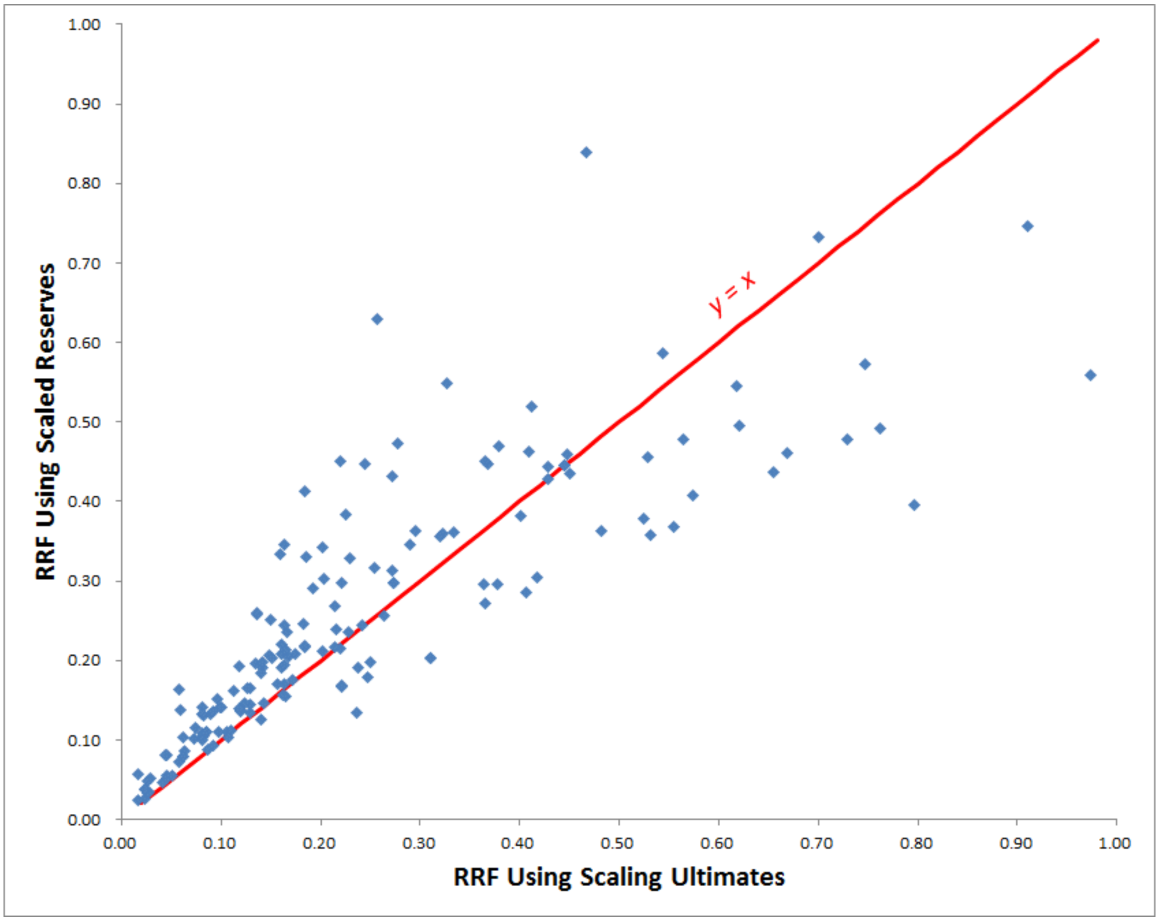


Table I-2
Scatter Plot of RRFs by Scaling Method –
Normal Bornhuetter-Ferguson Method

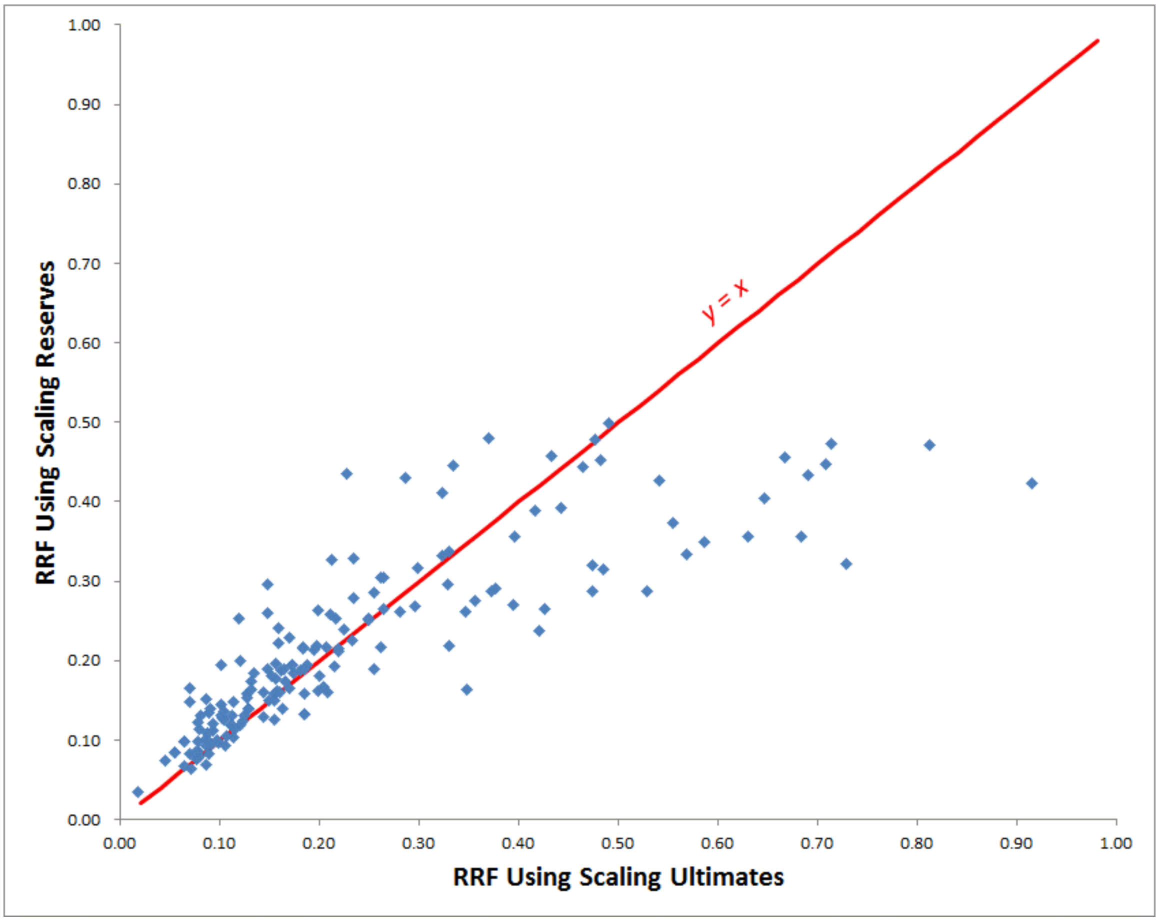


Table I-3
Scatter Plot of RRFs by Scaling Method –
Lognormal Chain Ladder Method

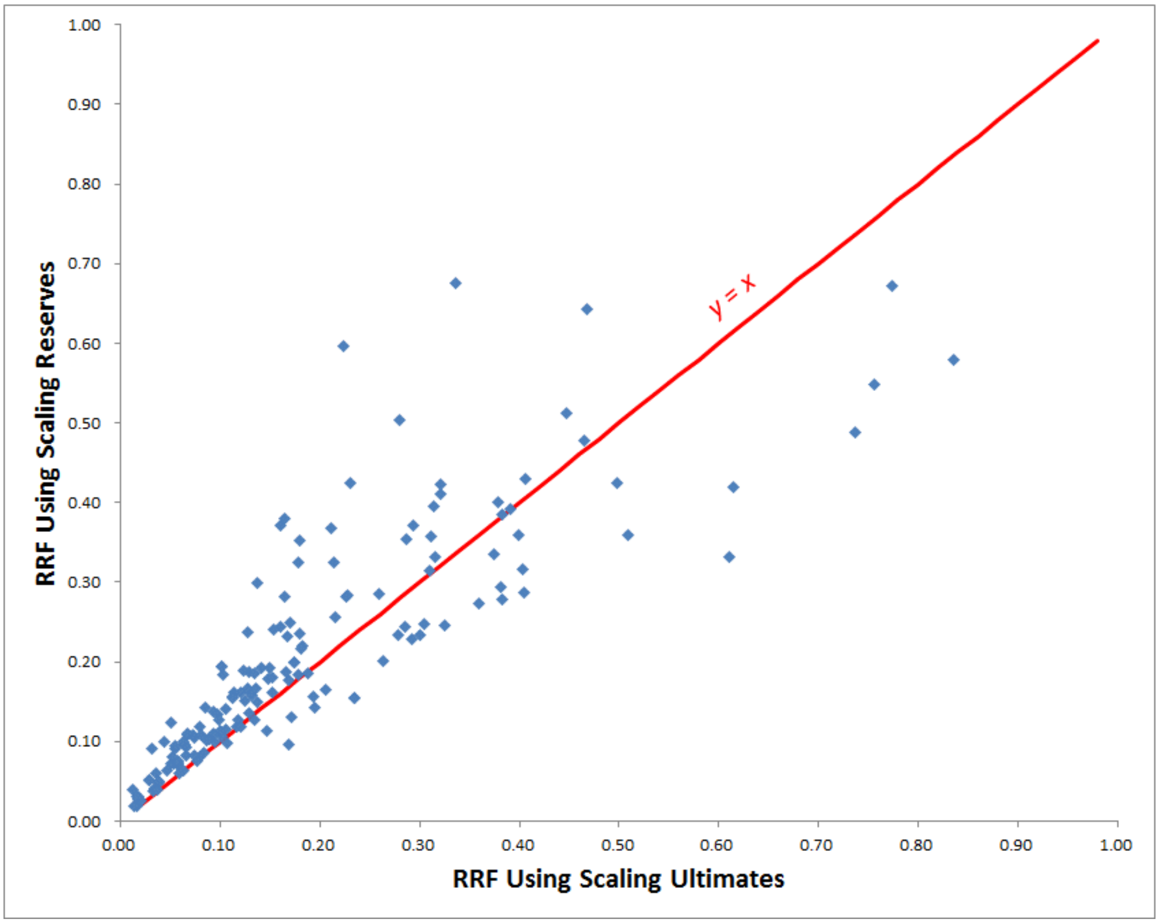


Table I-4
Scatter Plot of RRFs by Scaling Method –
Mack Method

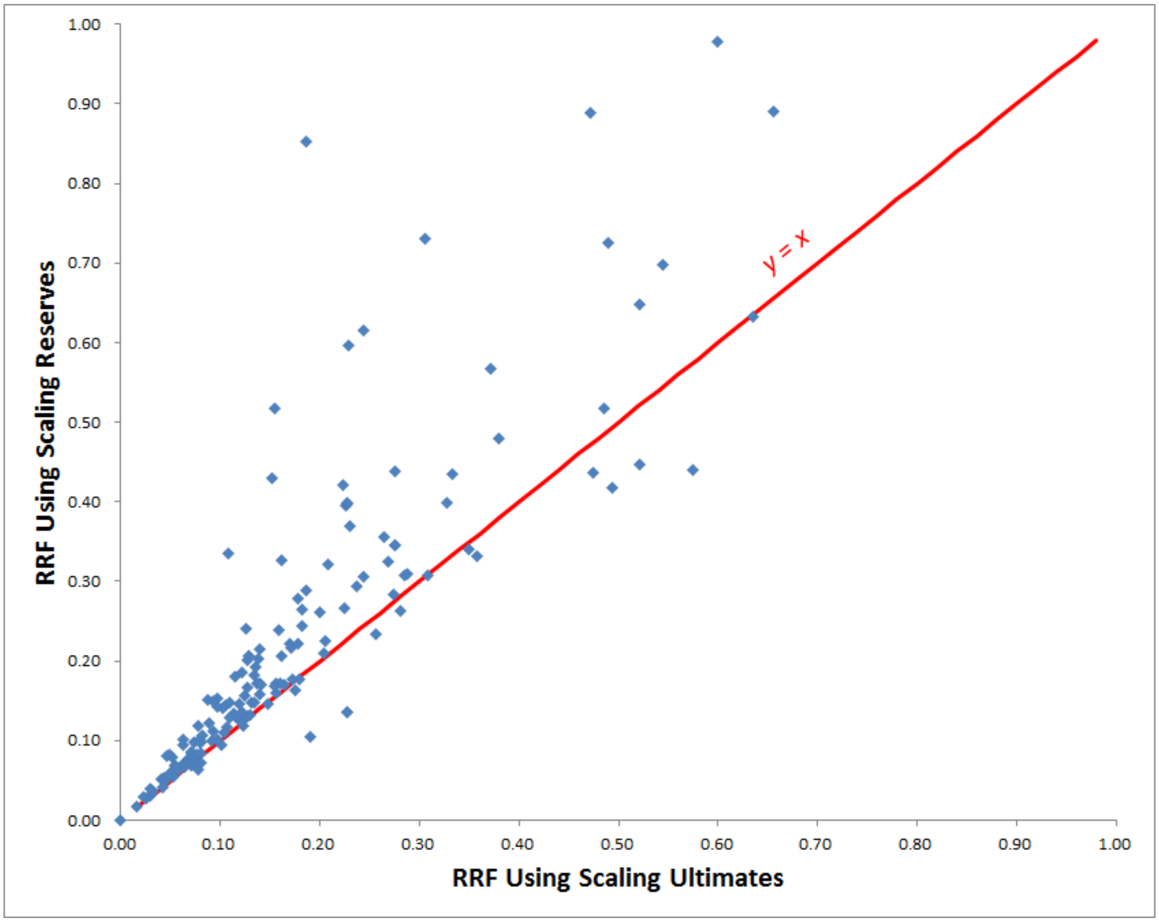
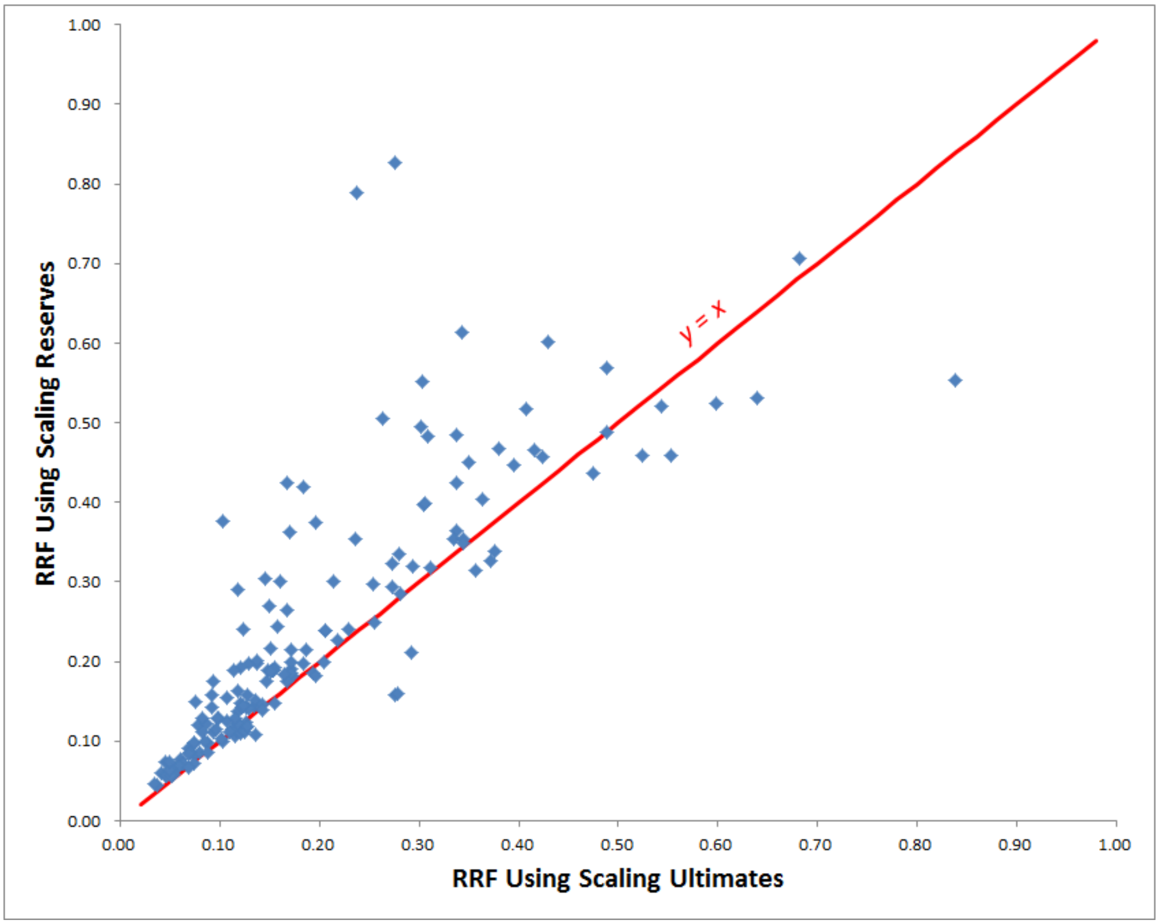


Table I-5
Scatter Plot of RRFs by Scaling Method –
Correlated Chain Ladder Method



Appendix II – Significance Testing of Log-Linear Regression

The table below shows the comparison of the T-ratio of the slope of the regression for each LOB and method against the T-statistic from the two-tail Student T-distribution with a 10% level of significance.

Table II-1
T-Ratio of Regression Slope by Method

		T-Ratio				
LOB	10% Significance Test Stat	Normal CL	Normal BF	LogN CL	Mack	CCL
A	2.110	3.958	3.958	3.761	3.760	2.712
B	2.101	4.021	4.021	5.268	3.394	4.359
C	2.110	6.305	6.305	7.346	2.804	6.955
D	2.086	5.070	5.070	5.027	5.073	5.034
E	2.110	2.605	2.605	2.340	1.847	2.139
F1	4.303	1.163	1.163	0.720	2.284	0.132
F2	2.571	0.334	0.334	0.069	2.723	2.416
G	2.201	3.279	3.279	1.170	2.761	2.575
H	2.074	1.900	1.900	2.216	1.719	2.778
N	2.776	1.318	1.318	0.808	0.772	1.196
O	3.182	2.506	2.506	0.255	0.985	0.392
R	2.447	1.251	1.251	1.686	0.690	1.702

Table II-2
Interpretation of the Two-Sided T-Test –
Is the Slope Statistically Significant?

LOB	Number of Companies	Normal CL	Normal BF	LogN CL	Mack	CCL
A	19	Yes	Yes	Yes	Yes	Yes
B	20	Yes	Yes	Yes	Yes	Yes
C	19	Yes	Yes	Yes	Yes	Yes
D	22	Yes	Yes	Yes	Yes	Yes
E	19	Yes	Yes	Yes	No	Yes
F1	4	No	No	No	No	No
F2	7	No	No	No	Yes	No
G	13	No	Yes	No	Yes	Yes
H	24	Yes	No	Yes	No	Yes
N	6	No	No	No	No	No
O	5	No	No	No	No	No
R	8	No	No	No	No	No

Generally the LOBs with large reserves and many companies represented result in statistically significant slopes. The Feldblum methods appear to be well suited for the large personal and commercial lines. Among the stochastic methods, only Mack produces a statistically significant slope for either of the med-mal lines. Finally, due to the limited number of available data points, the slopes of the regressions of the reinsurance lines are not statistically significant.