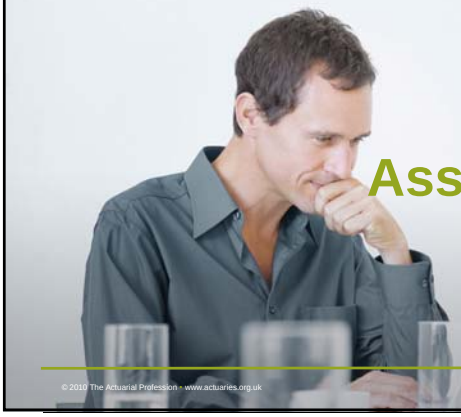
Assumption Consistency:
Back-testing and Other Validation Techniques

The Actuarial Profession
making financial sense of the future

GIRO Conference and Exhibition 2010
Jeff Courchene and Mark Shapland



Assumption Consistency
Back-testing and other Validation Techniques

12-15 October 2010

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Agenda

- Available guidance (CEIOPS 33/09 & Lloyd's)
- Validation and documentation of assumptions
  - Deterministic best estimate assumptions
  - Uncertainty assumptions
- Anticipating prospective CY figures relative to model
- Setting the threshold for a key performance indicator (KPI)

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Available Guidance (CEIOPS 33/09 & Lloyd's)

Purpose of Validation

- Demonstrate appropriate levels of BE element of TP
- Demonstrate applicability and relevance of methods applied
  - Appropriate for nature, scale & complexity of business
- Compare BE and assumptions with experience (back-testing)
  - Validation that the history is a good indicator of the future
  - Posterior validation of expert judgment
  - Identify significant deviations (actual vs. predicted)
    - Postulate explanation: randomness, systematic effect, assumption or parameter error
  - Enhance understanding of FCF emergence and calculations
  - Support for application of method(s)

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Available Guidance (CEIOPS 33/09 & Lloyd's)

Requirements of Validation & Back Testing

- Responsibility of actuarial function
  - Independent of those directly involved in setting TP
- Sufficient granularity (ideally level of homogeneous risks)
- At least once yearly
  - And where indications of substantial changes
  - And in response to significant changes in external environment, assumptions and results of goodness of fit

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Available Guidance (CEIOPS 33/09 & Lloyd's)

Scope of Validation & Back Testing

- Separately for gross/ceded and claim/premium provisions
  - Lloyd's: Expect back-testing to be conducted undiscounted and (likely) gross on a Solvency II line of business
- All relevant and material assumptions
  - Consistent from year to year (no arbitrary changes)
  - Testing of expert judgment
  - Appropriateness of underlying data (complete and accurate)
- Documentation at a level consistent with materiality
- Peer-review

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Available Guidance (CEIOPS 33/09 & Lloyd's)

Common validation approaches

- Percentiles and residual analysis (outliers/clusters)
- Diagnostics
- Stress / scenario testing (non-linearity, uncertainty, tail of distribution) and reverse stress testing (survival scenarios)
- Sensitivity analyses (changes in parameters, benchmarking, impact of changes in cover, deductibles or external factors)

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Deterministic (undiscounted) best estimate

Example

- Objective:
  - Validation of deterministic best estimate assumptions
  - Build a framework for back-testing methods/models prior to completion of next analysis
    - Early warning indicator using analysis input data (CY paid and incurred)
    - Provide important information to reserving actuary prior to analysis
    - Results are dissatisfactory unless add uncertainty analysis (and validation) using consistent assumptions
  - Extend framework to test historical amounts
    - Allows actuary to assess where methods/models perform well
  - Integrate approach into Risk Management Framework
    - Allows C-Suite to anticipate where (and by how much) prior models fell short

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Deterministic (undiscounted) best estimate

Methods – Paid Chain Ladder

Paid Loss and ALAE Data

	12	24	36	48	60	72	84	96	108	120	Tail
1999	525	866	1,021	1,114	1,165	1,192	1,204	1,210	1,213		1.004
2000	561	968	1,149	1,253	1,314	1,344	1,359	1,367			
2001	589	1,011	1,194	1,314	1,378	1,408	1,422				
2002	637	1,083	1,287	1,414	1,491	1,527					
2003	674	1,149	1,363	1,503	1,577						
2004	686	1,147	1,379	1,520							
2005	685	1,210	1,449								
2006	755	1,284									
2007	778										
AYLWA	1.706	1.190	1.098	1.050	1.023	1.010	1.006	1.002	1.002	1.002	1.000
CDF	2.445	1.433	1.205	1.098	1.046	1.022	1.012	1.006	1.004	1.002	1.000

	Paid To Date	Ultimate	Unpaid
1999	1,213	1,218	5
2000	1,367	1,376	8
2001	1,422	1,439	17
2002	1,527	1,561	34
2003	1,577	1,649	72
2004	1,520	1,668	148
2005	1,449	1,746	297
2006	1,284	1,841	557
2007	778	1,903	1,125
			2,263

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Deterministic (undiscounted) best estimate

Common Assumptions – Paid Chain Ladder Method

- History is a good indicator of future
- Each AY is independent and "has its own level"
  - The decay is changing at every development period interval
  - Selection of 9 LDFs is essentially 19 parameters (w/o Tail)
- Projection is result of multiple forces (inflation, practice, etc.)
  - Not a continuation of <u>all</u> observable trends
- Tail factor for paid losses
- Adjusting paid loss LDFs helps fit assumptions to data and adds predictive value

Predictive Value in this context refers to an improvement in accuracy or a reduction in volatility of the estimate

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Deterministic (undiscounted) best estimate

CL: Projection is not a continuation of <u>all</u> observable trends

Projection is Accurate When All Trends (AY, DY, CY) are Stable

Incremental

	1	2	3	4	5	6	7	8	9	10
1	100.0	75.0	50.0	35.0	25.0	20.0	10.0	5.0	2.5	1.0
2	100.0	75.0	50.0	35.0	25.0	20.0	10.0	5.0	2.5	
3	100.0	75.0	50.0	35.0	25.0	20.0	10.0	5.0		
4	100.0	75.0	50.0	35.0	25.0	20.0	10.0			
5	100.0	75.0	50.0	35.0	25.0	20.0				
6	100.0	75.0	50.0	35.0	25.0					
7	100.0	75.0	50.0	35.0						
8	100.0	75.0	50.0							
9	100.0	75.0								
10	100.0									

Actual Outcome

	1	2	3	4	5	6	7	8	9	10	
1											
2										1.0	1.0
3									2.5	1.0	3.5
4								5.0	2.5	1.0	8.5
5							10.0	5.0	2.5	1.0	18.5
6						20.0	10.0	5.0	2.5	1.0	38.5
7					25.0	20.0	10.0	5.0	2.5	1.0	63.5
8				35.0	25.0	20.0	10.0	5.0	2.5	1.0	98.5
9			50.0	35.0	25.0	20.0	10.0	5.0	2.5	1.0	148.5
10		75.0	50.0	35.0	25.0	20.0	10.0	5.0	2.5	1.0	223.5
											604.0

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Deterministic (undiscounted) best estimate

CL: Projection is not a continuation of all observable trends

Projection is Accurate When All Trends (AY, DY, CY) are Stable – Including Constant CY Trend

Incremental

	1	2	3	4	5	6	7	8	9	10
1	100.0	78.8	55.1	40.5	30.4	25.5	13.4	7.0	3.7	1.6
2	105.0	82.7	57.9	42.5	31.9	26.8	14.1	7.4	3.9	
3	110.3	86.8	60.8	44.7	33.5	28.1	14.8	7.8		
4	115.8	91.2	63.8	46.9	35.2	29.5	15.5			
5	121.6	95.7	67.0	49.2	36.9	31.0				
6	127.6	100.5	70.4	51.7	38.8					
7	134.0	105.5	73.9	54.3						
8	140.7	110.8	77.6							
9	147.7	116.3								
10	155.1									

Actual Outcome

	1	2	3	4	5	6	7	8	9	10	
1											
2										1.6	1.6
3									4.1	1.7	5.8
4								8.1	4.3	1.8	14.2
5							16.3	8.6	4.5	1.9	31.2
6						32.6	17.1	9.0	4.7	2.0	65.4
7					40.7	34.2	18.0	9.4	4.9	2.1	109.3
8				57.0	42.8	35.9	18.9	9.9	5.2	2.2	171.8
9			81.4	59.9	44.9	37.7	19.8	10.4	5.5	2.3	261.9
10		122.2	85.5	62.9	47.1	39.6	20.8	10.9	5.7	2.4	397.1
											1058.3

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Deterministic (undiscounted) best estimate

CL: Projection is not a continuation of all observable trends

Projection is Not Accurate When Some Trends (AY, DY, CY) are Not Stable – Changing CY Trend

Incremental

	1	2	3	4	5	6	7	8	9	10
1	100.0	75.0	50.0	35.0	25.0	21.0	11.0	5.8	3.0	1.3
2	100.0	75.0	50.0	35.0	26.3	22.1	11.6	6.1	3.2	
3	100.0	75.0	50.0	36.8	27.6	23.2	12.2	6.4		
4	100.0	75.0	52.5	38.6	28.9	24.3	12.8			
5	100.0	78.8	55.1	40.5	30.4	25.5				
6	105.0	82.7	57.9	42.5	31.9					
7	110.3	86.8	60.8	44.7						
8	115.8	91.2	63.8							
9	121.6	95.7								
10	127.6									

Actual Outcome

	1	2	3	4	5	6	7	8	9	10	
1											
2										1.3	1.3
3									3.4	1.4	4.8
4								6.7	3.5	1.5	11.7
5							13.4	7.0	3.7	1.6	25.7
6						26.8	14.1	7.4	3.9	1.6	53.8
7					33.5	28.1	14.8	7.8	4.1	1.7	90.0
8				46.9	35.2	29.5	15.5	8.1	4.3	1.8	141.4
9			67.0	49.2	36.9	31.0	16.3	8.6	4.5	1.9	215.4
10		100.5	70.4	51.7	38.8	32.6	17.1	9.0	4.7	2.0	326.7
											870.7

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Assumption Consistency: Back-testing and Other Validation Techniques

Deterministic (undiscounted) best estimate

CL: Projection is not a continuation of all observable trends

Projection is Not Accurate When Some Trends (AY, DY, CY) are Not Stable – Changing CY Trend

Incremental

	1	2	3	4	5	6	7	8	9	10
1	100.0	75.0	50.0	35.0	25.0	21.0	11.0	5.8	3.0	1.3
2	100.0	75.0	50.0	35.0	26.3	22.1	11.6	6.1	3.2	
3	100.0	75.0	50.0	36.8	27.6	23.2	12.2	6.4		
4	100.0	75.0	52.5	38.6	28.9	24.3	12.8			
5	100.0	78.8	55.1	40.5	30.4	25.5				
6	105.0	82.7	57.9	42.5	31.9					
7	110.3	86.8	60.8	44.7						
8	115.8	91.2	63.8							
9	121.6	95.7								
10	127.6									

Age-to-Age Factors

	1	2	3	4	5	6	7	8	9	10
1		1.750	1.286	1.156	1.096	1.074	1.036	1.018	1.009	1.004
2		1.750	1.286	1.156	1.101	1.077	1.038	1.019	1.010	
3		1.750	1.286	1.163	1.105	1.080	1.039	1.020		
4		1.750	1.300	1.170	1.109	1.082	1.040			
5		1.788	1.308	1.173	1.111	1.084				
6		1.788	1.308	1.173	1.111					
7		1.788	1.308	1.173						
8		1.788	1.308							
9		1.788								
10										
	VWA	1.772	1.299	1.167	1.106	1.079	1.038	1.019	1.010	1.004

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Deterministic (undiscounted) best estimate

CL: Projection is not a continuation of all observable trends

Projection is Not Accurate When Some Trends (AY, DY, CY) are Not Stable – Changing CY Trend

Incremental

	1	2	3	4	5	6	7	8	9	10
1	100.0	75.0	50.0	35.0	25.0	21.0	11.0	5.8	3.0	1.3
2	100.0	75.0	50.0	35.0	26.3	22.1	11.6	6.1	3.2	
3	100.0	75.0	50.0	36.8	27.6	23.2	12.2	6.4		
4	100.0	75.0	52.5	38.6	28.9	24.3	12.8			
5	100.0	78.8	55.1	40.5	30.4	25.5				
6	105.0	82.7	57.9	42.5	31.9					
7	110.3	86.8	60.8	44.7						
8	115.8	91.2	63.8							
9	121.6	95.7								
10	127.6									

Projection Error

	1	2	3	4	5	6	7	8	9	10	
1											
2										-0.05	-0.05
3									-0.17	-0.10	-0.27
4								-0.40	-0.27	-0.14	-0.81
5							-0.81	-0.53	-0.34	-0.17	-1.84
6						-1.37	-0.90	-0.58	-0.37	-0.18	-3.41
7					-1.56	-1.57	-1.01	-0.64	-0.41	-0.20	-5.38
8				-1.82	-1.83	-1.80	-1.14	-0.72	-0.45	-0.22	-7.97
9			-1.98	-2.24	-2.16	-2.10	-1.30	-0.81	-0.50	-0.24	-11.32
10		-2.01	-2.68	-2.79	-2.59	-2.47	-1.51	-0.92	-0.56	-0.27	-15.79
											-46.84

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Assumption Consistency: Back-testing and Other Validation Techniques

Deterministic (undiscounted) best estimate

CL: Projection is not a continuation of all observable trends

Projection is Not Accurate When Some Trends (AY, DY, CY) are Not Stable – Changing CY Trend
Shorter Average Age-to-Age Ratio Adds Predictive Value – But Still Not Accurate

Incremental

	1	2	3	4	5	6	7	8	9	10
1	100.0	75.0	50.0	35.0	25.0	21.0	11.0	5.8	3.0	1.3
2	100.0	75.0	50.0	35.0	26.3	22.1	11.6	6.1	3.2	
3	100.0	75.0	50.0	36.8	27.6	23.2	12.2	6.4		
4	100.0	75.0	52.5	38.6	28.9	24.3	12.8			
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7	110.3	86.8	60.8	44.7						
8	115.8	91.2	63.8							
9	121.6	95.7								
10	127.6									

Age-to-Age Factors

	1	2	3	4	5	6	7	8	9	10
1		1.750	1.286	1.156	1.096	1.074	1.036	1.018	1.009	1.004
2		1.750	1.286	1.156	1.101	1.077	1.038	1.019	1.010	
3		1.750	1.286	1.163	1.105	1.080	1.039	1.020		
4		1.750	1.300	1.170	1.109	1.082	1.040			
5		1.788	1.308	1.173	1.111	1.084				
6		1.788	1.308	1.173	1.111					
7		1.788	1.308	1.173						
8		1.788	1.308							
9		1.788								
10										
5-Yr VWA		1.788	1.309	1.167	1.106	1.079	1.038	1.019	1.010	1.004

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Deterministic (undiscounted) best estimate

CL: Projection is not a continuation of all observable trends

Projection is Not Accurate When Some Trends (AY, DY, CY) are Not Stable – Changing CY Trend
Shorter Average Age-to-Age Ratio Adds Predictive Value – But Still Not Accurate

Incremental

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2	100.0	75.0	50.0	35.0	26.3	22.1	11.6	6.1	3.2	
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6	105.0	82.7	57.9	42.5	31.9					
7	110.3	86.8	60.8	44.7						
8	115.8	91.2	63.8							
9	121.6	95.7								
10	127.6									

Projection Error

	1	2	3	4	5	6	7	8	9	10	
1											
2										-0.05	-0.05
3									-0.17	-0.10	-0.27
4								-0.40	-0.27	-0.14	-0.81
5							-0.81	-0.53	-0.34	-0.17	-1.84
6						-1.37	-0.90	-0.58	-0.37	-0.18	-3.41
7					-1.01	-1.52	-0.98	-0.63	-0.40	-0.20	-4.74
8				-0.70	-1.13	-1.66	-1.06	-0.68	-0.43	-0.21	-5.87
9			-0.34	-0.79	-1.23	-1.78	-1.14	-0.72	-0.45	-0.22	-6.67
10		0.00	-0.35	-0.83	-1.29	-1.87	-1.19	-0.76	-0.48	-0.23	-7.00
											-30.66

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Assumption Consistency: Back-testing and Other Validation Techniques

Deterministic (undiscounted) best estimate

Methods – Incurred Chain Ladder

Incurred Loss and ALAE Data

	12	24	36	48	60	72	84	96	108	120	Tail
1999	872	1,044	1,119	1,164	1,189	1,203	1,209	1,213	1,214		1.002
2000	941	1,166	1,257	1,309	1,340	1,357	1,365	1,370			
2001	973	1,212	1,306	1,369	1,403	1,421	1,428				
2002	1,046	1,317	1,407	1,478	1,520	1,538					
2003	1,103	1,381	1,497	1,568	1,605						
2004	1,111	1,404	1,519	1,585							
2005	1,167	1,474	1,584								
2006	1,219	1,536									
2007	1,238										
AYLWA	1.249	1.077	1.045	1.025	1.012	1.005	1.004	1.001	1.002	1.000	1.000
CDF	1.476	1.181	1.097	1.049	1.024	1.012	1.007	1.003	1.002	1.000	1.000

	Incurred To Date	Ultimate	IBNR	Unpaid
1999	1,214	1,217	2	4
2000	1,370	1,374	4	7
2001	1,428	1,437	9	15
2002	1,538	1,556	18	30
2003	1,605	1,644	39	67
2004	1,585	1,663	78	143
2005	1,584	1,737	154	288
2006	1,536	1,814	278	530
2007	1,238	1,827	589	1,049
			1,172	2,133

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Deterministic (undiscounted) best estimate

Common Assumptions – Incurred Chain Ladder Method

- History is a good indicator of future
- Each AY is independent and "has its own level"
  - The decay is changing at every development period interval
  - Selection of 9 LDFs is essentially 19 parameters (w/o Tail)
- Projection is result of multiple forces (inflation, practice, etc.)
  - Not a continuation of <u>all</u> observable trends
- Case reserve information adds predictive value
- Tail factor for incurred losses
- Adjusting incurred loss LDFs helps fit assumptions to data and adds predictive value

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Assumption Consistency: Back-testing and Other Validation Techniques

Deterministic (undiscounted) best estimate

Methods – Paid Bornhuetter-Ferguson

Paid Loss and ALAE Data

	12	24	36	48	60	72	84	96	108	120	Tail
1999	525	866	1,021	1,114	1,165	1,192	1,204	1,210	1,213		1.004
2000	561	968	1,149	1,253	1,314	1,344	1,359	1,367			
2001	589	1,011	1,194	1,314	1,378	1,408	1,422				
2002	637	1,083	1,287	1,414	1,491	1,527					
2003	674	1,149	1,363	1,503	1,577						
2004	686	1,147	1,379	1,520							
2005	685	1,210	1,449								
2006	755	1,284									
2007	778										
AYLWA	1.706	1.190	1.098	1.050	1.023	1.010	1.006	1.002	1.002	1.002	1.000
CDF	2.445	1.433	1.205	1.098	1.046	1.022	1.012	1.006	1.004	1.002	1.000
BF Unpaid	0.591	0.302	0.170	0.089	0.044	0.022	0.012	0.006	0.004	0.002	0.000

	Paid To Date	BF ULR	BF Ultimate	BF Unpaid
1999	1,213	79.3%	1,219	5
2000	1,367	78.1%	1,376	9
2001	1,422	78.1%	1,440	19
2002	1,527	73.8%	1,563	36
2003	1,577	71.8%	1,650	73
2004	1,520	72.2%	1,675	155
2005	1,449	68.1%	1,763	314
2006	1,284	70.8%	1,861	577
2007	778	73.7%	1,923	1,145
				2,333

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Deterministic (undiscounted) best estimate

Methods – Incurred Bornhuetter-Ferguson

Incurred Loss and ALAE Data

	12	24	36	48	60	72	84	96	108	120	Tail
1999	872	1,044	1,119	1,164	1,189	1,203	1,209	1,213	1,214		1.002
2000	941	1,166	1,257	1,309	1,340	1,357	1,365	1,370			
2001	973	1,212	1,306	1,369	1,403	1,421	1,428				
2002	1,046	1,317	1,407	1,478	1,520	1,538					
2003	1,103	1,381	1,497	1,568	1,605						
2004	1,111	1,404	1,519	1,585							
2005	1,167	1,474	1,584								
2006	1,219	1,536									
2007	1,238										
AYLWA	1.249	1.077	1.045	1.025	1.012	1.005	1.004	1.001	1.002	1.000	1.000
CDF	1.476	1.181	1.097	1.049	1.024	1.012	1.007	1.003	1.002	1.000	1.000
BF Unrported	0.322	0.153	0.088	0.047	0.024	0.012	0.007	0.003	0.002	0.000	0.000

	Incurred To Date	BF ULR	BF Ultimate	BF IBNR	BF Unpaid
1999	1,214	79.3%	1,217	3	4
2000	1,370	78.1%	1,374	4	7
2001	1,428	78.1%	1,438	10	16
2002	1,538	73.8%	1,558	19	31
2003	1,605	71.8%	1,644	40	68
2004	1,585	72.2%	1,667	82	147
2005	1,584	68.1%	1,747	163	298
2006	1,536	70.8%	1,828	292	544
2007	1,238	73.7%	1,863	624	1,084
				1,238	2,199

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Deterministic (undiscounted) best estimate

Additional Assumptions – Bornhuetter Ferguson Methods

- Each AY is independent and "has its own level"
  - "Own level" completely described by IELR, premium and development pattern
  - Selection of IELR replace AY levels of CL
  - Still have essentially 19 parameters (w/o Tail)
- Use of IELR adds predictive value

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Deterministic (undiscounted) best estimate

Extracting future expectations from actuarial methodology

- Not defined by paid (incurred) chain ladder methods in isolation
  - Unless give paid (incurred) chain ladder 100% weight
  - Completing the rectangle is the first step
- Weighted average of FCF all methods receiving weight
  - Conversion required for extracting paid expectations from incurred method (and vice versus)
- Steps
  1. Complete rectangle for method
  2. Convert cumulative incurred to cumulative paid (if applicable)
  3. Consecutive differences define incremental amounts
  4. Weight consistently

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Assumption Consistency: Back-testing and Other Validation Techniques

Deterministic (undiscounted) best estimate

Convert results of incurred methods to paid expectations

CL Incurred - Cumulative

	12	24	36	48	60	72	84	96	108	120	132
1999	872	1,044	1,119	1,164	1,189	1,203	1,209	1,213	1,214	1,217	1,217
2000	941	1,166	1,257	1,309	1,340	1,357	1,365	1,370	1,371	1,374	1,374
2001	973	1,212	1,306	1,369	1,403	1,421	1,428	1,433	1,434	1,437	1,437
2002	1,046	1,317	1,407	1,478	1,520	1,538	1,546	1,552	1,553	1,556	1,556
2003	1,103	1,381	1,497	1,568	1,605	1,624	1,633	1,639	1,640	1,644	1,644
2004	1,111	1,404	1,519	1,585	1,624	1,643	1,652	1,658	1,660	1,663	1,663
2005	1,167	1,474	1,584	1,655	1,696	1,717	1,726	1,732	1,734	1,737	1,737
2006	1,219	1,536	1,654	1,728	1,771	1,792	1,802	1,809	1,810	1,814	1,814
2007	1,238	1,547	1,666	1,741	1,784	1,806	1,815	1,822	1,824	1,827	1,827

$$E\left[CPL_{i,j} \mid CIL_{i,j}\right] = CPL_{i,j} \times \frac{CIL_{i,ULT}}{CPL_{i,ULT}}$$

CL Incurred - Cumulative - Paid Expectations

	12	24	36	48	60	72	84	96	108	120	132
1999	525	865	1,020	1,113	1,164	1,191	1,202	1,209	1,212	1,214	1,217
2000	561	967	1,148	1,251	1,312	1,342	1,358	1,366	1,368	1,371	1,374
2001	588	1,010	1,193	1,313	1,377	1,407	1,420	1,428	1,432	1,434	1,437
2002	635	1,080	1,283	1,410	1,487	1,523	1,538	1,547	1,550	1,553	1,556
2003	671	1,145	1,359	1,498	1,572	1,608	1,624	1,634	1,637	1,640	1,644
2004	683	1,143	1,375	1,515	1,590	1,627	1,643	1,653	1,656	1,660	1,663
2005	681	1,204	1,441	1,583	1,661	1,699	1,716	1,726	1,730	1,734	1,737
2006	744	1,265	1,505	1,653	1,734	1,774	1,792	1,803	1,807	1,810	1,814
2007	747	1,275	1,516	1,665	1,747	1,788	1,806	1,816	1,820	1,824	1,827

CL Incurred - Incremental - Paid Expectations

	12	24	36	48	60	72	84	96	108	120	132
1999	525	340	154	93	51	27	11	7	3	2	2
2000	561	407	181	104	61	30	15	8	3	3	3
2001	588	422	183	120	64	30	13	8	3	3	3
2002	635	445	204	126	77	36	15	9	3	3	3
2003	671	474	214	139	73	36	16	9	4	3	3
2004	683	460	232	140	75	37	16	9	4	3	3
2005	681	523	238	141	78	38	17	10	4	3	3
2006	744	521	240	147	82	40	18	10	4	4	4
2007	747	527	242	148	82	40	18	10	4	4	4

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Deterministic (undiscounted) best estimate

Convert results of incurred methods to paid expectations

- Conversion to total paid patterns by year
  - Consistent with paid / expected paid patterns by year
  - Changes Incurred unpaid amounts by year
  - Highlights consistency / differences in assumptions
- Conversion to unpaid patterns by year
  - Consistent with only expected paid patterns by year
  - Matches Incurred unpaid amounts by year
  - Can lead to extreme differences in results

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Assumption Consistency: Back-testing and Other Validation Techniques

Deterministic (undiscounted) best estimate

Convert results of incurred methods to paid expectations

	Incurred To Date	Ultimate	IBNR	Unpaid	Adjusted Unpaid	Adjusted Ultimate
1999	1,214	1,217	2	4	5	1,218
2000	1,370	1,374	4	7	8	1,376
2001	1,428	1,437	9	15	17	1,439
2002	1,538	1,556	18	30	34	1,561
2003	1,605	1,644	39	67	72	1,649
2004	1,585	1,663	78	143	148	1,668
2005	1,584	1,737	154	288	296	1,745
2006	1,536	1,814	278	530	548	1,832
2007	1,238	1,827	589	1,049	1,080	1,858
			1,172	2,133	2,208	

	Incurred To Date	BF ULR	BF Ultimate	BF IBNR	BF Unpaid	Adjusted Unpaid	Adjusted Ultimate
1999	1,214	79.3%	1,217	3	4	5	1,219
2000	1,370	78.1%	1,374	4	7	9	1,376
2001	1,428	78.1%	1,438	10	16	19	1,440
2002	1,538	73.8%	1,558	19	31	36	1,563
2003	1,605	71.8%	1,644	40	68	73	1,650
2004	1,585	72.2%	1,667	82	147	155	1,675
2005	1,584	68.1%	1,747	163	298	311	1,760
2006	1,536	70.8%	1,828	292	544	567	1,851
2007	1,238	73.7%	1,863	624	1,084	1,109	1,887
				1,238	2,199	2,283	

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Deterministic (undiscounted) best estimate

Weighting Methods and Assumptions

- Recognition that assumptions made were imperfect
  - Recognition that paid and/or incurred methods predict better
    - Common assumption that incurred superior for earlier development ages
  - Recognition that BF and/or CL methods predict better
    - Common assumption that BF superior for earlier development ages
- Review results (diagnostics) & “shift” as needed

	Ultimate Loss Indications													
	Paid Chain	Incurred Chain	Paid Bornhuetter	Incurred Bornhuetter	Selected	Weights				Paid	Incurred		Case	
AY	Ladder	Ladder	Ferguson	Ferguson	Ultimate	PCL	ICL	PBF	IBF	To Date	To Date	Unpaid	Reserves	IBNR
1999	1,218	1,218	1,219	1,219	1,218	50%	50%	0%	0%	1,213	1,214	5	1	3
2000	1,376	1,376	1,376	1,376	1,376	50%	50%	0%	0%	1,367	1,370	8	3	6
2001	1,439	1,439	1,440	1,440	1,439	50%	50%	0%	0%	1,422	1,428	17	6	11
2002	1,561	1,561	1,563	1,563	1,561	50%	50%	0%	0%	1,527	1,538	34	11	23
2003	1,649	1,649	1,650	1,650	1,649	50%	50%	0%	0%	1,577	1,605	72	28	44
2004	1,668	1,668	1,675	1,675	1,668	50%	50%	0%	0%	1,520	1,585	148	65	84
2005	1,746	1,745	1,763	1,760	1,754	25%	25%	25%	25%	1,449	1,584	305	135	170
2006	1,841	1,832	1,861	1,851	1,856	0%	0%	50%	50%	1,284	1,536	572	252	320
2007	1,903	1,858	1,923	1,887	1,905	0%	0%	50%	50%	778	1,238	1,127	460	667
Σ	14,400	14,345	14,470	14,419	14,424					12,137	13,097	2,288	961	1,327

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Assumption Consistency: Back-testing and Other Validation Techniques

Deterministic (undiscounted) best estimate

Extracting future expectations from actuarial methodology (detail)

- Consistency requires same weights & "shifting" to be used for expected future cash flows

	Paid Loss Expectations (during 2008)								
	Paid Chain	Incurred Chain	Paid Bornhuetter	Incurred Bornhuetter	Expected	Weights			
AY	Ladder	Ladder	Ferguson	Ferguson	Paid	PCL	ICL	PBF	IBF
1999	2	2	3	3	2	50%	50%	0%	0%
2000	3	3	3	3	3	50%	50%	0%	0%
2001	8	8	9	9	8	50%	50%	0%	0%
2002	15	15	16	16	15	50%	50%	0%	0%
2003	36	36	37	37	36	50%	50%	0%	0%
2004	75	75	79	78	75	50%	50%	0%	0%
2005	142	141	150	149	145	25%	25%	25%	25%
2006	243	240	252	248	250	0%	0%	50%	50%
2007	549	527	559	542	550	0%	0%	50%	50%
Σ	1,075	1,049	1,110	1,084	1,086				

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Deterministic (undiscounted) best estimate

Back testing 2008 using 12/2007 analysis

- Granularity of underlying analysis
- Basis for initial assessment of new (2008) information
  - Prior to starting 12/2008 analysis
  - Identification of prior assumptions that did not perform well
- Not very satisfying
  - Can we evaluate these differences?

AY	Age	Actual Paid (CY2008)	@12/2007 Deterministic Expected (CY2008)	A v E
1999	120	3	2	0
2000	108	3	3	0
2001	96	8	8	(1)
2002	84	14	15	(2)
2003	72	33	36	(3)
2004	60	76	75	1
2005	48	140	145	(6)
2006	36	235	250	(15)
2007	24	530	550	(21)
2008	12	764		
2007 & prior		1,041	1,086	(46)

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Assumption Consistency: Back-testing and Other Validation Techniques

Deterministic (undiscounted) best estimate

Disconnect when implementing Mack / W&M for risk metric

- Adding "Mack / W&M" Std Dev to weighted results of deterministic methods is **NOT** consistent with assumptions of weighted mean
  - Weighting implies a diagnostic evaluation of assumptions
  - Adding "Mack / W&M" ignores that evaluation
  - Normally based on the paid chain ladder method in isolation
- Are weighted results really the mean?
- Must assume a shape of the distribution
- Uncertainty in tail described by very few observations

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Bootstrap (undiscounted) best estimate

Models and model assumptions

- Use of a Bootstrap model:
  - Reflects skewness of data
    - Mean may differ from deterministic results
    - Skewness results in its own distribution shape
  - Can incorporate a variety of methodologies
  - Can be weighted with a variety of models (not just other bootstrap models)
  - Allows for statistical review / testing of assumptions
  - Final weighted (& shifted) results have consistent assumptions throughout.

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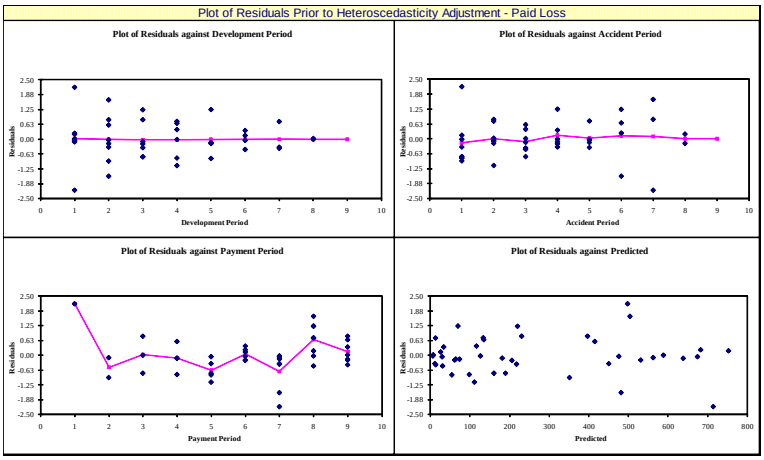
Assumption Consistency:
Back-testing and Other Validation Techniques

Bootstrap (undiscounted) best estimate

Additional diagnostics support validation of deterministic methods



- Review of residual plots indicates trends captured, but inconsistent variance (i.e., heteroscedasticity)

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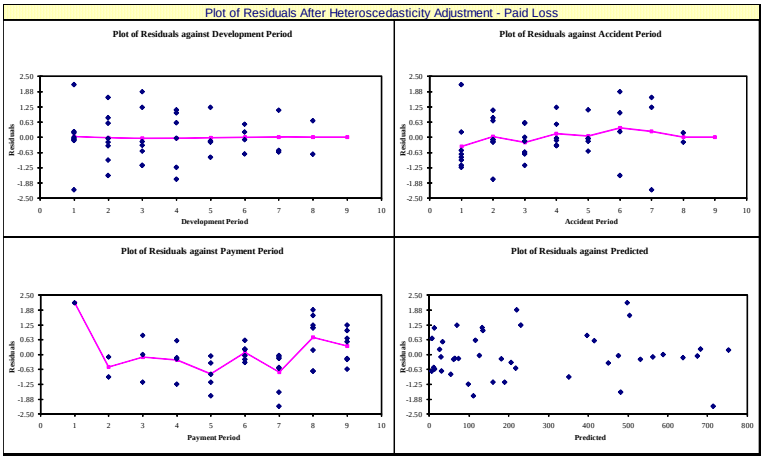
Bootstrap (undiscounted) best estimate

Additional diagnostics support validation of deterministic methods



- Adding variance parameters results in better fit of model to data characteristics

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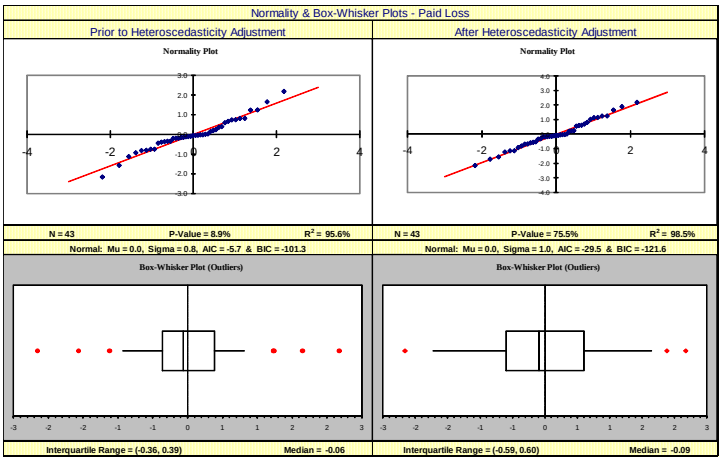
Assumption Consistency: Back-testing and Other Validation Techniques

Bootstrap (undiscounted) best estimate

Additional diagnostics support validation of deterministic methods



- Checking Normality & Outliers reveals model was improved by adding variance parameters

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Bootstrap (undiscounted) best estimate

Consistency with deterministic approach

	Deterministic Unpaid Loss Indications													
	Paid Chain	Incurred Chain	Paid Bornhuetter	Incurred Bornhuetter	Selected	Weights				Paid	Incurred		Case	
AY	Ladder	Ladder	Ferguson	Ferguson	Unpaid	PCL	ICL	PBF	IBF	To Date	To Date	Ultimate	Reserves	IBNR
1999	5	5	5	5	5	50%	50%	0%	0%	1,213	1,214	1,218	1	3
2000	8	8	9	9	8	50%	50%	0%	0%	1,367	1,370	1,376	3	6
2001	17	17	19	19	17	50%	50%	0%	0%	1,422	1,428	1,439	6	11
2002	34	34	36	36	34	50%	50%	0%	0%	1,527	1,538	1,561	11	23
2003	72	72	73	73	72	50%	50%	0%	0%	1,577	1,605	1,649	28	44
2004	148	148	155	155	148	50%	50%	0%	0%	1,520	1,585	1,668	65	84
2005	297	296	314	311	305	25%	25%	25%	25%	1,449	1,584	1,754	135	170
2006	557	548	577	567	572	0%	0%	50%	50%	1,284	1,536	1,856	252	320
2007	1,125	1,080	1,145	1,109	1,127	0%	0%	50%	50%	778	1,238	1,905	460	667
∑	2,263	2,208	2,333	2,283	2,288					12,137	13,097	14,424	961	1,327

	ODP Bootstrap Unpaid Loss Indications													
	Paid Chain	Incurred Chain	Paid Bornhuetter	Incurred Bornhuetter	Selected	Weights				Paid	Incurred		Case	
AY	Ladder	Ladder	Ferguson	Ferguson	Unpaid	PCL	ICL	PBF	IBF	To Date	To Date	Ultimate	Reserves	IBNR
1999	5	5	5	5	5	50%	50%	0%	0%	1,213	1,214	1,218	1	3
2000	8	8	9	9	8	50%	50%	0%	0%	1,367	1,370	1,376	3	6
2001	17	17	19	18	17	50%	50%	0%	0%	1,422	1,428	1,439	6	11
2002	34	34	36	36	34	50%	50%	0%	0%	1,527	1,538	1,561	11	23
2003	72	72	73	73	72	50%	50%	0%	0%	1,577	1,605	1,649	28	44
2004	148	148	155	154	148	50%	50%	0%	0%	1,520	1,585	1,668	65	83
2005	297	295	314	311	305	25%	25%	25%	25%	1,449	1,584	1,753	135	170
2006	557	548	577	566	571	0%	0%	50%	50%	1,284	1,536	1,855	252	320
2007	1,125	1,079	1,145	1,108	1,127	0%	0%	50%	50%	778	1,238	1,905	460	666
∑	2,264	2,206	2,332	2,281	2,287					12,137	13,097	14,423	961	1,326

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Assumption Consistency: Back-testing and Other Validation Techniques

Bootstrap (undiscounted) best estimate

Consistency with deterministic approach

Paid Loss Expectations (during 2008)

AY	Paid Chain Ladder	Incurred Chain Ladder	Paid Bornhuetter Ferguson	Incurred Bornhuetter Ferguson	Expected Paid	Weights PCL	ICL	PBF	IBF
1999	2	2	3	3	2	50%	50%	0%	0%
2000	3	3	3	3	3	50%	50%	0%	0%
2001	8	8	9	9	8	50%	50%	0%	0%
2002	15	15	16	16	15	50%	50%	0%	0%
2003	36	36	37	37	36	50%	50%	0%	0%
2004	75	75	79	78	75	50%	50%	0%	0%
2005	142	141	150	149	145	25%	25%	25%	25%
2006	243	240	252	248	250	0%	0%	50%	50%
2007	549	527	559	542	550	0%	0%	50%	50%
Σ	1,075	1,049	1,110	1,084	1,086				

ODP Bootstrap Paid Loss Expectations (during 2008)

AY	Paid Chain Ladder	Incurred Chain Ladder	Paid Bornhuetter Ferguson	Incurred Bornhuetter Ferguson	Expected Paid	Weights PCL	ICL	PBF	IBF
1999	2	2	3	3	2	50%	50%	0%	0%
2000	3	3	3	3	3	50%	50%	0%	0%
2001	8	8	9	9	8	50%	50%	0%	0%
2002	15	15	16	16	15	50%	50%	0%	0%
2003	36	36	37	37	36	50%	50%	0%	0%
2004	75	75	79	78	75	50%	50%	0%	0%
2005	142	141	150	149	145	25%	25%	25%	25%
2006	243	240	252	248	250	0%	0%	50%	50%
2007	550	527	559	541	550	0%	0%	50%	50%
Σ	1,076	1,048	1,108	1,084	1,086				

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Bootstrap (undiscounted) best estimate

Back testing 2008 using 12/2007 analysis

- Distribution expectations allows for evaluation
- Much more satisfying

AY	Age	Actual Paid (CY2008)	@12/2007 Deterministic Expected (CY2008)	A v E	@12/2007 Bootstrap Expected (CY2008)	@12/2007 Bootstrap Std Error (CY2008)	@12/2007 Bootstrap C.o.V. (CY2008)	@12/2007 Bootstrap Actual %ile (CY2008)
1999	120	3	2	0	2	1	50.0%	53.4%
2000	108	3	3	0	3	0	4.8%	**99.8%**
2001	96	8	8	(1)	8	0	3.8%	**2.3%**
2002	84	14	15	(2)	15	3	18.7%	30.0%
2003	72	33	36	(3)	36	4	11.7%	23.3%
2004	60	76	75	1	75	9	12.3%	55.6%
2005	48	140	145	(6)	145	10	6.9%	28.4%
2006	36	235	250	(15)	250	12	5.0%	**10.5%**
2007	24	530	550	(21)	550	27	4.9%	22.4%
2008	12	764						
2007 & prior		1,041	1,086	(46)	1,086	33	3.0%	**8.3%**

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Key Performance Indicator (KPI)

Information available after data compiled (prior to new analysis)

- Combine expectations in terms of point estimate and uncertainty in order to identify potential reserving issues.
  - Actual AY/CY incremental paid compared to expectations
  - If actual result percentile exceeds threshold
    - Alert appropriate resource of potential issue
    - Alert analyst of potential assumption issue (encourage identification of reason)
- Threshold for CRO different than for analyst, dependent on:
  - Preferred frequency of warning
  - Financial impact (materiality) of difference
  - Location of difference

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Questions or comments?

Expressions of individual views by members of The Actuarial Profession and its staff are encouraged.

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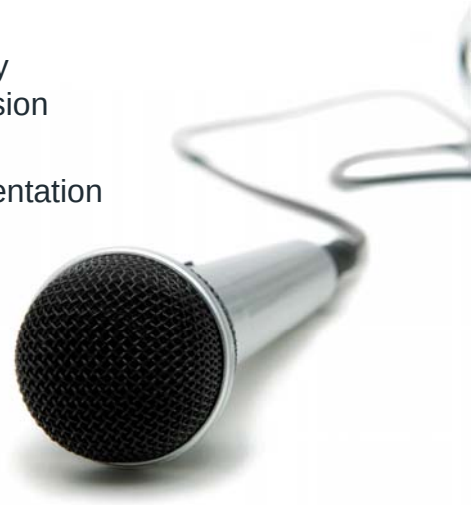

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