Stochastic Reserving
16 May 2012

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Let’s suppose…

- Friday morning start of July
  - Quarter end data has just been made available for multiple lines
  - You have a meeting at 9am on Monday morning to discuss the experience in the June quarter [first quarter – year end is 31/3]
  - You also need to provide some updates for the budget.

- Weather forecast for the weekend: **25C**

  from Monday:  **13C**

Snapshot of experience

Account:	A1	Payment Type:	m1

Monitoring Quarter: 1

Other Payment Types m2 m3

Other m1 Tables

Monitoring Period: 01/04/2011 To 30/06/2011

Opening Estimate		Change in Liabilities Due to Impact of Changes in:						Hindsight Estimate	
Date:	01/04/2011	Experience		Parameters (Indicative)		Experience and Parameters		Date:	30/06/2011
	$000s	$000s	%	$000s	%	$000s	%		$000s
Outstanding Claims	70,182	-544	-0.8%	-197	-0.3%	-743	-1.1%	Outstanding Claims	69,439
2012 Accident Year	17,946	2	0.0%	-263	-1.5%	-261	-1.5%	2012 Accident Year	17,685

Parameter Analysis

New Claims							
	Very Short Term (0)	Short Term (1)	Short Term (2)	Medium Term (3)	Medium Term (4 - 5)	Very Short Term (6 - 10)	Long Term (11+)
	Graphs	Graphs	Graphs	Graphs	✓ Graphs	✓ Graphs	▲ Graphs

Continuing Claims							
	Short Term (1)	Short Term (2)	Medium Term (3)	Medium Term (4)	Medium Term (5 - 8)	Long Term (9 - 19)	Long Term (20+)
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Payments Per Active Claim Levels					
	Very Short Term (0)	Short Term (1)	Medium Term (2 - 4)	Medium Term (5 - 7)	Long Term (8+)
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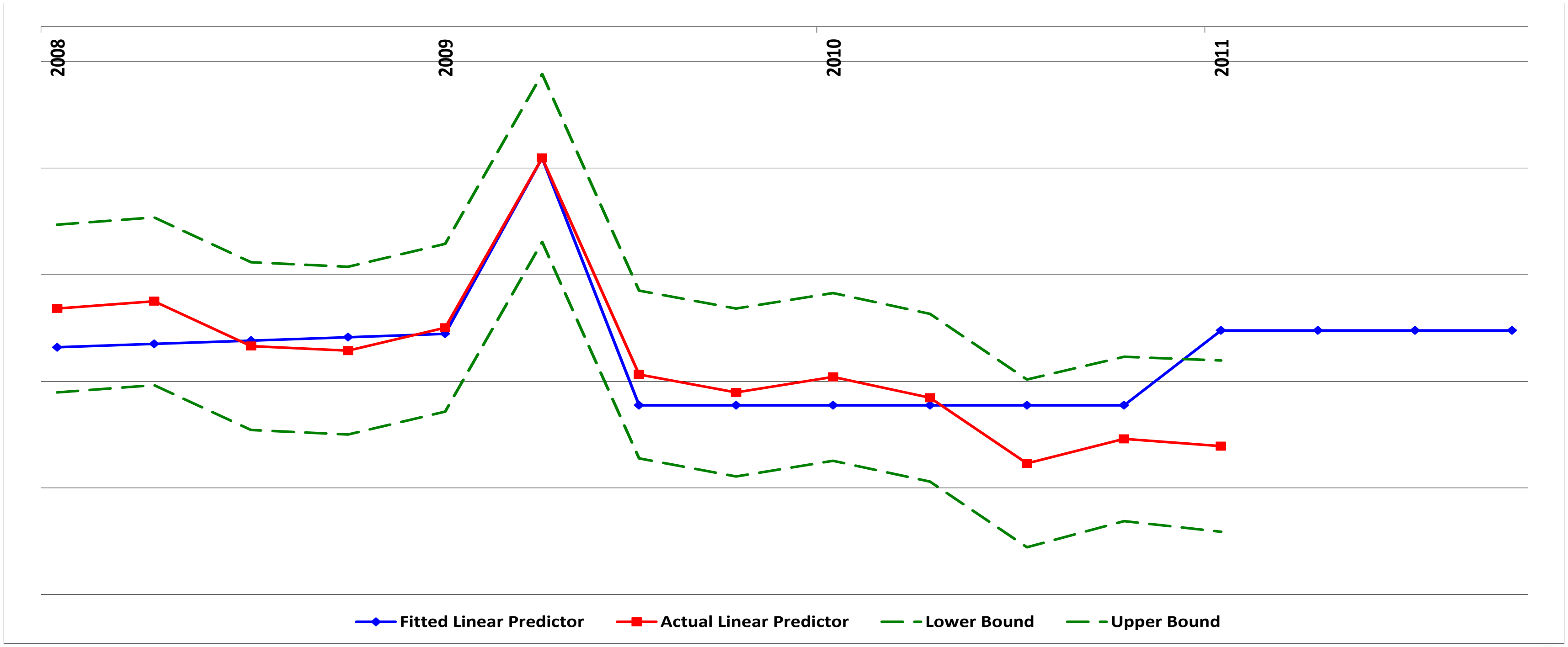
✓ Likely increase in surplus from parameter change
✗ Likely decrease in surplus from parameter change
▲ Possible Increase in Surplus
▼ Possible Decrease in Surplus

Drill down to details



Possible impact [if improved experience continues]:

- -0.9% OCL to Mar11
- -0.3% 2012 accident year

Budget updates

Account:	A1	Payment Type:	m1

Back to Tool m1

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Stochastic reserving - uses

- Central estimate of liabilities
- Distribution of outstanding claims liabilities
- Distribution of reserves at the end of the year
- Stochastic monitoring of experience
- Insights into the claims experience for both actuaries and non-actuaries
- Faster repeat valuation work
- A major part of an overall risk management tool for
  - Reserves
  - Capital management

Contents

BACKGROUND

Why do we use stochastic reserving? Some personal thoughts

- Risk margins required for returns
  - 2001 HIH insolvency
  - APRA [prudential regulator] reforms
    - Risk margins for outstanding claims liability and premium liabilities
    - Intended to reflect a fair price for the portfolio
    - Pragmatic definition of Risk margin = max(75th percentile, [Coefficient of Variation]/2)
- Statutory schemes
  - State based third party motor bodily injury [CTP] and workers compensation – large data sets and large liabilities
- Greg Taylor influence – at least within Taylor Fry

The long and winding road

- Presentation today results from many years of work within Taylor Fry
  - Frequency and size models
  - GLMs
  - Implementing non-parametric bootstraps
  - Synchronous bootstrapping of residuals to account for correlations
  - Adaptive reserving models (reserving robots)
  - “Fast” bootstrap/simulation
  - Dealing with systemic error
  - Full stochastic framework for liability/variability/monitoring

Lines of business considered today

- Long tailed liability business with lots of data, e.g.
  - Motor bodily injury, workers' compensation, accident compensation
  - Large amounts of data
    - Claim numbers
    - Claim finalisations
    - Active claims
    - Payments per claim
    - Case estimates
    - Other claim characteristics

- (Of course stochastic methods may be used for other types of business too)

Definition of terms

- OCL: Outstanding claims liability
- PL: Premium Liabilities
- RM: Risk margin
- Thongs: common Australian footwear, otherwise known as flip-flops and not be confused with underwear
- CoV = Coefficient of Variation
- CTP: Compulsory third party motor insurance = motor bodily injury
- WC: Workers’ compensation
- SI: superimposed inflation = claims inflation in excess of normal economic inflation
- UIUD: UnInflated and UnDiscounted values = future cashflows at current values – normally as at the valuation date. Includes SI
- IUD: Inflated and UnDiscounted values = future cashflows adjusted for economic inflation at date of payment
- ID: Inflated and Discounted values = future cashflows inflated to date of payment then discounted to valuation date
- GLM: Generalised Linear Model
- DRM: Dynamic risk model/DFA/Asset liability model

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Acknowledgements

- ACC (Accident Compensation Corporation, New Zealand) team
  - Swee Chang, Tore Hayward, Rutger Keijser, Bee Wong Sim, Jinning Zhao
- Taylor Fry
  - Richard Brookes, Martin Fry, Ben Locke, Julie Sims, Greg Taylor, plus all those who were involved in all the building blocks constructed over the years (research, SAS code development etc)
- Any shortcomings in this presentation are due to me alone.

FRAMEWORK

Definition (within this presentation)

- What is stochastic reserving?
  - The use of statistical models in claims reserving
  - Using the properties of these models to
    - Estimate outstanding claims liability and premium liabilities
    - Assess uncertainty in the liability estimates
    - Monitor emerging experience
  - Both deterministic (central estimates, monitoring, scenarios) and stochastic (uncertainty measures, simulations) output

Today’s focus

- For a particular line of business:
  - What do we model?
  - How do we model it?
  - How do we allow for variability?

- Some uses of the resulting models, e.g.:
  - OCL calculation
  - Stochastic monitoring
  - OCL uncertainty
  - One-year claims reserve uncertainty
    - both of these require inputs from an asset model

Modelling

BUILDING RESERVING MODELS

What do we model?

Remember: long tail liability classes with lots of data

- Chain ladder on payments or incurred costs
  - Ignores all the information we have on claim numbers
- Case estimates
  - Useful for experience in the tail
  - Not so helpful for more recent years – payments based models better here
- Claim Number and claim size models
  - Number and size trends may be very different and easier to model (and project) separately

Number and size models

- Payments per claim incurred (PPCI)
  1. Total number of incurred claims per accident period
  2. Average payment per claim in each development period
- Payments per claim finalised (PPCF)
  1. Total number of incurred claims per accident period including reporting pattern
  2. Claim finalisations by accident and development period
  3. Average claim size of a finalised claim
- Payments per active claim (PPAC)
  1. Total number of incurred claims per accident period including reporting pattern
  2. Continuance rates of claims – ie what proportion of claims in one development period stay active in the next
  3. Average payment per active claim

Which PP…??

- PPCF
  - Average claim size model, good for when payments typically made in lump sums (eg a lump sum motor bodily injury settlement)
- PPAC
  - On-going payments
    - Income replacement
    - Regular medical expenses
    - Care
  - Typically large number on benefits for short periods (eg knee injury that takes 3 months to recover from); smaller number on benefits indefinitely (until retirement /death)

How do we model?

- Traditional actuarial techniques
  - For each development period. averages over
    - All experience, most recent 1/2/3 years etc
    - Depending on claims experience, legislative changes, different assumptions may be required by accident period
  - Selecting assumptions manually using averages and actuarial judgement
- Disadvantages
  - Subjective
  - Can be difficult to discern trends in several directions (accident/development/calendar)
  - Time consuming
  - Repeat work is still time consuming

- What about the statistical approach? Generalised linear models?

Statistical models - Advantages

- Generalised linear models (GLMs)
  - Flexible set of models with readily available software
  - More objective basis for modelling.
    - Significance tests of parameters, Goodness of fit, model diagnostic tests, graphical tools
  - Multivariate models
  - Can capture complicated experience with a small number of parameters (relative to a chain ladder/picking averages)
  - Easier identification of trends and shifts [jumps] in experience
  - Opens the door to:
    - Better communication: graphical tools for illustrating assumption setting – non-actuaries are placed in the same position of knowledge and judgement as the actuaries
    - Stochastic monitoring
      - drill down to the drivers of movement in liabilities
      - Automatically update liability estimate each quarter
    - Simulation (uncertainty/risk margins/risk management)

Statistical models - Disadvantages

- Time needed to become a good modeller
  - Good modelling skills are not acquired overnight
  - Bad models can lead to bad results
- Blindly projecting (good) models can lead to silly results
  - Actuarial judgement is still required to determine how trends are projected forward
  - This disadvantage is equally shared with non-statistical models.

A quick Captain Cook* at GLM reserving models

- What is our dependent variable
  - Numbers of reported claims in a particular cell of an accident/development period triangle
  - Average claim size of individual claims
  - Total payments in an accident/development period divided by total number of active claims
- What explanatory variables can we use?
  - We must know future values of these variables
    - E.g. Accident/development/experience [calendar time] period

  OR

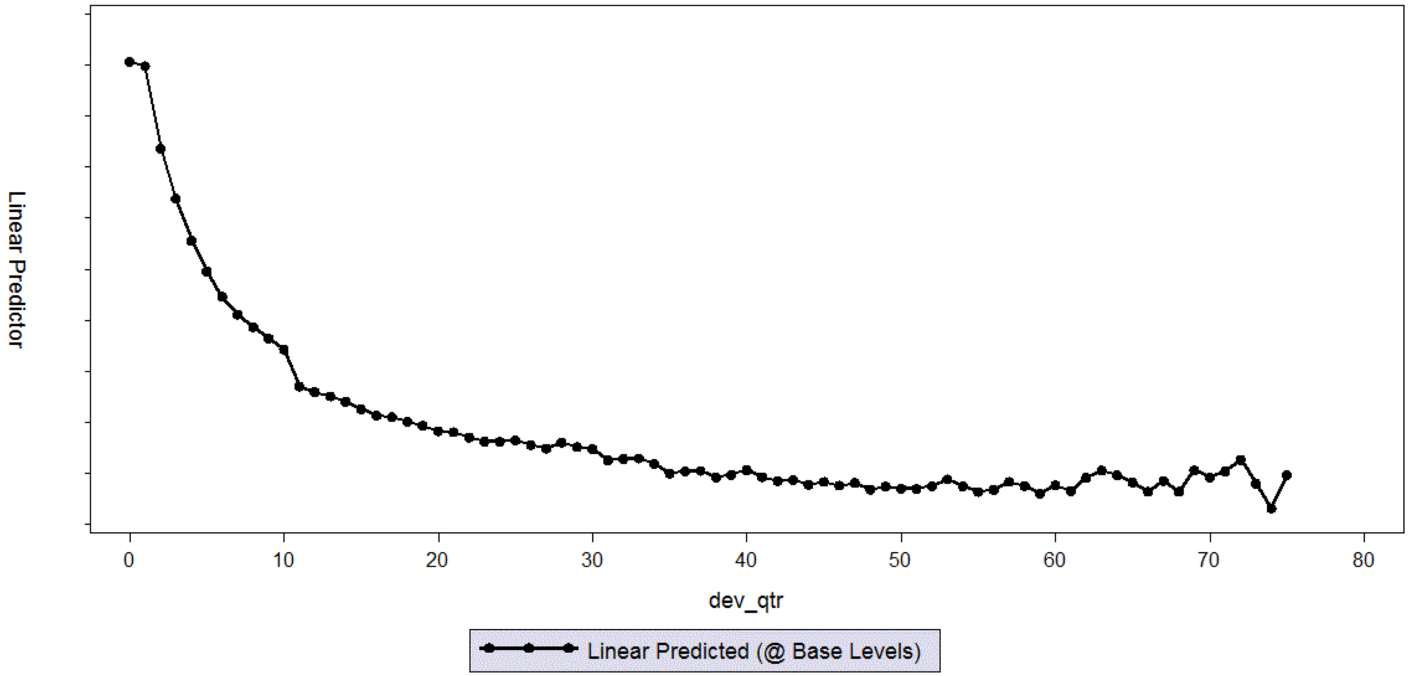
  - Be able to estimate their future values and gain more from using the estimated future variable than we lose through the additional uncertainty of having to estimate another quantity
    - Future finalisation of a claim
    - Number of active claims in the previous development period

*** "Captain Cook" = look (rhyming slang).**

Still with Captain Cook

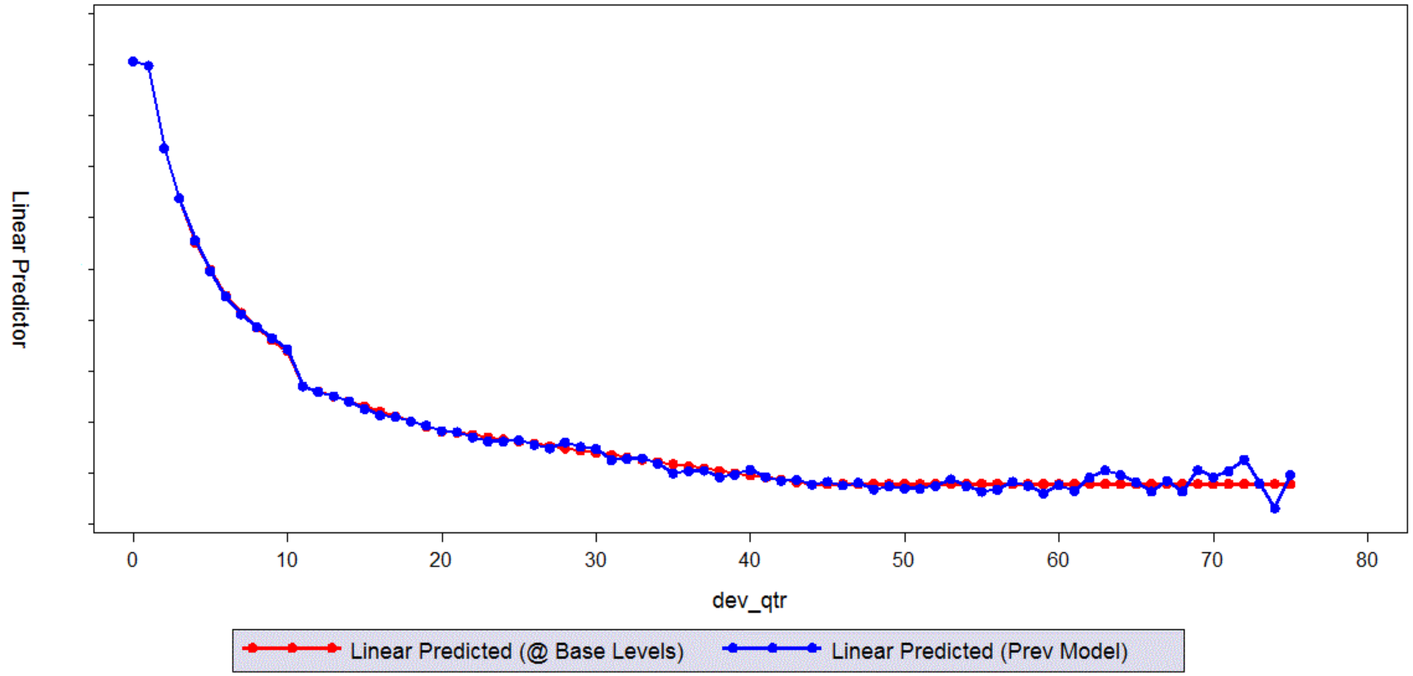
- Models with claim specific characteristics [age, gender, employment, earnings, injury etc] will lead to better estimates for an individual claim size but are usually not used for reserving
  - IBNR? When will the claim finalise?
- Beware of correlated variables
  - E.g.. accident, development and experience periods
- We also need to consider
  - Exposure measure
  - Error structures
  - Outliers
  - Whether data needs to be segmented
  - Parameterisation of model
  - Interactions
  - …
  - [There is a reason why it takes time to become a good modeller]

Incurred claims model – raw development period effect



Model is dev_qtr, rep_qtr

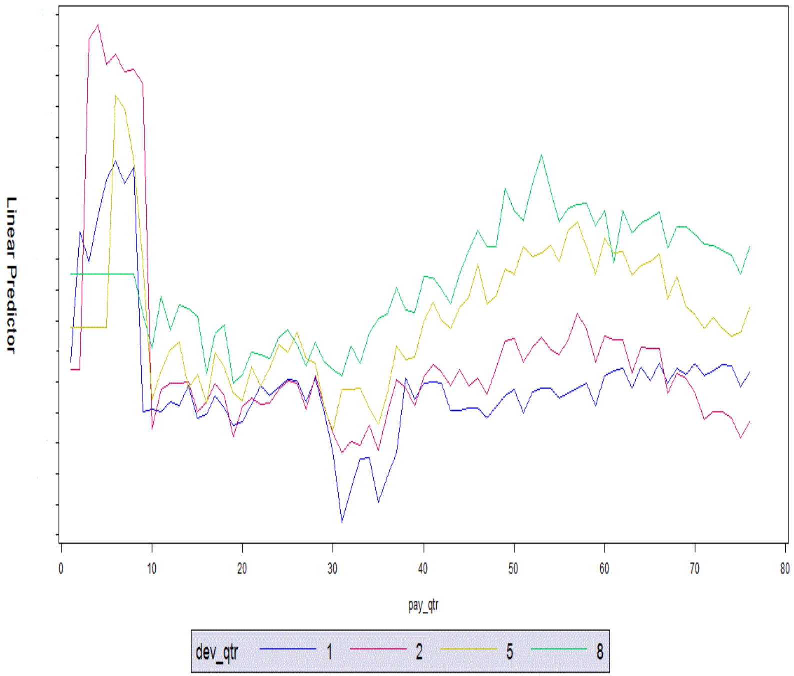
Incurred claims model – fitted development period effect

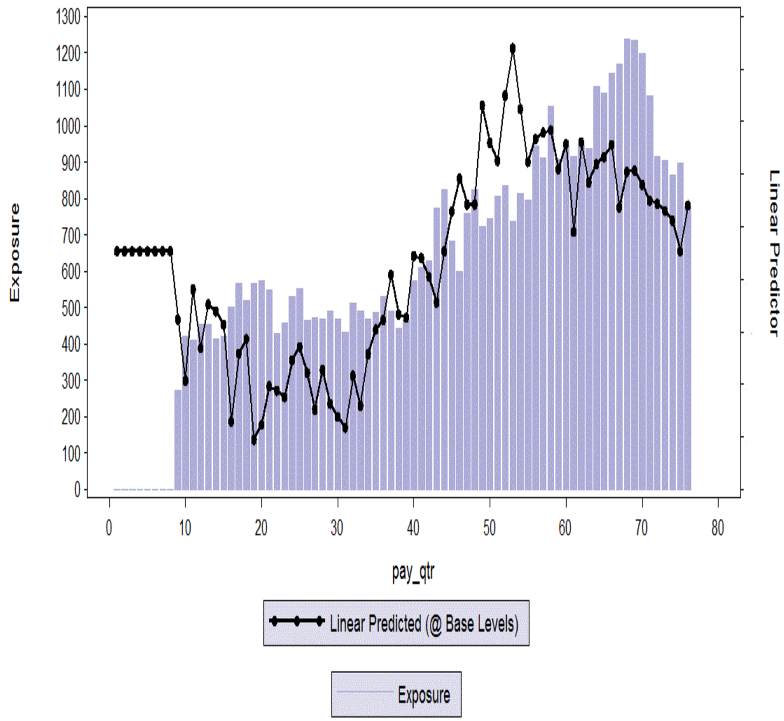


Model is 8 dev_qtr terms

Payments per active claim – raw payment period effect for different development qtr groups

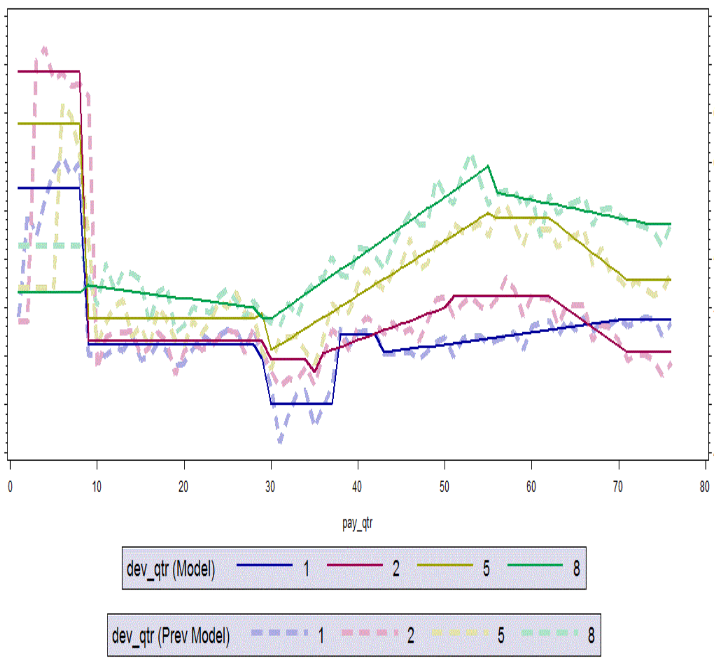
Dev_qtr 8+

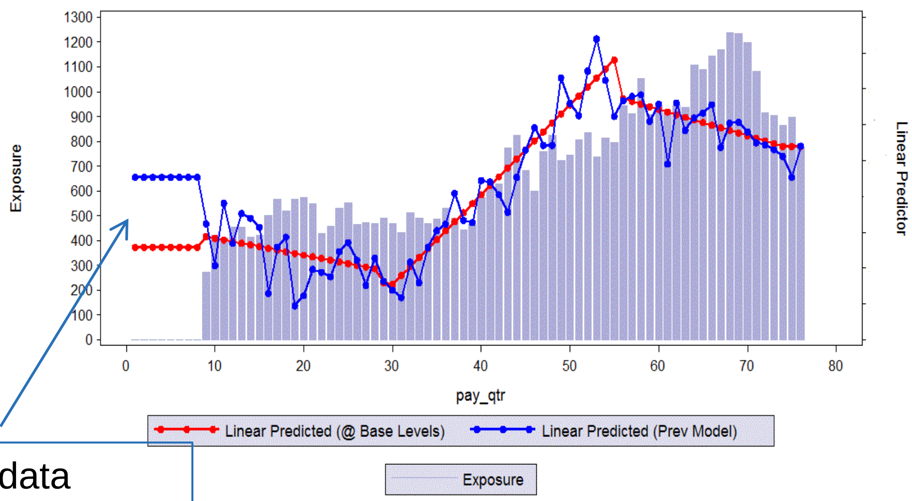




Payments per active claim – fitted payment period

Dev_qtr 8+

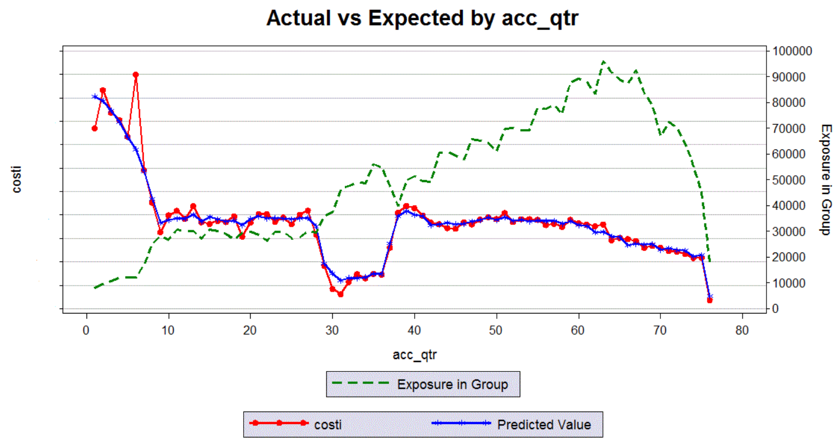


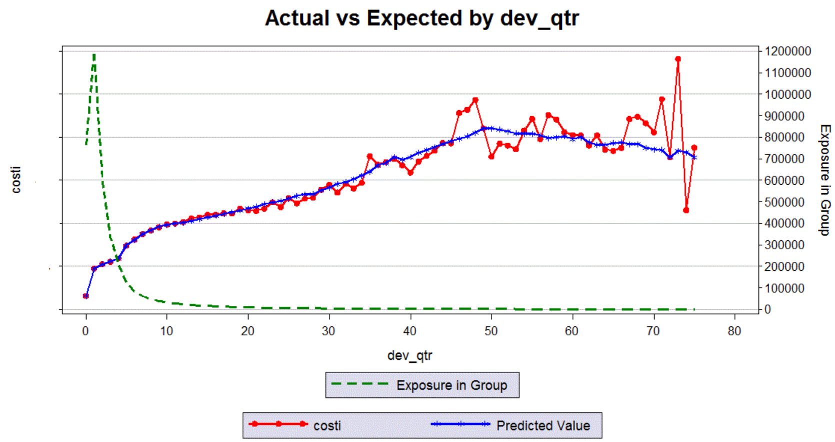


No data present here

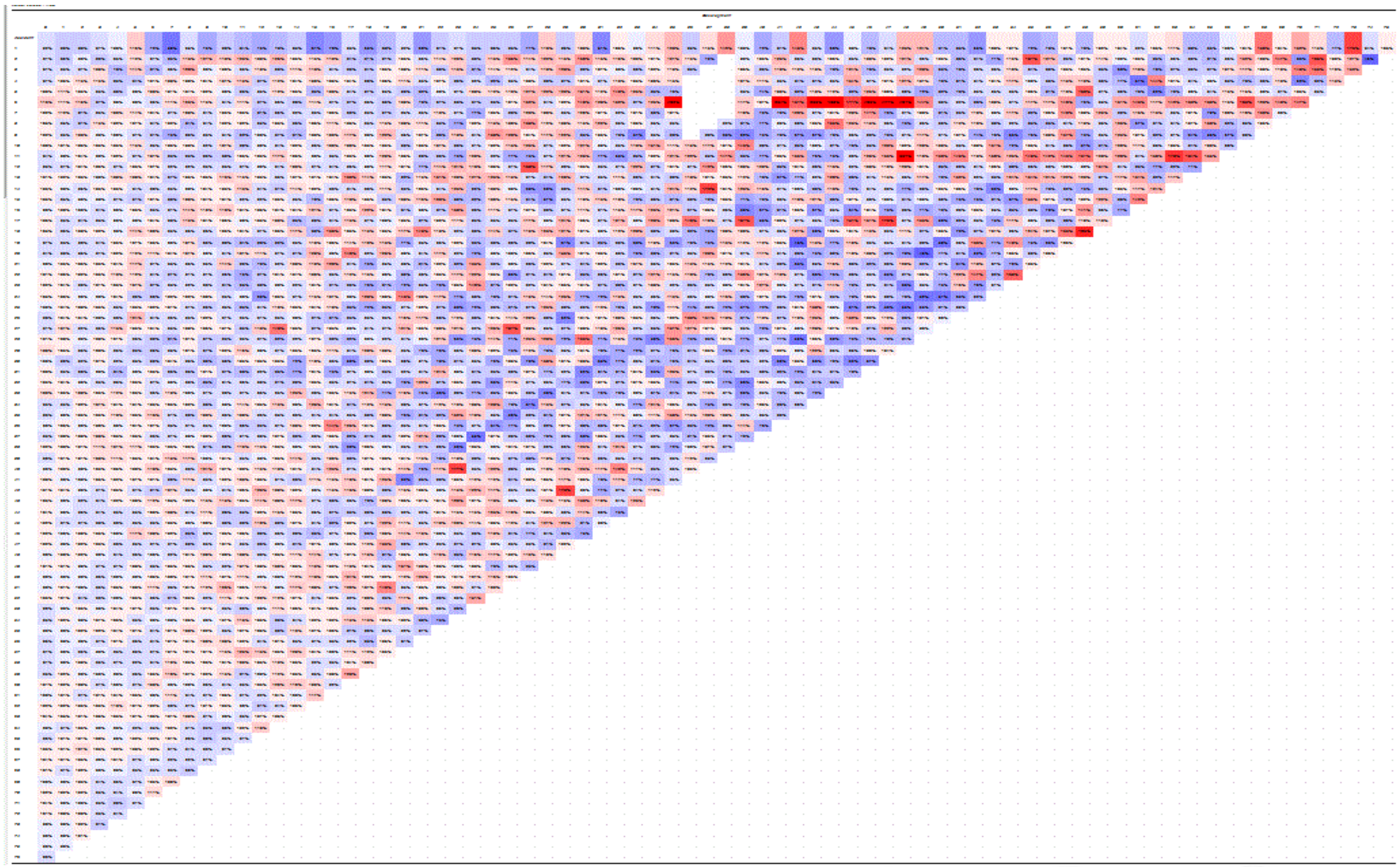
Dev_qtr 8+ group represented by 6 parameters (excl seasonality)

Checking the models – actual vs expected analysis

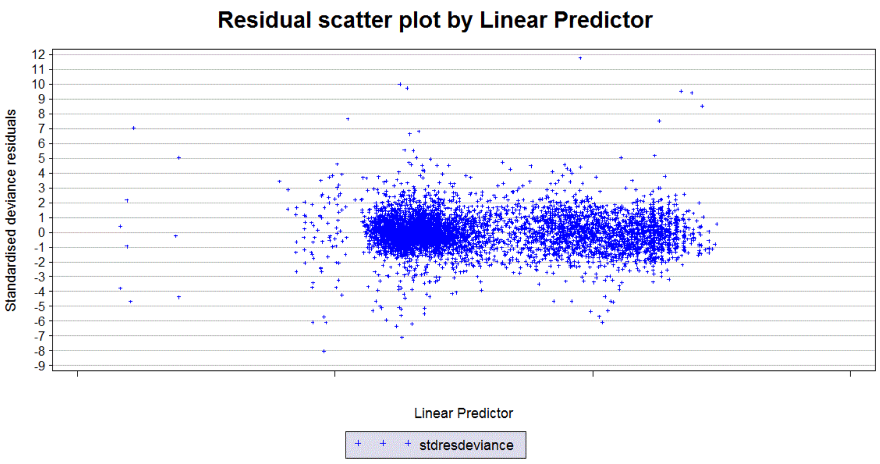


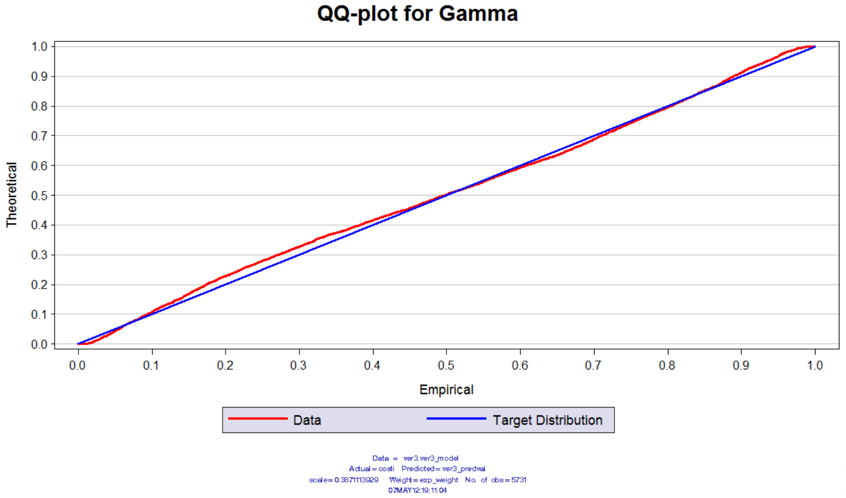


Triangular actual vs expected



Checking the models - residual graphs





Far more things to look at than just these examples!

USING THE MODELS

Central estimate of liabilities

- How do we go from parameters to a projection?
  - Consider the PPAC projection – payment period effect
  - Extract of parameter file shown below – payment quarter effects for development quarters 8 and higher [corresponds to graph]
  - Model uses a log link
  - Put the formula together

VIEWTABLE: Ver3.Ver3_p

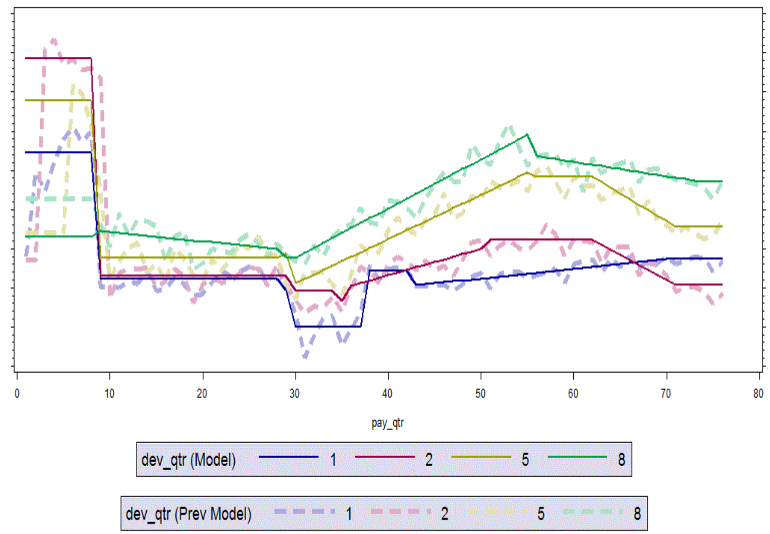
	Parameter	Level1	DF	Estimate
87	dq_ge8*first_0*pq_9_29		1	0.0302
88	dq_ge8*first_0*lin_pq_9_28		1	-0.0047
89	dq_ge8*first_0*pq_29_55		1	-0.0393
90	dq_ge8*first_0*lin_pq_29_55		1	0.0251
91	dq_ge8*first_0*pq_ge56		1	-0.1476
92	dq_ge8*first_0*lin_pq_56_74		1	-0.0074
93	Scale		0	0.3871

  - dq_ge8 = (dev_qtr ge 8)
  - pq_9_29 = (9 le pay_qtr le 29)
  - lin_pq_56_74 = min(28, max(0, pay_qtr-56))
  - first_0 = 1 if claim is a continuing claim, 0 otherwise [new claim]

Setting projection assumptions

- The model fitting graphs may be helpful in determining future assumptions
  - For dev_qtr 8+ group, why has the experience been as shown?
  - What does this tell us about what assumptions we should use going forward?
  - What other external information do we know (e.g. recent court decisions)
  - Use judgement to select appropriate assumptions for the projection

Payment period graph for an average size model



Getting the number

- Combine the results from all submodels to calculate the central estimate of liability
  - i.e. for accident period i and development period j, the liability under a PPAC model =

    (new claims + continuing claims)*(payment per active claim)
  - Sum up across all future triangle cells to get the current values estimate of liability
  - Add economic inflation to get IUDs (Inflated and Undiscounted)
  - Add discount rates to get IDs (Inflated and Discounted)

Distribution of liabilities

- To estimate the distribution of liabilities we must account for the following errors:
  - Parameter error
    - The form of the model is correct but the parameters are not estimated correctly due to random variability
  - Process error
    - The form of the model is correct and the parameters are correct but future experience will not be exactly as estimated due to random variability
  - Systemic error
    - Future systemic changes
    - Model specification error
    - Does not include economic variability

Simulation

- Since we have built a full statistical model, we do not need to use the non-parametric bootstrap. Instead we use the statistical properties and model estimates – a “fast” bootstrap
  - Parameter error: Generate simulations of the parameter vector and calculate the liability using these parameters
  - Process error: Simulate using the mean [based on simulated parameters] and the distributional properties
  - Systemic error: ???
    - Systemic error is by far the most significant.
    - By its nature it is hard to quantify
    - In comparison the non-systemic error [parameter and process] is small

Systemic error

- Estimating the coefficient of variation
  - O Dowd, Smith & Hardy, Risk Margins Task Force in Australia
    - A quick "squizz*" at these comprehensive papers in relation to systemic error:
      - Scorecard approach to assess model specification error
      - Future/external systemic risk: identify, rank and quantify
      - Work out where you are on a scale of riskiness and assign a CoV
  - Industry benchmarks
- Getting a distribution
  - Scale everything to give a wider spread (judgementally assessed)
  - Explicitly simulate systemic changes
    - Systemic changes will show up as trends/level shifts in a future model

* Squizz = look. Usage: take a squizz at this

Systemic error – explicit model

- Calibration of systemic error requires consideration of
  - Overall levels of variability for each line of business/payment type
  - What types of systemic changes to include?
    - Level shifts (permanent and temporary)
    - Trends
  - Relationships between different lines of business
    - How correlated are systemic effects?
    - Diversification benefit
  - Calibrated by the claims experience / views on possible future changes / industry benchmarks / scoring approach
  - Takes time and a number of iterations before settling on something reasonable

Economic risk

- Separate model of economic risk [asset model]
  - Stochastic inflation rates
  - Stochastic discount rates
- Australian risk margins require inflation risk to be included but not investment return risk
  - Risk margins incorporate stochastic inflation but are discounted at the current estimated risk-free rates

Outstanding claims liability - variability

- Consider the coefficient of variation (CoV) with and without
  - Systemic error
  - Economic (eg inflation) error
  - Set the base case as no systemic + no economic error
  - Systemic error has a huge impact

	No economic (inflation) error	With economic (inflation) error
No systemic error	1	1.5
With systemic error	2.5	2.8

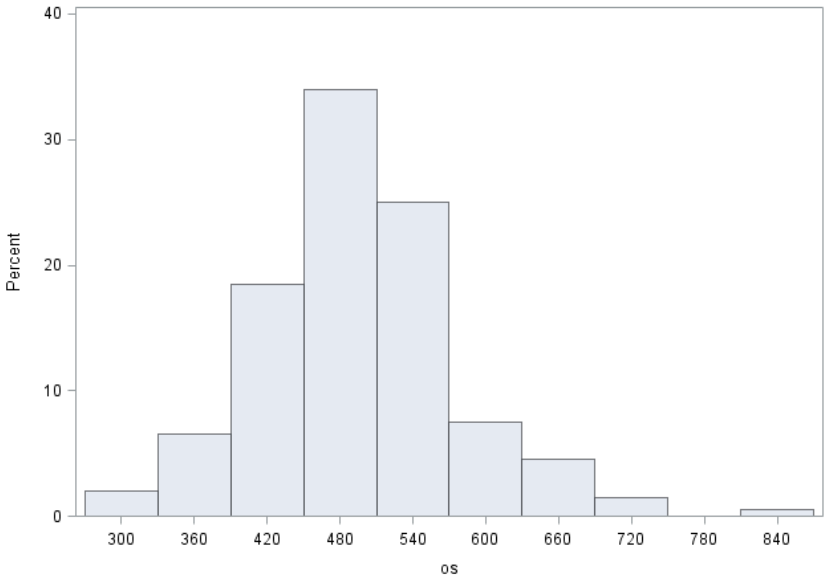
Results depend on the model and the line of business

Using the simulation results

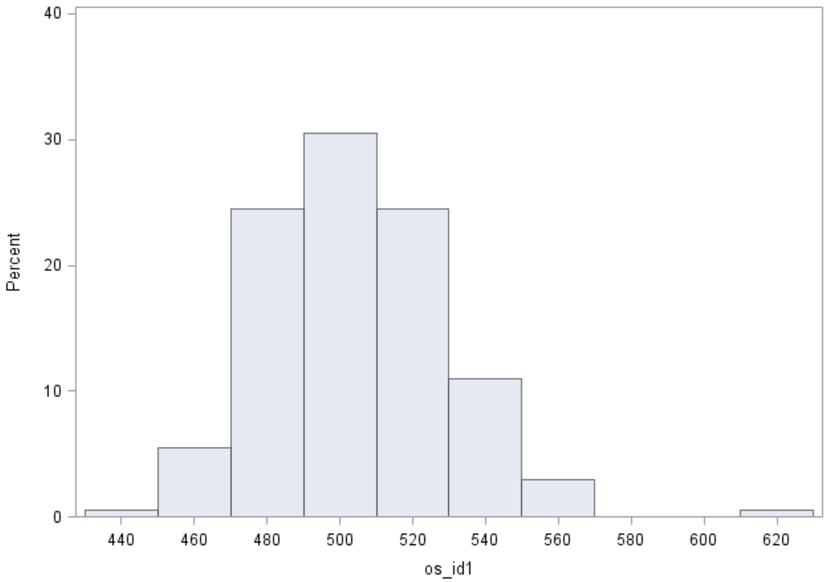
- Uncertainty measures for reporting
  - "Ultimo": Risk margins on technical provisions: measure of how variable the actual claim payments will be
    - Australian risk margin definition – 75th percentile (subject to min [CoV]/2) – pragmatic view on fair value of sales price of reserves
  - "One-year reserve risk" – how variable the reserves are in a year
    - Can use an "actuary in a box"
    - Starting point = current projection of OCL + next year's liability
    - Each simulation is a "realisation of actual data"
    - Apply rules to adjust the starting point valuation based on this "actual data"
    - Allow for changes in inflation and discount rates
      - "Actual" inflation in the year
      - "Forecast" inflation and discount rates at the end of the year

Ultimo and one-year reserve risk

Ultimo: CoV = 16%



One-year: CoV = 5%



Results depend on the rules used by the automatic actuary for adjusting the liability – using rules which carry through more variation would lead to a larger CoV for the one-year reserve risk

Stochastic monitoring

- A framework for comparing actual emerging experience to expectations/projections
  - Test whether any deviations are significant in an objective way
  - If significant changes are found, estimate change in liability
  - Updates liability estimates (useful eg for budgeting)
  - Aside: stochastic monitoring useful beyond reserving – e.g. in pricing models
- Process is
  - Automatic
  - Fast

Snapshot of experience

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Updated budgeting figures

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Repeat Valuation Work

- Quicker process with stochastic models
  - Stochastic monitoring identifies emerging experience that differs from expected using objective statistical tests
    - Models with no significant deviations may be refit in same form, leading to re-estimated parameters
    - Attention can be focussed on those classes where significant deviations have been identified
  - Even without statistical monitoring in place, statistical tests and graphical output speed up the modelling process

Stochastic reserving is bonza*

- Stochastic reserving is a full framework for reserving:
  - Full distribution of the liability
  - Stochastic monitoring
  - Faster repeat valuation work
  - Significant part of an asset-liability risk management model
  - Output (especially graphical) that is easy to communicate to non-actuaries

* Bonza = great / grand

AN INCOMPLETE LIST OF REFERENCES

Distributions / stochastic monitoring

- Predictive distributions of outstanding liabilities in general insurance. P.D. England and R.J.Verrall (2006) http://cassknowledge.co.uk/sites/default/files/article-attachments/371~~richardverrall_-_predictive_distributions_of_general_insurance_outstanding_liabilities.pdf
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- Adaptive reserving using Bayesian revision for the Exponential Dispersion Family. G Taylor and G McGuire (2007) http://www.economics.unimelb.edu.au/ACT/wps2007/No165.pdf

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- Individual claim modelling of CTP data. G McGuire (2007) http://actuaries.asn.au/Library/6.a_ACS07_paper_McGuire_Individual%20claim%20modellingof%20CTP%20data.pdf
- Loss reserving – an actuarial perspective. G Taylor (2000). Kluwer Academic Publishers, Boston
- Loss reserving with GLMs: a case study. G Taylor and G McGuire (2004) http://www.casact.org/pubs/dpp/dpp04/04dpp327.pdf

- There are many more relevant papers out there!