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Reserve Variability and Solvency II

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7 October 2009

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Agenda

- Reserve Variability / Risk
- Short-Term Reserving Risk
- Some Approaches / Issues

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Reserve Variability / Risk

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Reserve Variability / Risk

- A "range" is generally considered to be either a subset of the "possible outcomes" or a subset of "central estimates".
- A "possible outcome" will generally include random movements in the incremental values (e.g., calendar period payments within each accident period).
- For a "central estimate" the incremental values will essentially have the random movements "averaged" or "smoothed" out.

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Reserve Variability / Risk

- A “distribution” generally describes “all” possible outcomes.
- A purely statistical distribution will include all possible outcomes as defined by that distribution.
- The estimation of unpaid claims involves significant uncertainties that cannot be completely estimated, so “all” should be thought of as a reasonable estimate of the distribution to the extent that it can be estimated using historical data.

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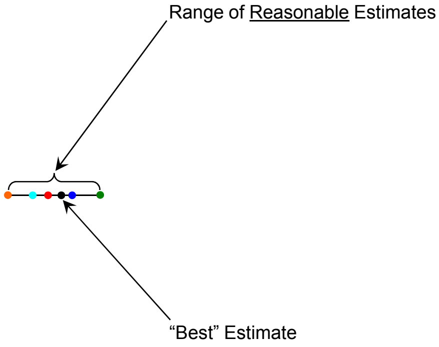
Reserve Variability / Risk



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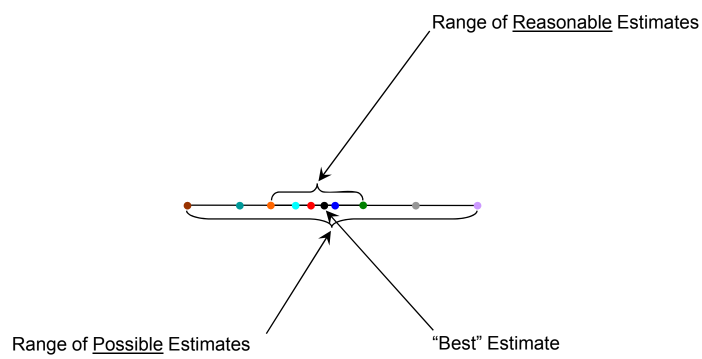
Reserve Variability / Risk



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Reserve Variability / Risk

- An aggregate range:
- can be determined by adding the LOB ranges if the *reasonable* estimates are intended to reflect a "mean" value, as this does not imply any particular correlation assumption.
- is more problematic for *possible* estimates as a correlation assumption would generally be required.

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Reserve Variability / Risk

- A "distribution of *statistical* outcomes" is:
- estimated using statistical distributions to essentially extend a deterministic central estimate.
- generally based on statistical properties estimated from the data, but some properties are simply assumed (e.g., the central estimate is assumed to be the mean).

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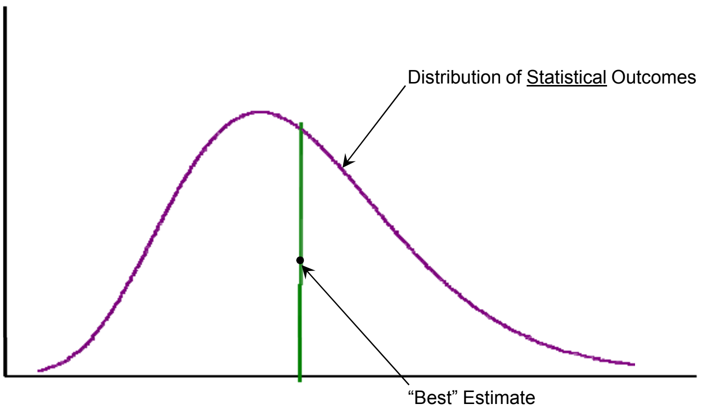
Reserve Variability / Risk



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Reserve Variability / Risk

- A "distribution of *possible* outcomes":
- is not intended to only be derived from a single probabilistic model – every model has strengths and weaknesses.
- can become a "best estimate" by weighting multiple distributions.
- can also be used to define subsets or ranges which are analogous to deterministic ranges.

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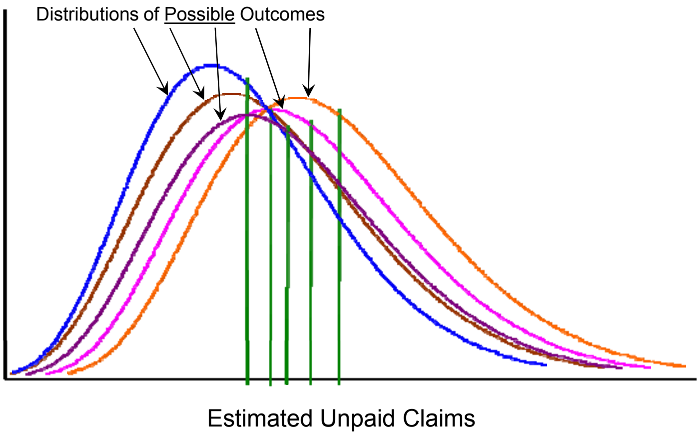
Reserve Variability / Risk



With multiple models:
You need to evaluate the relative strengths of each model

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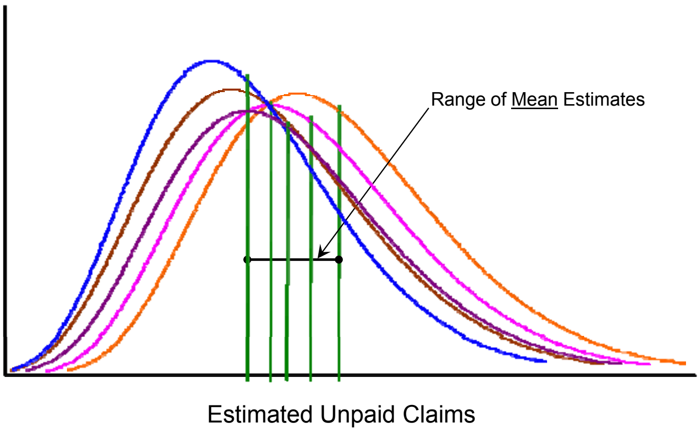

With multiple models:
You then have a "reasonable" range

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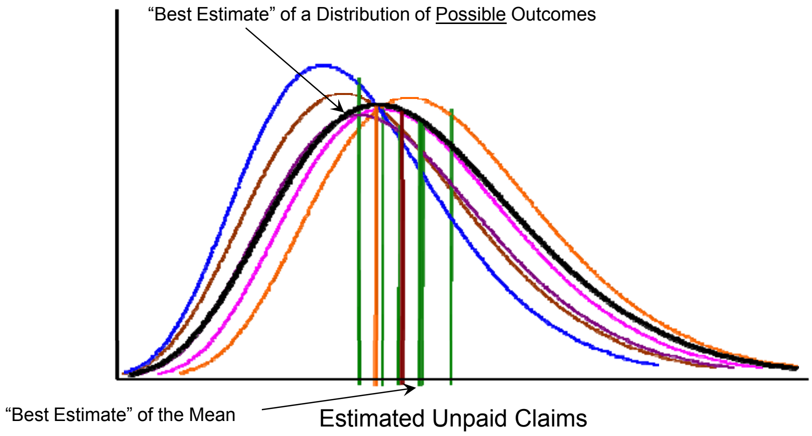

With multiple models:
You can use credibility weights to get your "best estimate"

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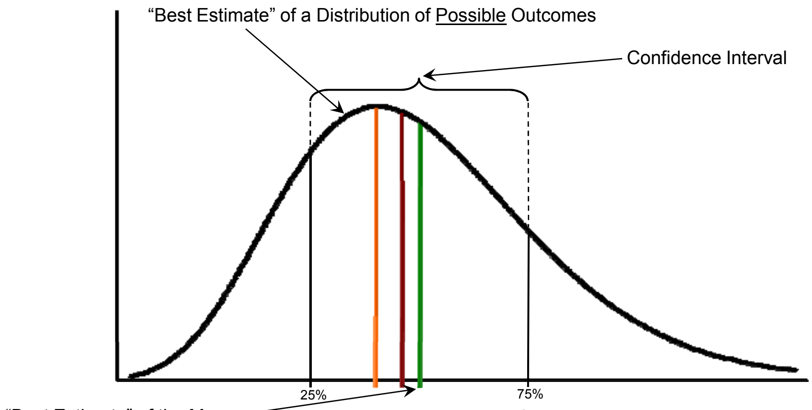
Reserve Variability / Risk



With multiple models:
You can calculate confidence intervals

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Reserve Variability / Risk

Summary of Results by Model

Accident Yr	Mean Estimated Unpaid						
	Chain Ladder		Bornhuetter Ferguson		Cape Cod		Best Est. (Weighted)
	Paid	Incurred	Paid	Incurred	Paid	Incurred	
1999	7,359	6,513	6,797	5,651	8,441	7,254	6,957
2000	7,437	6,761	6,952	5,943	8,249	7,282	7,085
2001	8,748	7,855	8,224	7,049	9,274	8,031	8,306
2002	12,351	13,013	11,719	12,131	10,198	10,741	12,688
2003	13,746	13,326	13,497	12,711	14,372	13,762	13,554
2004	21,833	20,614	20,650	19,252	21,382	20,104	21,154
2005	48,366	48,816	48,204	47,644	42,635	43,187	48,679
2006	78,291	78,938	76,288	76,485	75,578	75,796	78,566
2007	117,241	137,715	127,095	139,647	123,361	137,067	131,661
2008	186,369	201,954	204,631	207,663	222,017	220,903	213,608
Total	501,740	535,506	524,055	534,176	535,508	544,127	542,259

Range of Mean Estimates

Best Estimate of the Mean

You can use credibility weights to get your "mean estimate"

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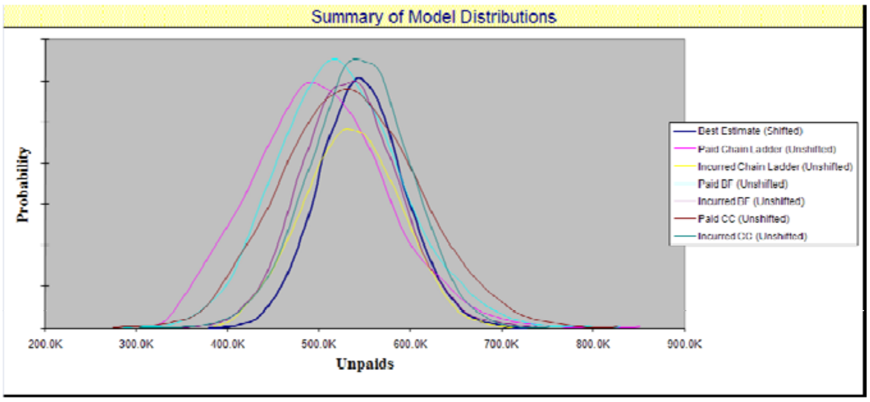

How does your best estimate compare to the individual models?

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Reserve Variability / Risk

- An aggregate distribution:
- can be determined by correlating the variances of the *statistical* LOB distributions.
- can be determined by correlating the outcomes of the *probabilistic* LOB distributions.
- can be used for Solvency II.

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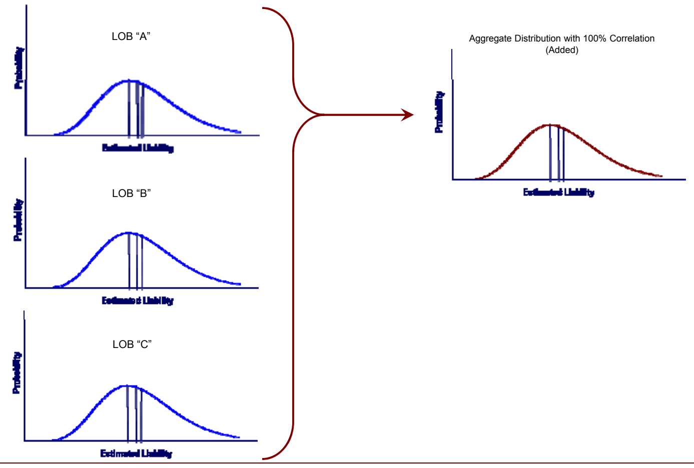
Reserve Variability / Risk

Adding the distributions to get the aggregate is not enough



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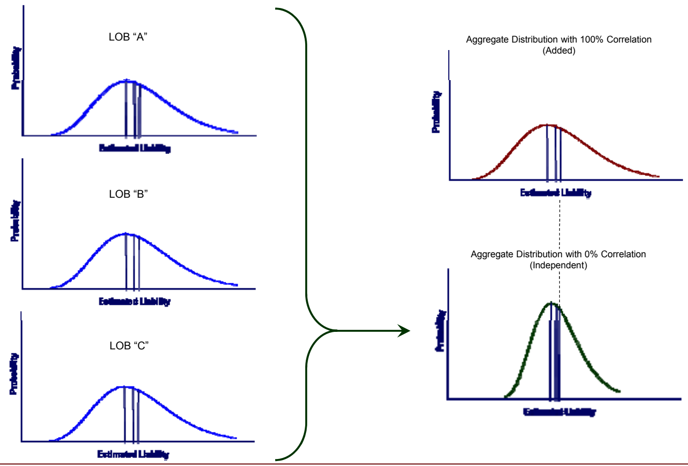
Reserve Variability / Risk

Correlation is critical for aggregate risk



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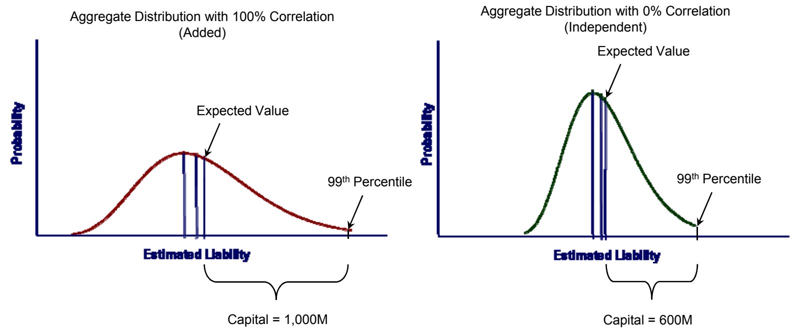
Reserve Variability / Risk

How much capital you need depends on correlation



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Short-Term Reserving Risk

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Short-Term Reserving Risk

Solvency II Capital and Reserving Bases

- SCR based on 99.5% VaR
- One-year time horizon
- Reserves calculated as discounted best estimate of cash-flows (unpaid claims) over infinite time horizon (augmented by a risk margin).

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Short-Term Reserving Risk

Solvency II Capital and Reserving Bases

- Risk margin calculated on a cost-of-capital approach (using components of SCR as it runs-off).
- Risk margin "caters" for uncertainty of claims emergence after one year.

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Short-Term Reserving Risk

Solvency II Capital and Reserving Bases

=> Short-term (one year) Capital Charge for Reserving risk under Solvency II

- Contrast this with the **ICA** regime where there is no explicit risk margin in the reserves and Reserving risk is long-term (i.e. to ultimate).

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Short-Term Reserving Risk

Long-Term Reserving Risk Models

- Traditionally, stochastic non-life unpaid claim models have estimated reserving risk with a focus on the long-term (i.e. on an ultimate basis).
- Frequently used methods are:
  - Mack's method
  - Bootstrapping

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Short-Term Reserving Risk

One Year Time Horizon

- There is less risk over a one year time horizon than over the whole future so risk measures should be less in the short-term than those using (say) Mack's method.
- Short-term risk should be less because:
  - parameter risk reduces as each future period brings more data;
  - future process risk reduces as future unpaid amounts decrease.

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Short-Term Reserving Risk

Other Considerations

- Model risk does not necessarily decrease.
- Systemic risk can be addressed to some extent by the framework of the implemented model.
- How do we move from long-term to short-term reserving risk measures?

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Short-Term Reserving Risk

"Closed Form" Approach

- A popular approach to estimating long-term reserve variability is to use a "closed form" approach, such as Mack's method.
- The perceived benefits of this approach include:
  - Relative ease of calculations
  - Ability to add to traditional deterministic reserving methods.

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Short-Term Reserving Risk

"Closed Form" Approach

- Mertz & Wüthrich have shown that Mack's method can be extended to calculate the change in standard error after a one-year time horizon.
- Short-term (one year) variance = long-term variance (v_0) less the expected long-term variance one year on (v_1) – using data at the valuation date.
- A reduction factor (r) for the long-term variance can be estimated as: $r \approx 1 - v_1/v_0$

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Short-Term Reserving Risk

"Closed Form" Approach

- Unfortunately the features of real data tend not to fit to this type of model.
- When the model does fit; research indicates that it will underestimate the extremes.
- Further, the approach does not generally include an estimate of the correlation between LOBs.

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Short-Term Reserving Risk

"Closed Form" Approach

- Even when the correlation between LOBs is estimated the aggregate distribution is approximated by calculating the correlated standard error and then selecting the form of the distribution.

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Short-Term Reserving Risk

Bootstrap Model

- The other popular approach to estimating long-term reserve variability is to use a bootstrap model.
- Possible outcomes of future claim amounts are simulated at each future period.
- A distribution of claim amounts can be estimated at each future duration, and the 99.5th percentile derived.

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Short-Term Reserving Risk

Bootstrap Model

- Since every incremental value for every AY is simulated for each iteration of the model, they can be summed in different ways to provide different distributions – total paid by AY, total paid by calendar year, etc.
- Simulation results can be directly correlated, rather than approximated by correlating standard errors – i.e. the shape of the distribution for each LOB remains intact when combined.

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Short-Term Reserving Risk

Bootstrap Model

- For calculating the SCR charge for one-year reserving risk, one of several variations could be considered. Should the 99.5th percentile be estimated:
  - For each AY individually within LOB [Option 1]?
  - For all AYs combined by LOB [Option 2]?
  - In aggregate for all lines of business combined [Option 3]?

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Short-Term Reserving Risk

Bootstrap Model

- The current standard formula approach seems to lean towards the third option (although not yet cast in stone).
- In summary, a bootstrap model has the following key advantages:
  - Projects possible future cash-flows (of claim amounts) one incremental period at a time to ultimate;
  - Contains all the ingredients for the measurement of short-term (one year) risk in addition to long-term (ultimate) risk.

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Short-Term Reserving Risk

Bootstrap Model

- We consider four approaches to measuring the capital charge for short-term reserving risk using a bootstrap model.

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Some Approaches / Issues

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Some Approaches / Issues

Do we base the estimate on paid or incurred data?

- Paid data:
- Represents cash flows of insurance entity.
- Cash payments are materialization of risk.
- Paid data seems like a logical choice.
- 99.5% of paid may underestimate risk.

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Some Approaches / Issues

Do we base the estimate on paid or incurred data?

- Incurred data:
- Represents cash flows of insurance entity, plus current assessment of future claims (case reserves).
- Case reserves create timing issues related to materialization of prior risk.
- 99.5% of paid + 99.5% of case reserves may overestimate risk.

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Some Approaches / Issues

Do we base the estimate on paid or incurred data?

- Most models use one or the other.
- A few models use both.
- Weighting of multiple distributions of possible outcomes allows use of both.
- “Blending” of models captures features of both paid and incurred data.

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Some Approaches / Issues

Does using “expected” values vs. possible outcomes affect results?

	1	2	3	4	5	6	7	8	9
1	358	1,125	1,735	2,218	2,746	3,320	3,466	3,606	3,834
2	352	1,236	2,170	3,353	3,799	4,120	4,648	4,914	
3	291	1,292	2,219	3,235	3,986	4,133	4,629		
4	311	1,419	2,195	3,757	4,030	4,382			
5	443	1,136	2,128	2,898	3,403				
6	396	1,333	2,181	2,986					
7	441	1,288	2,420						
8	359	1,421							
9	377								

Mack Model (t=0)

Development Factors F(*d*)

1	2	3	4	5	6	7	8	9
3.4742	1.7041	1.4609	1.1618	1.0958	1.1011	1.0501	1.0630	1.0770

	Ultimate	Unpaid	S.E.	CoV
1	4,129	295	18	6.1%
2	5,626	712	33	4.6%
3	5,565	936	80	8.6%
4	5,800	1,418	271	19.1%
5	4,935	1,533	427	27.9%
6	5,031	2,046	550	26.9%
7	5,957	3,537	884	25.0%
8	5,962	4,541	1,012	22.3%
9	5,490	5,113	1,514	29.6%
		20,131	2,563	12.7%

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Some Approaches / Issues

Does using "expected" values vs. possible outcomes affect results?

	1	2	3	4	5	6	7	8	9	10
1	358	1,125	1,735	2,218	2,746	3,320	3,466	3,606	3,834	4,129
2	352	1,236	2,170	3,353	3,799	4,120	4,648	4,914	5,224	
3	291	1,292	2,219	3,235	3,986	4,133	4,629	4,861		
4	311	1,419	2,195	3,757	4,030	4,382	4,825			
5	443	1,136	2,128	2,898	3,403	3,729				
6	396	1,333	2,181	2,986	3,469					
7	441	1,288	2,420	3,535						
8	359	1,421	2,422							
9	377	1,309								

Mack Model (t=1, EV for each Incremental)

Development Factors F(*d*)

1	2	3	4	5	6	7	8	9	10
3.4742	1.7041	1.4609	1.1618	1.0958	1.1011	1.0501	1.0630	1.0770	1.0000

	Ultimate	One-Year	Difference	Unpaid	S. E.	CoV
1	4,129	4,129	0	0	0	0.0%
2	5,626	5,626	0	402	0	0.0%
3	5,565	5,565	0	704	0	0.0%
4	5,800	5,800	0	975	50	5.1%
5	4,935	4,935	0	1,207	189	15.7%
6	5,031	5,031	0	1,563	357	22.8%
7	5,957	5,957	0	2,422	515	21.3%
8	5,962	5,962	0	3,540	774	21.9%
9	5,490	5,490	0	4,181	855	20.4%
			0	14,995	1,530	10.2%

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Some Approaches / Issues

Does using "expected" values vs. possible outcomes affect results?

	1	2	3	4	5	6	7	8	9	10
1	358	1,125	1,735	2,218	2,746	3,320	3,466	3,606	3,834	4,092
2	352	1,236	2,170	3,353	3,799	4,120	4,648	4,914	5,286	
3	291	1,292	2,219	3,235	3,986	4,133	4,629	4,874		
4	311	1,419	2,195	3,757	4,030	4,382	4,562			
5	443	1,136	2,128	2,898	3,403	3,814				
6	396	1,333	2,181	2,986	3,603					
7	441	1,288	2,420	3,349						
8	359	1,421	2,683							
9	377	1,239								

Mack Model (t=1, EV in Total, Possible Outcome for each Incremental)

Development Factors F(*d*)

1	2	3	4	5	6	7	8	9	10
3.4532	1.7296	1.4485	1.1690	1.1005	1.0846	1.0511	1.0703	1.0673	1.0000

	Ultimate	One-Year	Difference	Unpaid	S. E.	CoV
1	4,129	4,092	(37)	0	0	0.0%
2	5,626	5,641	15	356	61	17.1%
3	5,565	5,568	3	694	81	11.6%
4	5,800	5,478	(323)	916	94	10.2%
5	4,935	4,967	31	1,153	261	22.7%
6	5,031	5,163	132	1,561	408	26.1%
7	5,957	5,611	(346)	2,262	541	23.9%
8	5,962	6,511	549	3,828	859	22.4%
9	5,490	5,201	(289)	3,962	887	22.4%
			(264)	14,730	1,720	11.7%

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Some Approaches / Issues

Does using "expected" values vs. possible outcomes affect results?

	1	2	3	4	5	6	7	8	9	10
1	358	1,125	1,735	2,218	2,746	3,320	3,466	3,606	3,834	4,093
2	352	1,236	2,170	3,353	3,799	4,120	4,648	4,914	5,238	
3	291	1,292	2,219	3,235	3,986	4,133	4,629	4,865		
4	311	1,419	2,195	3,757	4,030	4,382	4,832			
5	443	1,136	2,128	2,898	3,403	3,733				
6	396	1,333	2,181	2,986	3,471					
7	441	1,288	2,420	3,545						
8	359	1,421	2,439							
9	377	1,346								

GLM Bootstrap Model (t=1, EV for each Incremental)

	Ultimate	One Year	Difference	Unpaid	S. E.	CoV
1	4,106	4,096	(10)	0	0	0.0%
2	5,597	5,606	9	360	240	66.7%
3	5,537	5,550	13	678	309	45.5%
4	5,788	5,800	12	956	369	38.6%
5	4,918	4,928	10	1,188	389	32.7%
6	5,027	5,040	13	1,557	456	29.3%
7	5,971	5,975	4	2,418	593	24.5%
8	5,995	6,000	5	3,562	839	23.5%
9	5,665	5,703	38	4,351	1,171	26.9%
			94	15,070	2,543	16.9%

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Some Approaches / Issues

Does using "expected" values vs. possible outcomes affect results?

	1	2	3	4	5	6	7	8	9	10
1	358	1,125	1,735	2,218	2,746	3,320	3,466	3,606	3,834	4,149
2	352	1,236	2,170	3,353	3,799	4,120	4,648	4,914	5,410	
3	291	1,292	2,219	3,235	3,986	4,133	4,629	4,838		
4	311	1,419	2,195	3,757	4,030	4,382	4,929			
5	443	1,136	2,128	2,898	3,403	3,690				
6	396	1,333	2,181	2,986	3,416					
7	441	1,288	2,420	3,483						
8	359	1,421	2,384							
9	377	1,262								

GLM Bootstrap Model (t=1, EV in Total, Possible Outcome for each Incremental)

	Ultimate	One Year	Difference	Unpaid	S. E.	CoV
1	4,106	4,155	49	0	0	0.0%
2	5,597	5,875	278	458	281	61.4%
3	5,537	5,706	169	860	361	41.9%
4	5,788	6,104	315	1,162	419	36.0%
5	4,918	5,062	145	1,363	432	31.7%
6	5,027	5,133	106	1,704	495	29.0%
7	5,971	6,071	100	2,575	648	25.2%
8	5,995	6,038	43	3,655	888	24.3%
9	5,665	5,477	(188)	4,209	1,181	28.1%
			1,018	15,986	2,755	17.2%

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Some Approaches / Issues

Bootstrap Model Approach 1

- The 99.5th %tile claim [payments] considered anomalous – i.e. do not influence the expected future claim [payments] beyond the one-year time horizon.
- One-year reserving risk = 99.5th %tile claim [payments], less the expected claim [payments].
- Straightforward, but invalidates the key assumption of the one-year horizon.

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Some Approaches / Issues

Bootstrap Model Approach 2

- The 99.5th %tile claim [payments] do influence the expected future claim [payments] beyond the one-year time horizon.
- One-year reserving risk = the 99.5th %tile claim [payments], less the expected claim [payments], plus the difference between the (re)estimated mean and the "original" mean unpaid claims.
- (Re)estimate using the algorithm underlying the valuation basis at the valuation date.

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Some Approaches / Issues

Bootstrap Model Approach 2

- Using 99.5th %tile for each incremental (for each accident year and LOB) [Option 1] assumes 100% correlation
- Will normally produce a larger result than the random future possible outcomes would imply.

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Some Approaches / Issues

Bootstrap Model Approach 2

- Option 2 adjusts the estimate for the correlation (whatever amount is assumed in the model) between accident years
- Requires either the allocation of the total to the accident years or finding the actual 99.5th %tile iteration for each LOB
- Accounts for correlation within each LOB, but not between LOBs, so would tend to give a result that is less than Option 1.

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Some Approaches / Issues

Bootstrap Model Approach 2

- Option 3 adjusts the estimate for both the correlation between accident years and correlation between lines of business
- Requires either the allocation of the total to the accident years or finding the actual 99.5th %tile iteration in the aggregate distribution
- Accounts for correlation within each LOB and between the LOBs, so would tend to give a result that is less than both of the other options.

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Some Approaches / Issues

Bootstrap Model Approach 2

Option 1 – By Incremental Values

Sample Insurance Company
Risk Based Capital Reserve Risk Analysis Summary

(No Discounting; Model Correlations)

		Reserve Risk (Simulated Values)						
Line	Mean Unpaid	99.50% Unpaid	Value at Risk (VaR)	99.50% Impact	SCR Capital	Capital / Unpaid	Allocated Capital *	Capital / Unpaid
BI	985,580	1,190,775	205,195	166,101	371,297	20.8%	427,346	43.4%
APD	128,315	198,546	70,231	7,974	78,204	54.7%	38,839	30.3%
GL	536,925	665,418	128,493	202,137	330,629	23.9%	223,549	41.6%
Sum	1,650,820	2,054,738	403,918	376,212	780,130	24.5%	689,734	41.8%
Aggregate Results	1,650,820	1,964,342	313,522	376,212	689,734	19.0%		
Correlation Effect			(90,397)	0	(90,397)	-5.5%		

* Capital is Allocated using a methodology that adjusts for both C.o.V and correlation.

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Some Approaches / Issues

Bootstrap Model Approach 2

Option 2 – Allocation By Line of Business

Sample Insurance Company
Risk Based Capital Reserve Risk Analysis Summary

(No Discounting; Model Correlations)

		Reserve Risk (Simulated Values)						
Line	Mean Unpaid	99.50% Unpaid	Value at Risk (VaR)	99.50% Impact	SCR Capital	Capital / Unpaid	Allocated Capital *	Capital / Unpaid
BI	985,580	1,190,775	205,195	121,918	327,113	20.8%	364,139	36.9%
APD	128,315	198,546	70,231	8,135	78,366	54.7%	33,252	25.9%
GL	536,925	665,418	128,493	144,389	272,882	23.9%	190,573	35.5%
Sum	1,650,820	2,054,738	403,918	274,442	678,361	24.5%	587,964	35.6%
Aggregate Results	1,650,820	1,964,342	313,522	274,442	587,964	19.0%		
Correlation Effect			(90,397)	0	(90,397)	-5.5%		

* Capital is Allocated using a methodology that adjusts for both C.o.V and correlation.

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Some Approaches / Issues

Bootstrap Model Approach 2

Option 3 – Allocation Of Aggregate

Sample Insurance Company
Risk Based Capital Reserve Risk Analysis Summary

(No Discounting; Model Correlations)

		Reserve Risk (Simulated Values)						
Line	Mean Unpaid	99.50% Unpaid	Value at Risk (VaR)	99.50% Impact	SCR Capital	Capital / Unpaid	Allocated Capital *	Capital / Unpaid
BI	985,580	1,190,775	205,195	102,787	307,982	20.8%	341,549	34.7%
APD	128,315	198,546	70,231	7,573	77,803	54.7%	31,231	24.3%
GL	536,925	665,418	128,493	127,671	256,164	23.9%	178,773	33.3%
Sum	1,650,820	2,054,738	403,918	238,032	641,950	24.5%	551,553	33.4%
Aggregate Results	1,650,820	1,964,342	313,522	238,032	551,553	19.0%		
Correlation Effect			(90,397)	0	(90,397)	-5.5%		

* Capital is Allocated using a methodology that adjusts for both C.o.V and correlation.

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Some Approaches / Issues

Bootstrap Model Approach 2

- Allocating the totals is the more straightforward option for the overall algorithm.
- Each incremental value will always be larger than expected in the one year diagonal.
- Disadvantage: introduces a non-random element (i.e. incrementals not random) into an otherwise random process (i.e. each iteration is a possible outcome).

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Some Approaches / Issues

Bootstrap Model Approach 3

- Option 3 actual iteration is more realistic, but random incremental values could influence the change in expected value after the one year time horizon.
- Third approach is to find all of the iterations at the 99.5th percentile and above
- This approach is consistent with a tail value at risk calculation.

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Some Approaches / Issues

Bootstrap Model Approach 3

- Disadvantage: introduces a more calculation intense approach.
- For example, each iteration (at 99.5% and above) needs to be simulated again.
- Using the same number of iterations as the original bootstrap (e.g. 10,000 original iterations would lead to 500,000 additional iterations).

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Some Approaches / Issues

Bootstrap Model Approach 4

- Use all of the iterations in the one-year time period and re-estimate the expected future claim [payments] for every iteration.
- This approach accounts for all possible influences beyond the one-year time horizon
- Disadvantage: introduces an even more calculation intense approach (e.g. 10,000 original iterations would lead to 100,000,000 additional iterations).

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Some Approaches / Issues

Bootstrap Model Approach 4

- Most complete influence of the one-year time horizon, but doesn't focus on the 99.5th %tile.
- Generally, this approach could significantly increase the variance, but its impact on the expected value (or mean) will depend on the skewness of the underlying data.

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Some Approaches / Issues

Additional Issues

- Use of the same algorithm throughout the estimation process is important.
- A closed form solution (like Mack) with a best estimate based on several different deterministic methods has *potential* to combine radically different algorithms.
- For example, you wouldn't combine a mean based on the assumptions for a roulette wheel with a standard deviation based on the assumptions of a toss of a coin.

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Some Approaches / Issues

Additional Issues

- Stochastic models can suffer from the same problem.
- For example, blindly forcing the mean of a standard paid chain ladder bootstrap model to equal the deterministic chain ladder ignores the assumptions of the bootstrap model that lead to a different mean.

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Some Approaches / Issues

Additional Issues

- Assessing the assumptions and “blending” results of multiple models is statistically much different than simply tacking some distribution assumptions onto an otherwise deterministic approach.

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