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The 1 year view of reserving risk: The "actuary-in-the-box" vs emergence patterns

Peter England and Robert Scarth

Casualty Loss Reserve Seminar, Boston

September 17, 2013, 0830-1000

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Agenda

- The reserve risk puzzle
- Background to the 1 year view of reserve risk
- Characteristics of the "actuary-in-the-box" approach
- Emergence pattern methods as an alternative
- Calibrating emergence patterns from the "actuary-in-the-box" approach
- Characteristics of two emergence pattern approaches
- Benchmarking emergence patterns from industry data
- Data Analysis
- Final Considerations

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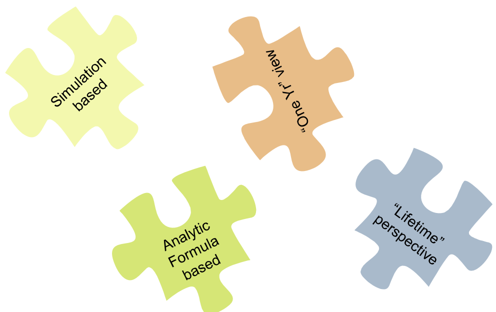
The Reserve Risk Puzzle



Reserve Risk: The traditional actuarial view
Summary

- The traditional actuarial view of reserve risk looks at the uncertainty in the outstanding liabilities over their lifetime (the "ultimo" view)
  - We have to start talking statistics
  - Given a statistical model, we can derive analytic formulae for the standard deviation of the forecasts
  - Given a statistical model, we can also generate distributions of outstanding liabilities, and their associated cash-flows, using simulation techniques (eg bootstrap or MCMC techniques)
  - We can do this in a way that reconciles the analytic and simulation approaches

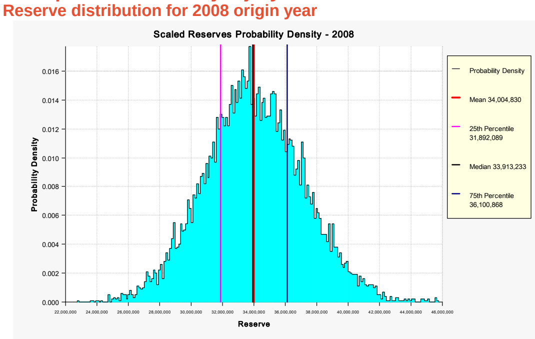
Example - Motor Bodily Injury
Reserve Variability – "Mack's Model"

Accident Year	Latest Paid	Expected Reserve	Analytic Prediction Error	Analytic Prediction Error %	Bootstrap Prediction Error	Bootstrap Prediction Error %
1999	58,630,645	0	0	0.00%	0	0.00%
2000	56,879,684	-121	63,942	52,728.45%	63,394	52,276.19%
2001	67,718,735	44,440	96,177	216.42%	95,502	214.90%
2002	70,369,404	202,167	169,896	84.04%	168,120	83.16%
2003	70,250,797	433,816	188,642	43.48%	188,698	43.50%
2004	86,764,768	1,347,472	329,921	24.48%	328,420	24.37%
2005	81,207,103	2,815,969	549,066	19.50%	552,678	19.63%
2006	74,012,328	6,783,546	1,111,083	16.38%	1,120,143	16.51%
2007	54,638,491	14,208,374	1,645,108	11.58%	1,651,177	11.62%
2008	40,197,355	34,004,830	3,161,824	9.30%	3,130,820	9.21%
2009	11,247,860	66,703,096	9,248,676	13.87%	9,340,689	14.00%
Total	**671,917,170**	**126,543,590**	**10,288,086**	**8.13%**	**10,276,627**	**8.12%**

We can apply Mack's model analytically (giving a SD of reserves only), or we can bootstrap Mack's model* (giving a full predictive distribution)

* *England, PD and Verrall, RJ (2006). Predictive Distributions of Outstanding Liabilities in General Insurance. Annals of Actuarial Science, 1, II, p221-270*

Example - Motor Bodily Injury
Reserve distribution for 2008 origin year



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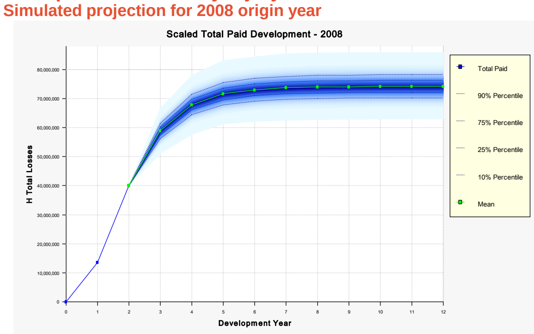
Example - Motor Bodily Injury
Simulated projection for 2008 origin year



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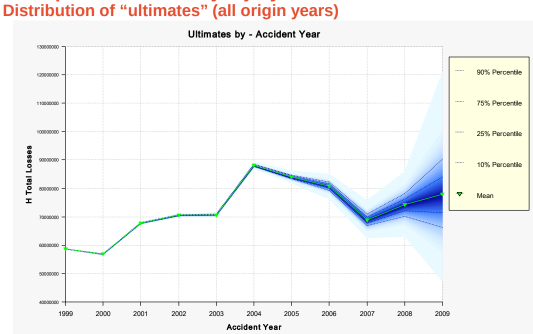
Example - Motor Bodily Injury
Distribution of "ultimates" (all origin years)



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Reserve Risk: The one-year view of Solvency II
Summary

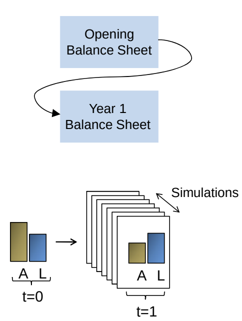
- Under Solvency II, reserving risk takes on a different meaning. It considers the distribution of the profit/loss on the (estimated) reserves over a 1 year time horizon
- On an undiscounted basis for a single origin period (ignoring risk margins), the profit/loss is the change in the (estimated) ultimate claims over a 1 year time horizon
- Clearly, this is different from the traditional actuarial view of reserve risk, which considers the distribution of the outstanding liabilities over their lifetime
- However, the two views can be reconciled…

DIRECTIVE OF THE EUROPEAN PARLIAMENT
Article 101

- "The Solvency Capital Requirement shall be calibrated so as to ensure that all quantifiable risks to which an insurance or reinsurance undertaking is exposed are taken into account. With respect to existing business, it shall cover unexpected losses.
- It shall *correspond* to the Value-at-Risk of the basic own funds of an insurance or reinsurance undertaking subject to a confidence level of 99.5% over a one-year period."
- *So it seems straightforward to estimate the SCR using a simulation-based model: simply create a simulated distribution of the basic own funds over 1 year, then calculate the VaR @ 99.5%.*

A Projected Balance Sheet View

- From Article 101, the SCR is calculated from a distribution of net assets over a 1 year time horizon
- When projecting Balance Sheets for solvency, we have an opening balance sheet with expected outstanding liabilities
- The bulk of those liabilities are the "reserves" (provisions) set aside to pay unsettled claims that have arisen on policies sold in the past
- We then project one year forwards, simulating the payments that emerge in the year, and require a closing balance sheet, with (simulated) expected outstanding liabilities conditional on the payments in the year, together with the market value of assets at the end of the year



Reserve Risk under Solvency II…

It's all about the CDR*…

* Claims Development Result (a.k.a. the Run-off Result)

The one-year run-off result (undiscounted)
(The view of profit or loss on reserves after one year)

- For a particular origin year, let:
  - The opening reserve estimate be R_0
  - The reserve estimate after one year be R_1
  - The payments in the year be C_1
  - The run-off result (claims development result) be CDR_1
- Then

$$CDR_1 = R_0 - C_1 - R_1 = U_0 - U_1$$

  - Where the opening estimate of ultimate claims and the estimate of the ultimate after one year are U_0, U_1

Examples – Claims Development Result for a particular cohort of claims

Reserve study as at 31/12/2010

Cashflow period	2011	2012	2013
Expected payments	100	80	60
Reserve	240 *(assumes no discounting)*		

Reserve Study as at 31/12/2011

Actual payment	120		
Cashflow period		2012	2013
Expected payments		85	65
Reserve	150 *(assumes no discounting)*		

Summary

2011 Opening Reserve	240
Paid in 2011	120
2011 Closing Reserve	150
Incurred surplus	-30

This is the Claims Development Result (CDR)

The One-year view of Reserve Risk
Why do we want it?

- Main driver is Solvency II regulation
- Other uses:
  - Reasonable view of earnings
  - Actual versus Expected
  - Modelling certain Reinsurance contracts
- Note: Although we are not really interested in the one-year view of reserve risk based on the CDR outside the Solvency II context, we still require the expected value of reserves for each simulation in 1 year ahead balance sheets (and beyond) in capital models

The One-year view of Reserve Risk
How do we measure it?

- Don't bother?
  - Just use "perfect foresight" (the traditional actuarial "lifetime" view)
- Use analytic (formula based) approaches
  - Based only on data, eg Solvency II QIS 5 USP Method 1
  - Based on a model and data, *eg* Merz-Wuthrich formula (used in QIS 5 USP Methods 2 & 3)
- Use simulation based approaches
  - Actuary-in-the-box
  - Emergence patterns

The One-year view of Reserve Risk
(The view of profit or loss on reserves after one year)

- Merz & Wuthrich (2008) derived analytic formulae for the standard deviation of the claims development result after one year assuming:
  - The opening reserves were set using the pure chain ladder model (no tail)
  - Claims develop in the year according to the assumptions underlying Mack's model
  - Reserves are set after one year using the pure chain ladder model (no tail)
  - The mathematics is quite challenging.
- The M&W method is gaining popularity, but has limitations. What if:
  - We need a tail factor to extrapolate into the future?
  - Mack's model is not used – other assumptions are used instead?
  - We want another risk measure, not just a standard deviation (*eg* VaR @ 99.5%)?
  - We want a distribution of the CDR?

Merz & Wuthrich (2008)

Data Triangle

Accident Year	12m	24m	36m	48m	60m	72m	84m	96m	108m
0	2,202,584	3,210,449	3,468,122	3,545,070	3,621,627	3,644,636	3,669,012	3,674,511	3,678,633
1	2,350,650	3,553,023	3,783,846	3,840,067	3,865,187	3,878,744	3,898,281	3,902,425	
2	2,321,885	3,424,190	3,700,876	3,798,198	3,854,755	3,878,993	3,898,825		
3	2,171,487	3,165,274	3,395,841	3,466,453	3,515,703	3,548,422			
4	2,140,328	3,157,079	3,399,262	3,500,520	3,585,812				
5	2,290,664	3,338,197	3,550,332	3,641,036					
6	2,148,216	3,219,775	3,428,335						
7	2,143,728	3,158,581							
8	2,144,738								

Merz & Wuthrich (2008)

Prediction errors

	Analytic Prediction Errors	
Accident Year	1 Year Ahead CDR	Mack Ultimate
0	0	0
1	567	567
2	1,488	1,566
3	3,923	4,157
4	9,723	10,536
5	28,443	30,319
6	20,954	35,967
7	28,119	45,090
8	53,320	69,552
Total	81,080	108,401

Expressed as a percentage of the opening reserves, this forms a basis of the reserve risk parameter under Solvency II (QIS 5 Technical Specification)

QIS 5: Undertaking Specific Parameters

For the reserving risk parameter:

Method 2: $\sigma_{U,lob} = \frac{\sqrt{MSEP_{lob}}}{PCO_{lob}}$

Method 3: $\sigma_{U,lob} = \frac{\sqrt{MSEP_{lob}}}{CLPCO_{lob}}$

There is also a credibility weighting between this and the standard parameter:

$\sigma_{res,lob} = c.\sigma_{U,res,lob} + (1-c).\sigma_{M,res,lob}$

$MSEP$ is from the Merz-Wuthrich formulae. Clearly there are some inconsistencies here:

- PCO is discounted, but $MSEP$ is calculated using undiscounted amounts
- $MSEP$ is only valid under the chain-ladder model and Mack's assumptions
- What if other assumptions are used?

The one-year run-off result in a simulation model
The EASY way

- For a particular origin year, let:
  - The opening reserve estimate be R_0
  - The expected reserve estimate after one year be $R_1^{(i)}$
  - The payments in the year be $C_1^{(i)}$
  - The run-off result (claims development result) be $CDR_1^{(i)}$
- Then

$$CDR_1^{(i)} = R_0 - C_1^{(i)} - R_1^{(i)} = U_0 - U_1^{(i)}$$

  - Where the opening estimate of ultimate claims and the expected ultimate after one year are $U_0, U_1^{(i)}$
  - for each simulation i

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The one-year run-off result in a simulation model
The EASY way

1. Given the opening reserve triangle, simulate all future claim payments to ultimate using bootstrap (or Bayesian MCMC) techniques.
2. Now forget that we have already simulated what the future holds.
3. Move one year ahead. Augment the opening reserve triangle by one diagonal, that is, by the simulated payments from step 1 in the next calendar year only. An actuary only sees what emerges in the year.
4. For each simulation, estimate the outstanding liabilities, conditional only on what has emerged to date. (The future is still “unknown”).
5. A reserving methodology is required for each simulation – an “actuary-in-the-box” is required*. We call this re-reserving.
6. For a one-year model, this will underestimate the true volatility at the end of that year (even if the mean across all simulations is correct).

- ** The term “actuary-in-the-box” was coined by Esbjörn Ohlsson*

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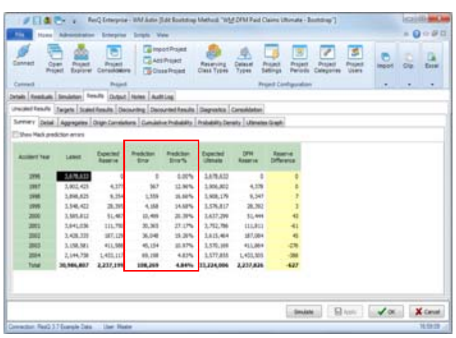
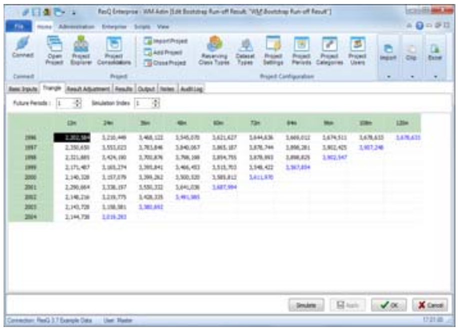
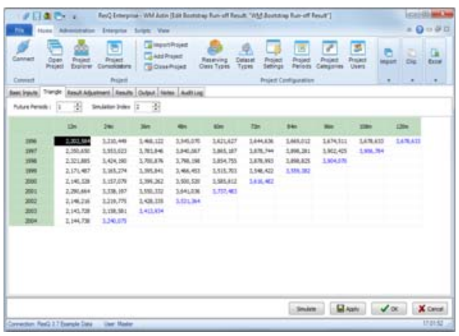
Example
Bootstrap Results Summary – “Ultimo” perspective



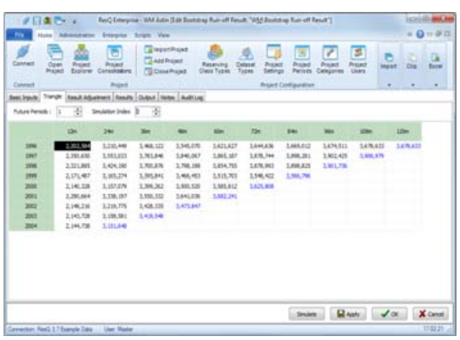
Example
1 Year ahead – Simulation 1



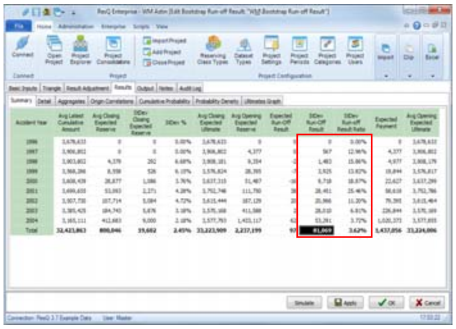
Example
1 Year ahead – Simulation 2



Example
1 Year ahead – Simulation 3



Example
Bootstrap Run-off Results Summary – 1 year perspective



Merz & Wuthrich (2008)
Analytic vs Simulated: Summary

	Analytic		Simulated	
	Prediction Errors		Prediction Errors	
Accident Year	1 Year Ahead CDR	Mack Ultimate	1 Year Ahead CDR	Mack Ultimate
0	0	0	0	0
1	567	567	567	567
2	1,488	1,566	1,483	1,559
3	3,923	4,157	3,925	4,168
4	9,723	10,536	9,718	10,499
5	28,443	30,319	28,451	30,365
6	20,954	35,967	20,966	36,048
7	28,119	45,090	28,010	45,154
8	53,320	69,552	53,291	69,198
Total	81,080	108,401	81,069	108,269

We can develop simulation based models that are analogous to their analytic counterparts

CDR in a Simulation Model

- Note that when simulating the CDR, we have a causal chain:

- The “actuary-in-the-box” uses the same model for re-reserving as the original model at the start of the chain, allowing the method to be generalised beyond the chain ladder model used by Merz-Wuthrich (and also giving a distribution of the CDR, not just a standard deviation)

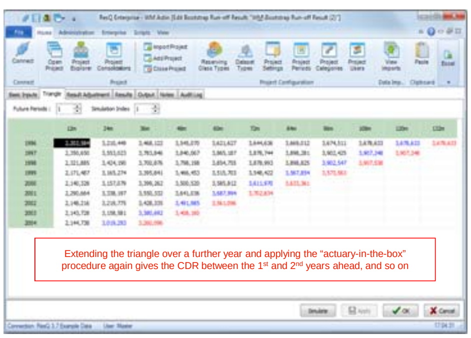
Cascading CDRs in a Simulation Model

- The process can be repeated over multiple time horizons:

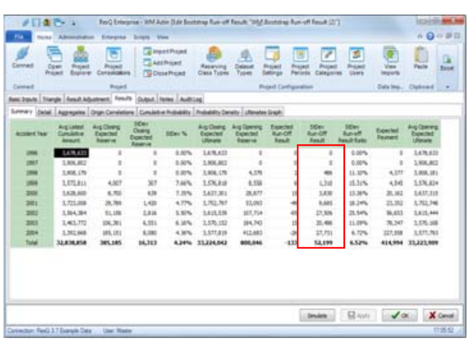
Model for Best Estimate ⇨ Bootstrap ⇨ Bootstrap CDR*1* ⇨ Bootstrap CDR 2 ⇨ … ⇨ Bootstrap CDR *n*

- We can collect the standard deviations of the CDRs for each year ahead, and create a full table across all future years. This leads to an interesting result (for the chain ladder model)…

ResQ Example
Cascading Bootstrap Run-off Results



ResQ Example
Cascading Bootstrap Run-off Results



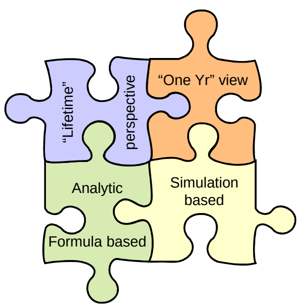
Multiple 1 yr ahead CDRs
An interesting result

- Creating cascading CDR SDs over all years gives the following results:

Accident Year	Number of years ahead 1 Yr	2 Yrs	3 Yrs	4 Yrs	5 Yrs	6 Yrs	7 Yrs	8 Yrs	Sqrt(Sum of Squares)	Mack Ultimate
1	0	0	0	0	0	0	0	0	-	0
2	567	0	0	0	0	0	0	0	567	567
3	1,483	486	0	0	0	0	0	0	1,561	1,559
4	3,925	1,310	433	0	0	0	0	0	4,160	4,168
5	9,718	3,830	1,285	425	0	0	0	0	10,533	10,499
6	28,451	9,685	3,824	1,276	425	0	0	0	30,327	30,365
7	20,966	27,506	9,364	3,683	1,223	410	0	0	36,042	36,048
8	28,010	20,486	27,001	9,237	3,619	1,211	404	0	45,093	45,154
9	53,291	27,731	20,146	26,593	9,101	3,609	1,200	400	69,422	69,198
Total	81,069	52,199	38,463	28,972	10,107	3,887	1,282	400	108,327	108,269
	56.01%	79.23%	91.83%	98.99%	99.86%	99.98%	100.00%	100.00%	Cumulative Risk Emergence (Variance)	

- The sum of the variances of the repeated 1 yr ahead CDRs (over all years) equals the variance over the lifetime of the liabilities
- This means that we expect the risk under the 1 year view to be lower than the standard "ultimo" perspective

The Reserve Risk Puzzle
Harmony has been restored



Characteristics of the "actuary-in-the-box" approach
Chain ladder model: Mack or ODP assumptions

- For 1 yr ahead, there is a dependency structure between the CDRs by origin period
- The sum of the variances of the repeated 1 yr ahead CDRs (over all years) equals the variance over the lifetime of the liabilities. This implies that:
  - The 1 year view of Solvency II gives a lower measure of risk than the traditional actuarial view
  - The CDRs between future years are uncorrelated
- For the chain ladder model, the expected CDR is zero
- Using bootstrapping, where curves are fitted (for smoothing or estimating tail factors), the expected CDR will not be zero, so scaling is required to eliminate bias
  - The independence of CDRs between future years may also break down

Advantages of the "Actuary-in-the-Box" approach

- The advantages of investigating the claims development result (using "re-reserving") in a simulation environment is that the procedure can be generalised:
  - Not just the chain ladder model
  - Not just Mack's assumptions
  - Can include curve fitting and extrapolation for tail estimation
  - Can incorporate a Bornhuetter-Ferguson step
  - Can be extended beyond the 1 year horizon to look at multi-year forecasts
  - Provides a *distribution* of the CDR, not just a standard deviation
  - Can be used to help calibrate Solvency II internal models

Actuary-in-the-box issues

- The "Actuary-in-the-box" method is not without its difficulties:
  - What if you've applied a lot of judgement?
  - What if the claims triangle is sparse, or very volatile?
  - What if you have no claims triangle?
  - What if you used a parametric model?
- In addition, the actuary-in-the-box approach is fairly computationally intensive in simulation models
- It may be harder than "ultimo" bootstrapping to produce sensible results for some triangles
- So we need simpler alternatives:
  - Simply allow the "ultimo" variability to emerge steadily over time?

Alternatives to the "actuary-in-the-box": Emergence patterns

- What do we do when bootstrapping is not appropriate (and hence the "actuary-in-the-box" cannot be used), or the "actuary-in-the-box" fails?
- Well, we know that we expect the "ultimo" (lifetime) volatility to emerge over time, so if we have an estimate of the "ultimo" volatility, then we can create approaches that allow it to emerge using an "emergence pattern"

Alternatives to the "actuary-in-the-box":
Emergence patterns based on Ultimates

- If, for a particular origin period:
  - We have a distribution of the ultimate cost of claims $\tilde{U}_0$ at time zero
  - Then let $U_1^{(i)} = \alpha \tilde{U}_0^{(i)} + (1-\alpha) E\left[\tilde{U}_0\right]$
  - and $CDR_1^{(i)} = U_0 - U_1^{(i)}$ where $U_0 = E\left[\tilde{U}_0\right]$
  - The CDR then becomes a function of *α* and the SD of the CDR can be controlled using *α*
  - Note: each origin period has a different value of *α*
  - We call *α* an "emergence factor", and the set of alphas an "emergence pattern"

Alternatives to the "actuary-in-the-box":
Emergence patterns: Notes

- The method relies on having a distribution of the ultimate cost of claims under the "lifetime" view
- Each origin period has a different value of *α*, depending on how developed it is
- The pattern is expressed by development period, since a tail may be required. Each origin period is associated with only one development period
- If $\alpha = 1$, the SDs of the CDRs will be maximised and will match the "lifetime" view
- If $\alpha = 0$, the SD of the CDRs will be zero
- The calibration problem is finding appropriate values of *α*

Calibrating the emergence pattern
Where the "actuary-in-the-box" approach is possible

- Given the SDs of the 1 year ahead CDR by origin period using the "actuary-in-the-box" approach, find *α* such that the SDs of the CDR using the emergence pattern approach are the same
- For a single origin period, it is straightforward to show that $\alpha = \dfrac{SD\left[CDR_1^{AIB}\right]}{SD\left[\tilde{U}_0\right]}$
- But the dependencies between origin periods are different using the emergence pattern approach relative to the "actuary-in-the-box"
  - If *α* is calibrated to the origin period SDs, the SD of the total CDR will be different
  - An alternative is to adjust the *α*s until the SD of the total CDR matches
- (Calibration alternatives based on a sequence of 1 year ahead views are possible)

Taylor & Ashe Data
Prediction errors

	Prediction Errors	
Accident Year	1 Year Ahead CDR	Mack Ultimate
1	0	0
2	76,210	76,210
3	106,164	122,494
4	80,585	133,428
5	231,538	257,706
6	318,598	409,466
7	360,036	554,675
8	627,638	878,730
9	586,187	963,470
10	1,030,989	1,357,727
Total	1,776,119	2,444,130

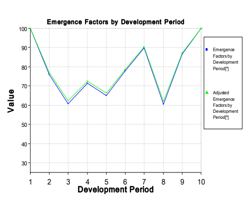
Taylor & Ashe Data
"Actuary-in-the-box" vs Emergence patterns based on Ultimates

SDs of 1 Yr ahead CDRs

		Emergence Patterns			
Accident Year	Actuary-in-the-box	100%	0%	Calibrated (unadjusted)	Calibrated (adjusted)
1	0	0	0	0	0
2	76,210	76,210	0	76,210	76,210
3	106,164	122,494	0	106,164	106,836
4	80,585	133,428	0	80,585	82,759
5	231,538	257,706	0	231,538	232,614
6	318,598	409,466	0	318,598	322,337
7	360,036	554,675	0	360,036	368,044
8	627,638	878,730	0	627,638	637,968
9	586,187	963,470	0	586,187	601,710
10	1,030,989	1,357,727	0	1,030,989	1,044,432
Total	1,776,119	2,444,130	0	1,747,742	1,776,119

Taylor & Ashe Data
"Actuary-in-the-box" vs Emergence patterns based on Ultimates

	Emergence Pattern	
Development Period	Unadjusted	Adjusted
1	100.0	100.0
2	75.9	76.9
3	60.8	62.5
4	71.4	72.6
5	64.9	66.4
6	77.8	78.7
7	89.8	90.3
8	60.4	62.0
9	86.7	87.2
10	100.0	100.0



Note: In a standard analysis, we only have data to calibrate from development period 2. The value of 100% at development period 1 was chosen arbitrarily. This can be discussed further.

Emergence Patterns based on Ultimates
Pros and Cons

- Pro: Very easy to calibrate
- Con: Can result in negative expected reserves one year ahead for some simulations, for example

Expected Opening Ultimate	100	
Simulation *n*		
Perfect Foresight Opening Ultimate	180	
Cumulative Claims at end of Year	170	
Emergence Factor (alpha)	0.75	
Closing Booked Ultimate	160	= 0.75 x 180 + 0.25 x 100
Claims Development Result	-60	= 100 - 160
Closing Booked Reserve	-10	= 160 - 170

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Alternatives to the "actuary-in-the-box":
Emergence patterns based on Reserves

- For example, if for a particular origin period:
  - We have a distribution of the outstanding liabilities L_0 at time zero
  - with payments in each future year $C_1,\ldots,C_n$ such that $L_0 = \sum_{k=1}^{n} C_k$
  - Then let $R_1^{(i)} = \beta\left(L_0^{(i)} - C_1^{(i)}\right) + (1-\beta)E\left[L_0 - C_1\right]$
  - and $CDR_1^{(i)} = R_0 - C_1^{(i)} - R_1^{(i)}$
  - The CDR then becomes a function of β and the SD of the CDR can be controlled using β
  - Note: each origin period has a different value of β
  - We call β an "emergence factor", and the set of alphas an "emergence pattern"

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Calibrating the emergence pattern
Where the "actuary-in-the-box" approach is possible

- Given the SDs of the 1 year ahead CDR by origin period using the "actuary-in-the-box" approach, find β such that the SDs of the CDR using the emergence pattern approach are the same
- This is not as straightforward as finding α for the method based on Ultimates
- The dependencies between origin periods are different using the emergence pattern approach relative to the "actuary-in-the-box"
  - If β is calibrated to the origin period SDs, the SD of the total CDR will be different
  - An alternative is to adjust the βs until the SD of the total CDR matches
- (Calibration alternatives based on a sequence of 1 year ahead views are possible)

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Calibrating the emergence pattern method 1
Where the "actuary-in-the-box" approach is possible

- If $\beta=1$, the SDs of the CDRs will be maximised and will match the "lifetime" view
- If $\beta=0$, the SDs of the CDRs will be minimised, and will reflect the SDs of the payments in the year
- Given the SDs of the 1 year ahead CDR by origin period using the "actuary-in-the-box" approach, find β such that the SDs of the CDR using the emergence pattern approach are the same
  - But the dependencies between origin periods are different using the emergence pattern approach relative to the "actuary-in-the-box"
  - If β is calibrated to the origin period SDs, the SD of the total CDR will be different
  - An alternative is to adjust the βs until the SD of the total CDR matches
- (Calibration alternatives based on a sequence of 1 year ahead views are possible)
- In a multi-year model, using the emergence pattern method described here, the CDRs between years are perfectly correlated (they are uncorrelated with the "actuary-in-the-box" approach)

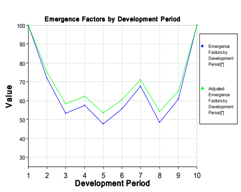
Taylor & Ashe Data
"Actuary-in-the-box" vs Emergence patterns based on Reserves

SDs of 1 Yr ahead CDRs

		Emergence Patterns			
Accident Year	Actuary-in-the-box	100%	0%	Calibrated (unadjusted)	Calibrated (adjusted)
1	0	0	0	0	0
2	76,210	76,210	76,210	76,210	76,210
3	106,164	122,494	94,487	106,164	107,712
4	80,585	133,428	53,001	80,585	85,910
5	231,538	257,706	195,521	231,538	234,236
6	318,598	409,466	247,200	318,598	327,732
7	360,036	554,675	250,906	360,036	379,593
8	627,638	878,730	376,752	627,638	654,312
9	586,187	963,470	240,217	586,187	627,309
10	1,030,989	1,357,727	246,658	1,030,989	1,067,405
Total	1,776,119	2,444,130	660,304	1,694,736	1,776,119

Taylor & Ashe Data
"Actuary-in-the-box" vs Emergence patterns based on Reserves

	Emergence Pattern	
Development Period	Unadjusted	Adjusted
1	100.0	100.0
2	72.1	75.2
3	53.3	58.5
4	57.6	62.3
5	47.6	53.5
6	55.7	60.6
7	67.6	71.3
8	48.6	54.3
9	60.7	65.1
10	100.0	100.0



Note: In a standard analysis, we only have data to calibrate from development period 2. The value of 100% at development period 1 was chosen arbitrarily. This can be discussed further.

Calibrating the emergence pattern
Where the "actuary-in-the-box" approach is NOT possible

- When bootstrapping has not been used, or the "actuary-in-the-box" method fails, what emergence pattern should be used?
- This is difficult in the absence of an alternative method.
- In practice, either use 100% (*ie* go straight to ultimate), or use an appropriate benchmark
- Using benchmarks:
  - Find a suitable benchmark triangle where the "actuary-in-the-box" approach can be used
  - Calibrate an emergence pattern to the SDs of the CDRs given by the "actuary-in-the-box" approach
  - Apply the benchmark emergence pattern

Using Benchmarks

- The obvious question when using benchmarks is "Which benchmark is appropriate?"
- For emergence patterns, does it matter too much?
  - Do short tailed lines etc exhibit similar patterns?
  - How stable are the patterns in practice?
  - Do emergence patterns for different lines of business display common characteristics?
- To assist answer these (and other) questions, we took some publicly available data, and calibrated emergence patterns using a simple underlying model

Data Analysis

We used publically available paid claims triangles:
Schedule P – 2011 loss triangles

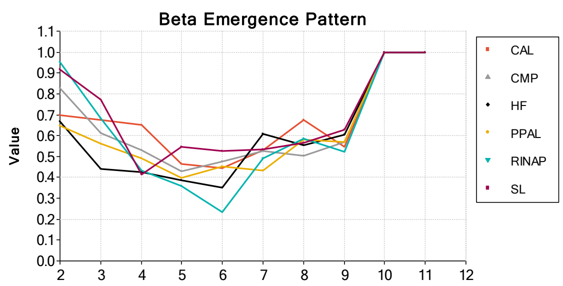
Schedule P data

		Duration	Volatility	Opening Reserves in USD bn
HF	Homeowner & Farmowners	1.4	5%	23.1
PPAL	Private Passenger Auto Liability	2.1	1%	76.4
SL	Special Liability	2.4	11%	4.7
RINAP	Reinsurance: Nonproportional Assumed Property	2.4	24%	7.6
Int	International	2.5	55%	0.2
RINAF	Reinsurance: Nonproportional Assumed Financial	2.6	67%	0.1
CMP	Commercial Multiple Peril	2.6	5%	33.2
CAL	Commercial Auto Liability	3.0	2%	21.2
WC	Workers' Compensation	3.2	3%	49.1
MPLCM	Medical Professional Liability - Claim Made	3.9	4%	11.1
OLO	Other Liability: Occurrence	3.9	6%	32.4
RINAL	Reinsurance: Nonproportional Assumed Liability	4.0	24%	6.8
PLCM	Product Liability: Claims Made	4.2	22%	0.9
OLCM	Other Liability: Claims Made	4.2	5%	30.5
PLO	Product Liability: Occurrence	5.3	9%	6.2
MPLO	Medical Professional Liability - Occurrence	5.3	13%	4.5

Models used

- For each paid claims triangle we fit four models:
  - Bootstrap
    - Mack and ODP (with varying scale parameters)
    - No curve fit (ie chain ladder model only)
  - Actuary-in-the-Box
    - With and without Bornhuetter-Ferguson adjustment for all origin years (where BF priors equal expected Ultimates from the Bootstrap results)
  - For each model we calculate the following emergence factors
    - Adjusted betas
    - Adjusted alphas

Schedule P – short tail lines – no BF



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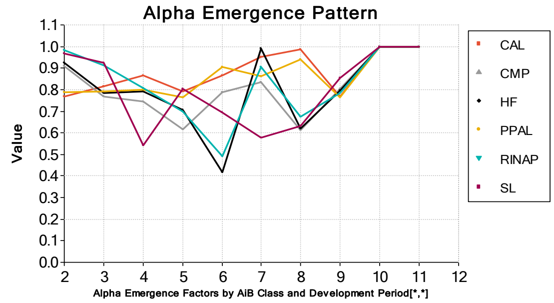

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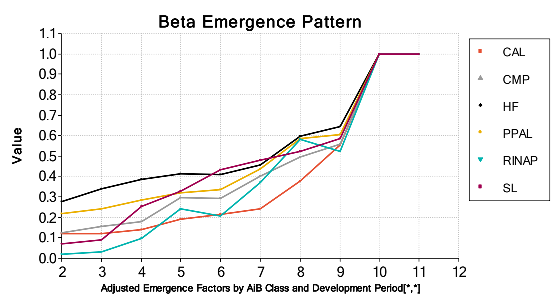

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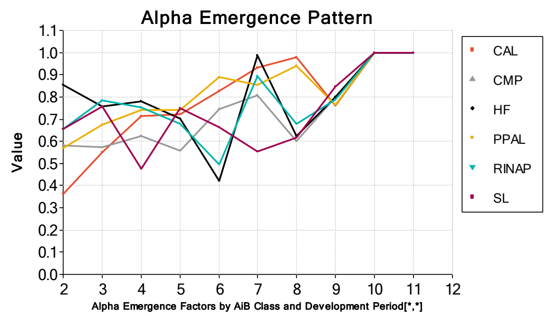

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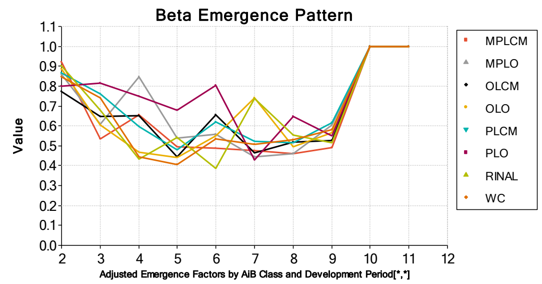
Schedule P – long tail lines – no BF



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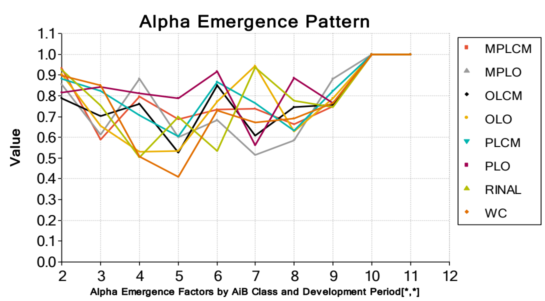
Schedule P – long tail lines – no BF



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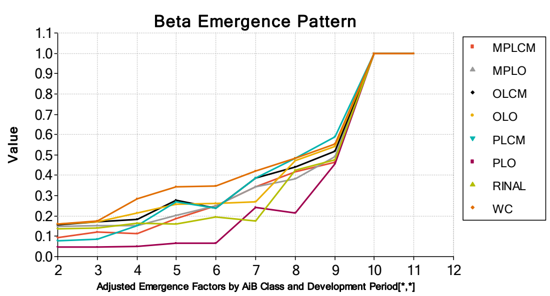
Schedule P – long tail lines – BF



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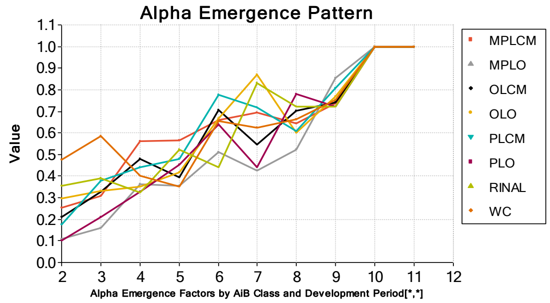
Schedule P – long tail lines – BF



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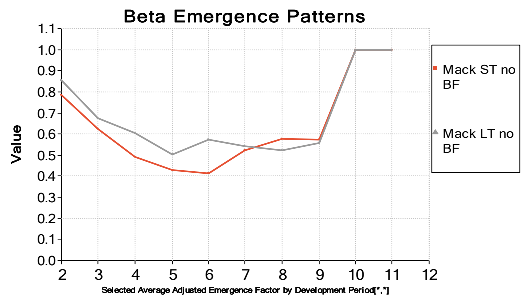
Schedule P – short tail v long tail – no BF



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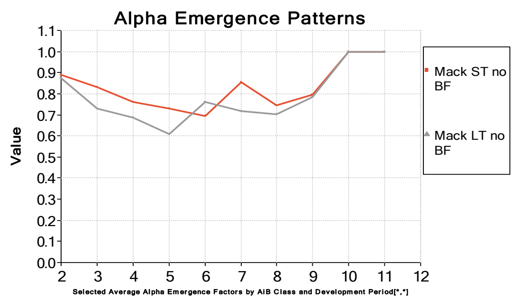
Schedule P – short tail v long tail – no BF



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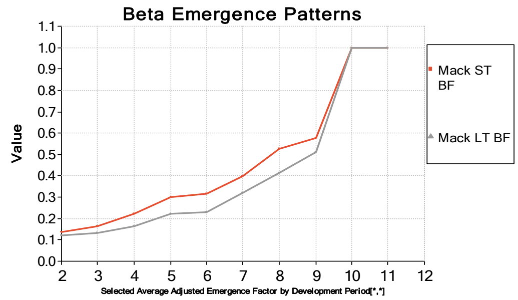
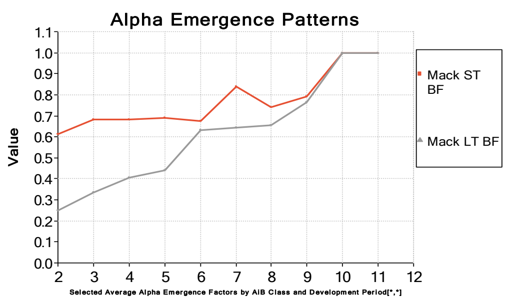
Schedule P – short tail v long tail – BF



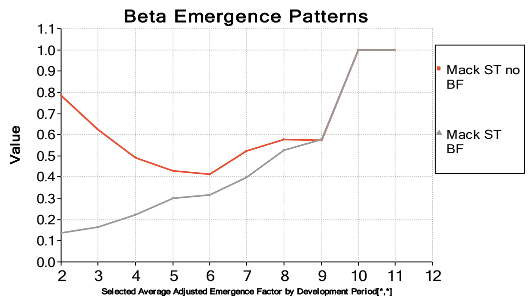
Schedule P – short tail v long tail – BF



Rank correlations: duration v emergence factor (Mack)

Development Period	Beta		Alpha	
	BF	no BF	BF	no BF
2	-20%	15%	-94%	-38%
3	-29%	28%	-89%	-39%
4	-50%	67%	-76%	8%
5	-62%	60%	-78%	-45%
6	-58%	75%	-8%	28%
7	-60%	-32%	-66%	-54%
8	-80%	-41%	-14%	2%
9	-70%	-22%	-25%	-17%

Schedule P – short tail – BF v no BF



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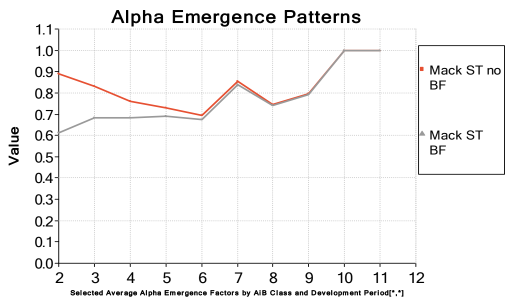
Schedule P – short tail – BF v no BF



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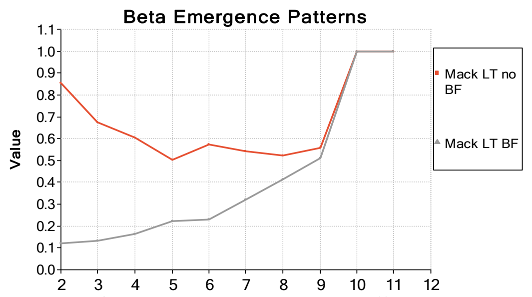
Schedule P – long tail – BF v no BF



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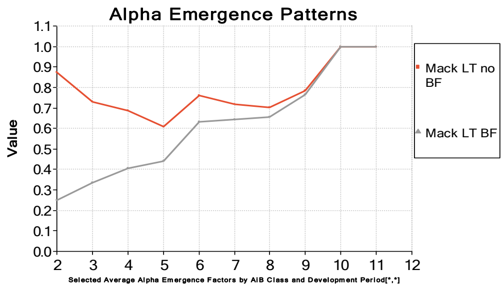
Schedule P – long tail – BF v no BF



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Summary of Observations

- *Beta* patterns are smoother than alpha patterns
- *Beta* patterns show clearer relationships (see below) than alpha patterns
- Without BF adjustment
  - Beta patterns show clear U shape
  - Longer tail lines tend to have higher values
- With BF adjustment
  - Pattern starts low and increases with the development period
  - Longer tail lines tend to have lower values
- Patterns with and without the BF adjustment converge

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Industry view: Why would you use emergence patterns?

- When the Actuary-in-the-Box approach doesn't work
- Allows expert judgement
- Gives different dependencies between lines of business
- Potentially not as restrictive as the "actuary-in-the-box"
- Other risks – can be used for net, gross, expenses, cats, latent claims etc
- Transparency and communication
- Model efficiency – the actuary-in-the-box approach is computationally intensive

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Reserve Risk under Solvency II…

Actually, it's not all about the CDR…

Other considerations
Reserve setting and re-reserving for technical liabilities

At each accounting date the following balance / reserves for future cashflows are required:

- Gross Outstanding Claims Provisions
  - Claims;
  - Premiums;
  - Expenses;
- RI Outstanding Claims Provisions
  - Claims;
  - Premiums;
  - Expenses
- Bad Debt Outstanding Claims Provisions
- Gross Premium Provisions
  - Claims;
  - Premiums;
  - Expenses;
- RI Premium Provisions
  - Claims;
  - Premiums;
  - Expenses
- Bad Debt Premium Provisions

Conclusions

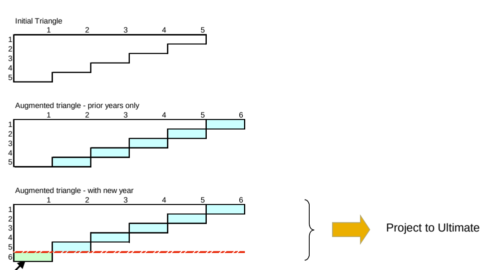
- Quantifying reserve uncertainty requires statistical models. Obtaining a SD of forecast reserves analytically can be difficult. Simulation techniques can simplify the modelling enormously, giving results that are analogous to the analytic results (when applied correctly).
- Care needs to be taken over definitions of "reserve risk". The one-year view of Solvency II is different from the traditional actuarial view.
- A reconciliation between the 1 year view and the "ultimo" view can be obtained by understanding the differences between the perspectives.
- The "actuary-in-the-box" approach attempts to replicate real life
  - It demonstrates that we expect the "lifetime" risk to emerge steadily over time
- Emergence pattern approaches use this feature while trying to simplify the analysis
  - However, there is a calibration problem, for which we can use benchmarks combined with judgement

Further considerations

Working with "new" accident years

- With simulation based internal capital models, it is necessary to model business written over the year ahead
- For the overall SCR calculations, the 1 year ahead balance sheet includes liabilities in respect of the new year, and the expected outstanding liabilities for that year are required for each simulation, conditional on what has emerged in the first development period
- The "actuary-in-the-box" and emergence pattern methods can be extended to obtain this

Modus Operandi with a new year



Note: Bottom left value does not affect estimation of development factors when re-reserving in a 1 year model, so we can obtain a distribution of development factors using the "actuary-in-the-box" approach without this new year then apply those simulated development factors to the payment in the new year

Working with "new" accident years
Notes

- If the emergence pattern methods are used, the patterns need extending (backwards) for the 12 month emergence factor
- Check the volatility of the 12 month cash flow payment for the new year
  - If it is too high, the "actuary-in-the-box" method in particular may give unrealistic results
- Dependencies between the results for the new year and prior years will need to be considered

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A Note on Dependencies

- When applying dependencies between lines of business in an internal model, it is traditional to apply the dependency to the total outstanding liabilities using the "lifetime" view
  - This is different from the interpretation of the reserve risk correlations using the standard parameters for the standard formula, which relate to the profit/loss distributions (CDRs) over a 1 year period
- Using the traditional approach, it is straightforward to apply dependencies between lines of business to the total outstanding liabilities, and observe the dependencies of the total 1 yr-ahead CDRs (and beyond) that emerge as a result
  - These can be compared to the standard parameters if required
- Technically, it would be possible (but troublesome) to apply the dependency to the total CDRs instead, but in a multi-year setting, which year should be chosen?
  - 1 yr-ahead? 2 yrs-ahead? etc
  - Note: All the simulations are tied for a given line of business (lifetime view, *n* yrs-ahead CDRs), so only one item can be chosen to apply the dependencies between lines of business to. The total outstanding liabilities using the lifetime view is a convenient choice

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Questions or comments?

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