Rebalancing the off-Balance Factor Using the Complement of Credibility

Joseph Boor, FCAS, Ph.D., CERA/Jeffery Smith, FCAS, MAAA

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Key Point of Presentation

- Off-balance from credibility arises when post-credibility (or "after credibility process") rates by class don't weight to the total average rate.

- Current practice is to spread off-balance with factor multipied by all rates.

- **Key Point: You get more accurate and more reasonable rates when you just spread the off-balance from credibility across the complement of credibility terms $(1 - Z) \times ...$**

Why is Using the Complement of Credibility Term Better?

- For a fully credible or “nearly fully credible”, the current process alters a rate that is known to be proper and then modifies it.
  - This takes a rate that’s right and makes it wrong.
- As we’ll see, the present process is suboptimal

Example—Similar to Data Seen in Actual Practice

Coverage	(1) (Data) On-Level Earned Premium	(2) (Data) Trended Ultimate Losses	(3) (2)/(1) Loss Ratio	(4) (Data) Credibility	(5) (Data) Permssble Loss Ratio	(6) ((3)/(5))-1.0 Indicated Changes	(7) [Comb(6)] /[Wtd.(6)] Off-Balance Factor	(8) (1.0+(6))×(7)-1.0 Revised Indicated Changes
A	$ 450,000	$ 900,000	200.0 %	25 %	65 %	52.3 %		63.0 %
B	$ 500,000	$ 500,000	100.0 %	27 %	65 %	14.3 %		22.3 %
C	$ 1,000,000	$ 800,000	80.0 %	38 %	65 %	8.7 %		16.3 %
D	$ 3,000,000	$ 1,400,000	46.7 %	65 %	65 %	-18.3 %		-12.6
E	$ 5,000,000	$ 3,800,000	76.0 %	100 %	65 %	16.9 %		25.1 %
Wtd. Average						6.9 %		14.4 %
Comb. Total	$ 9,950,000	$ 7,400,000	74.4 %	100 %	65 %	14.4 %	1.070	

Made up Example-Class Pure Premium Ratemaking-Worse Experience in Smaller Classes

Main Calculations for Class Rates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	(Data)	(Data)	(1)/(2)	(1)×C	Sqrt((4)/683)	(3)×(5) +A(1.0-(5))	(6) × E
Class	Exposure	Losses	Raw Rate "L"	Expected Claim Count	Credibility of Class	Credibility Adjusted Rate	Corrected (Rate
A	25	$ 78,427	$ 3,137	65	31 %	$ 1,324	$ 1,564
B	30	$ 40,687	$ 1,356	78	34 %	$ 800	$ 946
C	36	$ 65,073	$ 1,808	93	37 %	$ 994	$ 1,174
... D-L not shown ...							
M	223	$ 69,726	$ 313	577	92 %	$ 329	$ 389
N	267	$ 64,108	$ 240	692	100 %	$ 240	$ 283
O	321	$ 86,197	$ 269	831	100 %	$ 269	$ 317
Total	1,801	$ 932,211	$ 518	4,661	%	$ 438	$ 518

Reference Values for All Classes

A =Needed Overall Average Rate	$518
B = Severity (Computed Outside the Table)	$200
C = A/B = Expected Claims/Exposure	2.588
D = Average Z-Adjusted Rate	$438
E = A/D = Off-Balance Factor	1.1814

Skipped Example-Using Loss Ratio Method or Assigning Complement to the Overall Average Relativity Instead of Pure Premium Method

- As long as the complement is multiplied by something containig the overall claims costs—same resulting rates.

What About When Complement of Credibility is Multiplied by the Current Relativity

Main Calculations for Class Relativities

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	(Data)	(Data)	(1)/(2)	(3)/ [Cls O (3)]	(1) × C	$\sqrt{((5)/683)}$	(Data)	(4) × (6) +(1.0-(6))×(7)	[Avg(8)] × [(3) for Class O]	A/(9)	[Cls O (3)]) ×(8)×(10)
Class	Exposure	Losses	Raw Rate	Raw Relativity Indication	Expected Claim Count	Credibility of Class	Current Relativity	Credibility Adjusted Relativity	Average Rate	Off-Balance Correction Factor	Final Rates
A	25	$ 78,427	$ 3137	11.682	65	31 %	8	9.133			$ 2550
B	30	$ 40,687	$ 1356	5.05	78	34 %	6	5.68			$ 1586
C	36	$ 65,073	$ 1808	6.731	93	37 %	5	5.639			$ 1575
... D-L not shown ...											
M	223	$ 69,726	$ 313	1.165	577	92 %	1.25	1.172			$ 327
N	267	$ 64,108	$ 240	0.892	692	100 %	1	0.892			$ 249
O	321	$ 86,197	$ 269	1	831	100 %	1	1			$ 279
Total/Avg	1801	$ 932,211	$ 518	1.928	4661		1.836	1.858	$ 499	1.038	$ 518

Reference Values for All Classes : Continue Values A-C from earlier Table

General Results

- Present method takes rates that are right (fully credible rates) and makes them wrong.

- Especially when small classes have different loss experience than large classes, off-balance generated by smaller classes impacts large classes that did not generate off-balance.

- Off balance may be smaller, especialy when complement is close to experience data, but can also be large.

What to Do About It?-Classical Credibility

- Maximum (optimum) Plausibility approach-Leave the Credible Data Alone
  - No change to fully credibile rates.
  - Assuming overall change is proper and must be matched, assign off-balance to rates where it is most plausible the rate is wrong (small classes).
  - Only two unbiased estimators of classes' losses to allocate across, overall rate and class rates, using class rates generates obvious bias. Allocate soloely across the overall rate in $(1 - Z)$ term.

Does Allocating the Balance Across the Complement Term Make a Difference?—Difference From First Example

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	(Data)	(Data)	(2)/(1)	(Data)	(Data)	((3)/(5))-1.0	(1.0-(4))*(5)	((1)*(7)	(1)×[Comb (6)] -[Wtd(6)]	(9)×(8) [Total (8)]	(6)+ [(10)/(1)]	Prev. Col.(8)
Coverage	On-Level Earned Premium	Trended Ultimate Losses	Loss Ratio	Credibility	Permssble Loss Ratio	Indicated Changes	Complmnt of Credibility Term	Dollar Amount of Complement	Dollar Deficiency in Base Calculation	Off-Balance Correction Pro-Rated by Dollars in Complement	Off-Balance Corrected Indications	Indications Under Old Off-Balance
A	$ 450,000	$ 900,000	200.0 %	25 %	65 %	52.3 %	48.6	$ 218,865		$ 105,474	75.7 %	63.0 %
B	$ 500,000	$ 500,000	100.0 %	27 %	65 %	14.3 %	47.8	$ 238,758		$ 115,061	37.3 %	22.3 %
C	$ 1,000,000	$ 800,000	80.0 %	38 %	65 %	8.7 %	40.6	$ 406,070		$ 195,691	28.2 %	16.3 %
D	$ 3,000,000	$ 1,400,000	46.7 %	65 %	65 %	-18.3 %	22.8	$ 682,500		$ 328,906	(7.4) %	(12.6) %
E	$ 5,000,000	$ 3,800,000	76.0 %	100 %	65 %	16.9 %	0.0	$ 0			16.9 %	25.1 %
Wtd Average						6.9 %					14.4 %	14.4 %
Comb Total	$ 9,950,000	$ 7,400,000	74.4 %	100 %	65 %	14.4 %		$ 1,546,192	$ 745,132	$ 745,132		

Allocation of Off-Balance /using Complement of Credibility

Main Calculations for Class Rates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
i	e_i	l_i	L_i	c_i	Z_i	$Z_iL_i + (1-Z_i)M$	$R_i \times e_i$	$e_i(1-Z_i)$	$e_i(1-Z_i)M \times C$	$e_i \times r_i$	$final\ r_i$	$old\ r_i$
	(Data)	(Data)	(1)/(2)	(1)×C	Sqrt of ((4)/683)	(3)×(5) +A(1.0-(5))	(6)×(1)	((1)×(1.0-(5)) × A	(8)×H	(5)×(3)×(1) +(9)	(5)×(10)/(1)	Prev Col. 7
Class	Exposure	Losses	Raw Rate "L"	Expected Claim Count	Credibility of Class	Credibility Adjusted Rate	Losses in Adjusted Rates	Losses From Complement of Credibility	Complement Losses After Off-Balance Correction	Off-Balance Corrected Total Losses	Off-Balance Corrected (Rate	Indications Under Old (Off-Balance
A	25	$ 78,427	$ 3,137	65	31 %	$ 1,324	$ 33,097	$ 8,958	$ 15,465	$ 39,605	$ 1,584	$ 1564
B	30	$ 40,687	$ 1,356	78	34 %	$ 800	$ 24,012	$ 10,293	$ 17,771	$ 31,489	$ 1,050	$ 946
C	36	$ 65,073	$ 1,808	93	37 %	$ 994	$ 35,787	$ 11,752	$ 20,290	$ 44,324	$ 1,231	$ 1,174
						... D-L not shown ...						
M	223	$ 69,726	$ 313	577	92 %	$ 329	$ 73,422	$ 9,338	$ 16,122	$ 80,206	$ 360	$ 389
N	267	$ 64,108	$ 240	692	100 %	$ 240	$ 64,108	-	-	$ 64,108	$ 240	$ 283
O	321	$ 86,197	$ 269	831	100 %	$ 269	$ 86,197	-	-	$ 86,197	$ 269	$317
Total	1,801	$ 932,211	$ 518	4,661		$ 438	$ 789,053	$ 197,065	$ 340,223	$ 932,211	$ 518	$ 518

Reference Values for All Classes

A =Needed Overall Average Rate	$518
B = Severity (Computed Outside the Table)	$200
C = A/B = Expected Claims/Exposure	2.588
D = Total Losses in Data	$932,211
E = Total Losses in Adjusted Rates	$789,053
F = D-E = Off-Balance in $	$143,158
G = Total Losses in $(1-Z_i)$ Term	$197,065
H = 1.0+F/G = Off-Balance Factor	1.742

Is This Actually Better?

- Rates of fully credibile classes not distorted.

- Classes that generate the off-balance are most responsible for absorbing it.

- No method, that isn't an additional credibility method, and uses the two unbiased estimators for each class (overall rate and class loss data) generates more plausible results.

  – "This could happen." The calculations could actually hit the true underlying loss costs.

Do Large Off-Balances Actually Happen in Regular Actuarial Work?

- Not just listed as “off-balance”, could be “effect of changes in relativity factor”, or some other adjustment (credibility-induced) needed to achieve overall rate level.
- Some off-balances are per data differences, e.g., relativities-per 5 years of countrywide data, in state indication. For data differences, old method likely best.
- If you say “my off-balance has never been over 0.5%, well ”If it’s immaterial, it’s immaterial how you handle it”.
  - If you may ever have to change, it’s easier to start when it doesn’t matter.

Bailey's Best Estimate $Z = P/(P + K)$ Credibiliy

- Excellent idea that is underutilized—Maybe because of processing limitations in 1945

- By design, gives the most accurate estimate of rate needs

  – Much attention give to removing overlap factor with GLMs, or adding new predictors to improve rate accuracy.

  – If just converted to best estimate credibility (example later) could pers get even better results.

Optimum Off-Balance Approach for Best Estimate Credibility

- This also requires allocating the off-balance using the complement of credibility term.

- Why? If you start with the post-credibility (credibility-weighted class loss rate and the overall loss rate) rates as the "right", but require that the results weight to the overall average rate, "constrained optimization" shows that allocating the difference according to the complement of credibility produces the least expected square error.

- One example (second one) rerun with best estimate credibility on next page.

Second Example Data Rerun as Best Estimate

First Step: Calculation of Basic Variance Parameters

I. Sum of Squared Differences from Sample Means Within Classes "i" $= \alpha^2 =$	7.379E+9
II. Sum of Exposures Times Squared Differences Between Class Sample Means "L_i's" and Overall Mean "M" $= \beta^2 =$	3.941E+8
III. = I./((total(1)-15(="n"))=Process Variance $= s^2 =$	4,131,869
IV. = [II.- (n-1.0)III.]/[total(1)-n/total(1)]= Variance of Hypothetical Means $= \sigma^2 =$	186,740
V. III./IV = Credibility Constant=K =	22.13

Second Step: Main Calculations for Class Rates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i	e_i	l_i	L_i	Z_i	R_i	$R_i] \times e_i$	$e_i(1-Z_i)$	$e_i(1-Z_i)M \times C$	$e_i \times r_i]$	$final\ r_i$
	(Data)	(Data)	(1)/(2)	(1)/ ((1)+V.)	(3)×(4) +A×(1.0-(4))	(5)×(1)	(1) × (1.0-(5))	(7)×A×F	(6)+(8)	(5)×(9)/(1)
Class	Exposure	Losses	Raw Rate "l"	Credibility of Class	Credibility Adjusted Rate	Losses in Adjusted Rates	Off-Balance Correction Basis	Additional Losses From Off-Balance Correction	Off-Balance Corrected Total Losses	Off-Balance Corrected (Rate
A	25	$ 78,427	$ 3,137	53 %	$ 1,907	$ 47,681	$ 12	$ 3,265	$ 50,945	$ 2,038
B	30	$ 40,687	$ 1,356	58 %	$ 1,000	$ 30,008	$ 13	$ 3,542	$ 33,550	$ 1,118
C	36	$ 65,073	$ 1,808	62 %	$ 1,317	$ 47,396	$ 14	$ 3,811	$ 51,207	$ 1,422
					... D-L not shown ...					
M	223	$ 69,726	$ 313	91 %	$ 331	$ 73,849	$ 20	$ 5,598	$ 79,448	$ 356
N	267	$ 64,108	$ 240	92 %	$ 261	$ 69,789	$ 20	$ 5,684	$ 75,473	$ 282
O	321	$ 86,197	$ 269	94 %	$ 285	$ 91,353	$ 21	$ 5,757	$ 97,110	$ 303
Total	1,801	$ 932,211	$ 518		$ 478	$ 860,709	$ 257	$ 71,501	$ 932,211	$ 518

Reference Values for All Classes

A = Overall Average Rate	$518
B = Total Loss in Credibility Adjusted Rates	$860,709
C= Total Losses in Data	$932,211
D = C-B = Shortfall	$71,501
E =Total Off-Balance Correction Basis	$257
F = D/E = Off-Balance Factor	278.13

Calculation of Best Estimate Credibillity and Best Estimate Allocation of the Off=Balance

- Calculations not too bad-allocating the off-balance is the easiest part.

- Not hard to do the top variance estimates in R.

- It was diferent in Bailey's time.

Non-Bailey Situations Where Off-Balance Should be Allocated Using $1 - Z$

- Bailey formula $= Z = P/(P + K)$; $K =$(Expected process variance)/(Variance of hypothetical means).

- Allocatiion across $(1 - Z)$'s still optimal when expected process variance differs among classes.

- When variance of hypothetical means varies among classes allocate by
  - (Variance of hypothetical means for this class)$\times(1 - Z)$.

Bühlmann’s Complement of Credibility

- Not new, but was ‘new to me”
- Standard ratemaking uses exposure-weighted average of loss rates, Bühlmann’s complement of credibility = loss rates weighted with the credibility of each class.
- Then post-credibility rates weight exactly to overall rate—no off-balance allocation needed.
- Results exactly equal results of allocating off-balance across the complement of credibiity.

Consequences of Matching Bühlmann's Complement of Credibility

- Given all the data for all the classes, each final Bühlmann credibility weighted rate, or $(1-Z)$ off-balance allocated rate is the expected loss rate for the class.

- If there is enough data for Central Limit Theorem to govern the distribution, mean of normal from above = maximum likelihood estimate.

- Allocating off-balance gives (in context) minimum expected squared difference from post credibility rates, mean estimate of loss costs, and (often) maximum likelihod estimate.

Why Not Just Use Bühlmann's Complement of Credibility

- Doesn't work for capped data

- Presentation of calculations is less intuitive.

  - Our audience usually includes more than actuaries: company mahangers, underwriters, financial staff, and in my case, regulators and judges.

  - Helpful to make the presentation as intuitive as possible.

Test Correction

- Test Correction vs. Off-Balance Correction: Off-balance correction spreads off-balance resulting from credibility, test correction spreads that off-balance plus the off-balance resulting from capping.
- Often requires multiple iterations- classes fall in and out of capping
- Allocating off-balance by $(1-Z)$ is "scalable ". You can just increase the amount multiplied by $(1-Z)$'s to offset capping, while still getting first type of optimum estimate.
- Bühlmann's complement of credibility not suitable for test correction process.

Test Correction Example - Best Estimate Data-First Step Follows

First Step: Calculations Using Uncapped Rates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	(Data)	Prev. Table col.(5)	Prev. Table col.(10)	(1)*(3)	(Data)	.85*(5)	1.15*(5)	(3) within (6),(7)	(1)*(8)	Y=Knocked Out
Class	Exposures	Credibility Adjusted Rate	Pre-Cap Test Corrected Rate (Set 0)	Losses in Pre-Cap Test Corrected Rate	Present Rate	Cap Below	Cap Above	Capped Rates (Set 0)	Total Losses in Capped Rates	Is Rate Knocked Out of TCF by Capping?
A	25	$ 1,907	$ 2,038	$ 50,945	$ 2,000	$ 1,700	$ 2,300	$ 2,038	$ 50,945	
B	30	$ 1,000	$ 1,118	$ 33,550	$ 1,500	$ 1,275	$ 1,725	$ 1,275	$ 38,250	Y
C	36	$ 1,317	$ 1,422	$ 51,207	$ 1,200	$ 1,020	$ 1,380	$ 1,380	$ 49,680	Y
... D-L not shown ...										
M	223	$ 331	$ 356	$ 79,448	$ 350	$ 298	$ 403	$ 356	$ 79,448	
N	267	$ 261	$ 282	$ 75,473	$ 250	$ 213	$ 288	$ 282	$ 75,473	
O	321	$ 285	$ 303	$ 97,110	$ 300	$ 255	$ 345	$ 303	$ 97,110	
Total	1,801	$ 478	$ 518	$ 932,211	$ 489	$	$	$ 513	$ 923,362	

Second Step: Test Correction Step Post Capping

	(11)	(12)	(13)	(14)	(15)	(16)	(17)
	Prev. Table col.(7)	(11)) Less Knockouts	F*(10)	(4)+(13)	(14)/(1)	(15) within (5),(6)	Y=Knocked Out
Class	Original Test Correction Basis	Test Correction Basis Less Knockouts	Additional Losses for Test Correction	Revised Test Corrected Total Losses	Test Corrected Rate (Set 1)	Capped Rates (Set 1)	Is Rate Knocked Out of TCF by Capping?
A	$ 12	$ 12	$ 598	$ 51,543	$ 2,062	$ 2,062	
B	$ 13	$	$ 648	$ 34,198	$ 1,140	$ 1,275	Y
C	$ 14	$	$ 698	$ 51,905	$ 1,442	$ 1,380	Y
... D-L not shown ...							
M	$ 20	$ 20	$ 1,025	$ 80,473	$ 361	$ 361	
N	$ 20	$ 20	$ 1,041	$ 76,513	$ 286	$ 286	
O	$ 21	$ 21	$ 1,054	$ 98,164	$ 306	$ 306	
Total	$ 257	$ 174	$ 13,091	$ 945,302	$ 525	$ 517	

Reference Values for All Classes

A = (Prev. Table) Overall Average Rate in Data	$518
B = Total Loss in Set 0 Rates	$923,632
C= Total Losses in Data	$932,362
D = C-B = Shortfall	$8,849
E =Total Test Correction Basis on Non-Capped Classes (12)	$174
F = D/E = Test Correction Factor	50.92

Test Correction Example - Best Estimate Data-Last Step Follows

First Step: Calculations Using Rates from First Iteration

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	(Data)	Prev. Table col.(5)	Prev. Table col.(14)	(1)*(3)	(Data)	.85*(5)	1.15*(5)	(3) within (6),(7)	(1)*(8)	Y=Knocked Out
Class	Exposures	Credibility Adjusted Rate	Pre-Cap Test Corrected Rate (Set 1)	Losses in Pre-Cap Test Corrected Rate	Present Rate	Cap Below	Cap Above	Capped Rates (Set 1)	Total Losses in Capped Rates	Is Rate Knocked Out of TCF by Capping?
A	25	$ 1,907	$ 2,062	$ 51,543	$ 2,000	$ 1,700	$ 2,300	$ 2,062	$ 51,543	
B	30	$ 1,000	$ 1,140	$ 34,198	$ 1,500	$ 1,275	$ 1,725	$ 1,275	$ 38,250	Y
C	36	$ 1,317	$ 1,442	$ 51,905	$ 1,200	$ 1,020	$ 1,380	$ 1,380	$ 49,680	Y
... D-L not shown ...										
M	223	$ 331	$ 361	$ 80,473	$ 350	$ 298	$ 403	$ 361	$ 80,473	
N	267	$ 261	$ 286	$ 76,513	$ 250	$ 213	$ 288	$ 286	$ 76,513	
O	321	$ 285	$ 306	$ 98,164	$ 300	$ 255	$ 345	$ 306	$ 98,164	
Total	1,801	$ 478	$ 1,978	$ 945,302	$ 489			$ 517	$ 931,786	

Second Step: Test Correction Step Post Capping

	(11)	(12)	(13)	(14)	(15)	(16)	(17)
	Prev. Table col.(7)	(11)) Less Knockouts	F*(10)	(4)+(13)	(14)/(1)	(15) within (5),(6)	Y=Knocked Out
Class	Original Test Correction Basis	Test Correction Basis Less Knockouts	Additional Losses for Test Correction	Revised Test Corrected Total Losses	Test Corrected Rate (Set 2)	Capped Rates (Set 2)	Is Rate Knocked Out of TCF by Capping?
A	$ 12	$ 12	$ 32	$ 51,575	$ 2,063	$ 2,063	
B	$ 13	$	$ 35	$ 34,233	$ 1,141	$ 1,275	Y
C	$ 14	$	$ 38	$ 51,943	$ 1,443	$ 1,380	Y
... D-L not shown ...							
M	$ 20	$ 20	$ 55	$ 80,528	$ 361	$ 361	
N	$ 20	$ 20	$ 56	$ 76,569	$ 286	$ 286	
O	$ 21	$ 21	$ 57	$ 98,221	$ 306	$ 306	
Total	$ 257	$ 155	$ 704	$ 946,006	$ 525	$ 518	

Reference Values for All Classes

A = (Prev. Table) Overall Average Rate in Data	$518
B = Total Loss in Set 1 Rates	$931,786
C= Total Losses in Data	$932,362
D = C-B = Shortfall	$424
E =Total Test Correction Basis on Non-Capped Classes (12)	$155
F = D/E = Test Correction Factor	2.74

Overall considerations-Part 1

- We are all likely to agree the ratemaking process is improved when we consider that higher credibility classifications should not be impacted by the additional rate need effect when class changes alone do not address the full rate need; Making a Correct Rate, Wrong.

- In allocating the remaining rate need, the choice of credibility method is crucial; if our method says the credibility is higher or lower than in fact it is, than we must recognize that our allocation of the remaining rate need, so some extent will be off.

Overall considerations-Part 2

- Parameter shift also has effects on the credibility beyond what our standard, or even more sophisticated credibility methods suggest, we should always keep this in mind; generally parameter shift implies actual credibility is different than what our methods might suggest.

- The methodology suggested by the paper implies a better rate making process; not withstanding that fact, there are always real world factors such as finite IT resources which may not always have sufficient time to implement more dynamic rate making processes, or real world demands on how far rate changes can go on limited credibility classes.

Bottom Line

If you have an off-balance from credibility or capping, you're best off spreading it across the complement of credibility terms.

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