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Improving portfolio analyses: GLMs in life and health insurance

Life Convention 2006

Ryan Warren
Matthew Edwards
Watson Wyatt Limited

Agenda

- Overview of application areas
- Healthcare claims analysis
- Life portfolio analysis
- Other uses of GLMs

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Application areas (non-non-life!)

Class of business	Typical claim frequency	GLM application
Healthcare	10%	Increasing use
Annuitants	1%	Last 2-3 years (BBO)
Term assurance	0.1%	Little (reinsurers?)

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Different areas – much in common

Use of splines

Interpretation of GLM results

Geographical clustering techniques

Underlying mathematics

Commercial application of GLM results

Data!

Interactions v correlations

Communication of results

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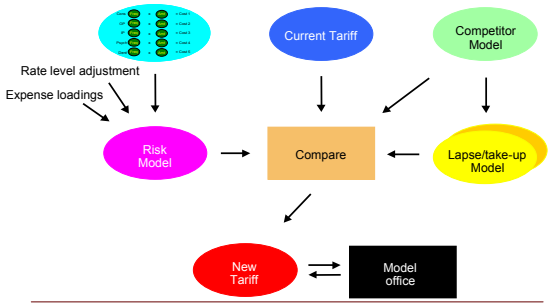
The premium rating process



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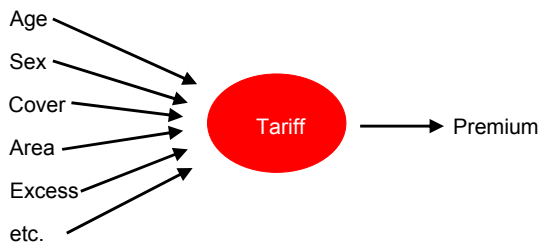
Objective



"Tariff" is this context means "rating structure" - it does not imply regulated fixed tariff, nor anything related to tax!

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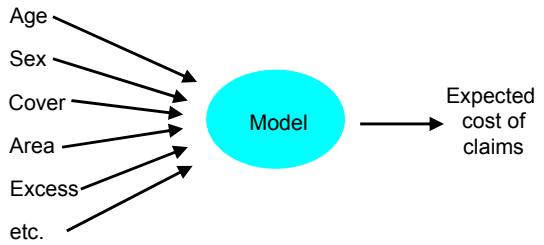
Modelling the cost of claims



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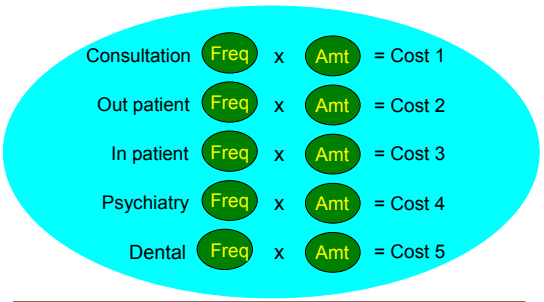

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Modelling the cost of claims

- Data and rating factors
- Statistical techniques

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Data required

- For each policy:
  - period of exposure
  - rating factors applicable at time
  - number of claims (by type) during period
  - paid claim information, by claim type, based on most recent estimates
  - earned premium (current basis)

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Data required

- Cancellations / amendments
- Factors applicable at time
  (but categorised on current basis)
- Delay to reduce effect of IBNR
  & reserve inaccuracy
- Time
- External data

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Data required

- Claims could be classified by ICD or OPCS codes
- Preferable to link all claim payments to a single medical event
- Individual claim payments can be individually dependent
  - eg visit to a doctor, followed by visit to the specialist, hospital and surgeon etc
- Where claim payments cannot be linked to a medical event then consider grouping within claim types by period of time

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Example PMI rating factors

- Standard factors:
  - Age of member
  - Cover
  - Age / number of additional member(s)
  - Excess
  - Optional benefits
  - Hospital band
- Enhanced factors:
  - Sex
  - Marital status
  - Occupation
  - Postcode
  - Lifestyle
  - Medical history
  - Payment frequency
  - NCD / previous claims
- External data:
  - individual data
  - geodemographic data
  - geophysical data
- Data from other products:
  - banking data
  - other insurance data

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The failings of one way analysis

True risk

* 2

	Old	Young
M	40%	20%
F	20%	10%

Claims

	O	Y	Total
M	80	20	100
F	20	20	40
Total	100	40	140

Exposure

	O	Y	Total
M	200	100	300
F	100	200	300
Total	300	300	600

One-way

* 2.5

	Exp	Claims	Ratio
M	300	100	33.3%
F	300	40	13.3%
O	300	100	33.3%
Y	300	40	13.3%

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Generalised linear models

$$E[\underline{Y}] = \underline{\mu} = g^{-1}(\mathbf{X}.\underline{\beta} + \underline{\xi})$$

$$Var[\underline{Y}] = \phi.V(\underline{\mu}) / \underline{\omega}$$

- Consider all factors simultaneously
- Allow for nature of random process
- Robust and transparent
- EU and increasingly global industry standard

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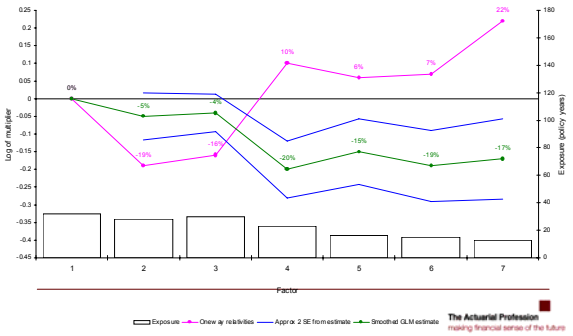
Example of GLM output (real UK data)



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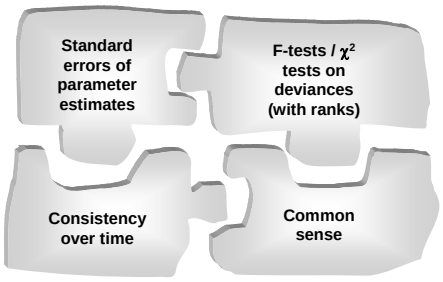
Model iteration



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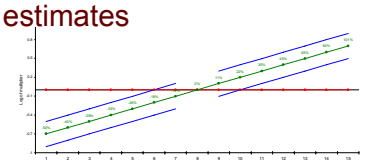
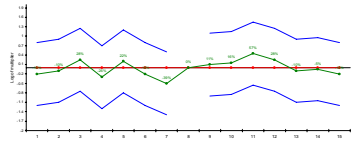
Standard errors of parameter estimates





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Deviances

Age
Sex
Cover
Zone
Excess
NCD

Model A → Fitted value

Deviance = 9585
df = 109954

?

Age
Sex
Cover
Excess
NCD

Model B → Fitted value

Deviance = 9604
df = 109965

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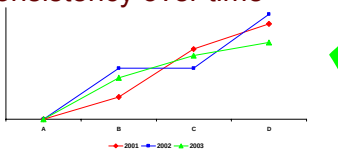
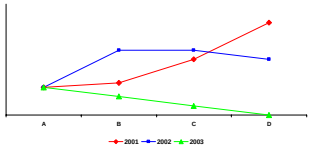
Consistency over time





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Common sense

- Does it make sense given correlations?
- Are ordered categorical variables well behaved?
- Can you believe it?
- Can the underwriters believe it?
- Consider results for frequency and amounts at the same time
- Consider results for each claim type at the same time

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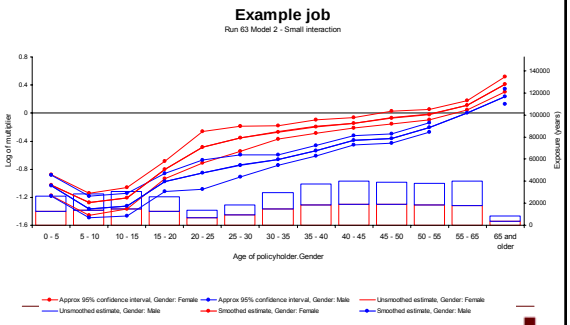
Interactions



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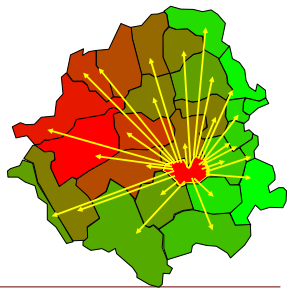
Spatial smoothing

- Blends experience of one region with that of surrounding regions according to distance and credibility
- Credibility and spatial smoothing parameters are trained on sample dataset



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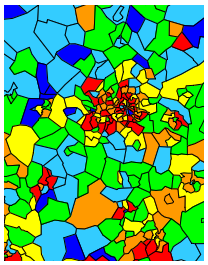
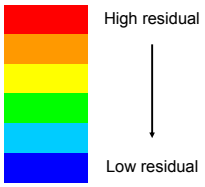
Residual risk





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Model

$r_i^* = Z(e_i).r_i + (1 - Z(e_i))\Sigma_j e_j.r_j.f(d_{ij}) / \Sigma_j e_j.f(d_{ij})$

where

r_i^* = smoothed residual r_i = unsmoothed residual

$Z(e_i) = \{ e_i / (e_i + a) \}^m$ e_i = exposure in region i

$d_{ij} = \{ (x_i - x_j)^2 + (y_i - y_j)^2 \}^{½}$

$f(d_{ij}) = 1/d_{ij}^n$ or $1/(d_{ij}^n + b^n)$ or $\exp(-n.d_{ij})$

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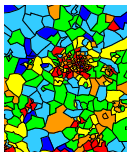
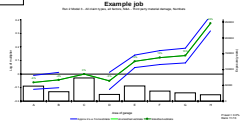
Finding the parameters

Calculate residuals | Seek parameters which minimise error | Save for determining zoning relativities



a, m, n, b



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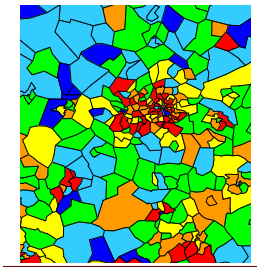
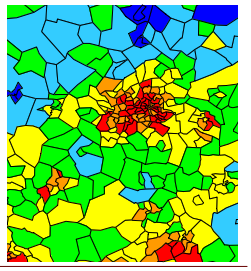
Example results

Unsmoothed residuals



Smoothed residuals



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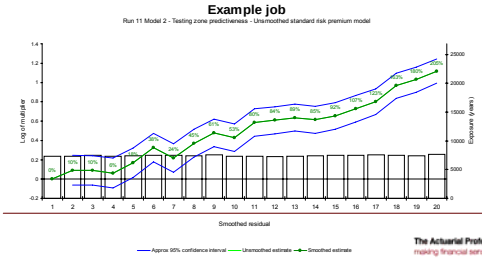
Spatial smoothing

- Postcode quite predictive of PMI experience
- Potential correlations with Hospital Band/list



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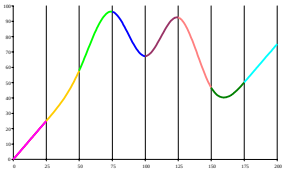
Splines

- A series of polynomial functions, with each function defined over a short interval



- Intervals are defined by k+2 knots
  - two exterior knots at extremes of data
  - variable number (k) of interior knots
- At each interior knot the two functions must join "smoothly"

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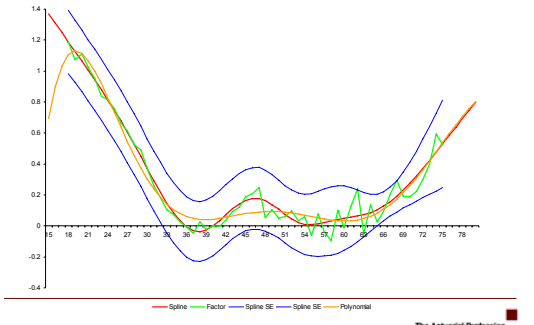
Splines



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Modelling cash benefits

- For hospitalisation cash benefits modelling average duration of stay in hospital in addition to claim frequency can increase model accuracy
- Claim amount can then be fixed amount (eg cost per day of stay negotiated with hospital)

Freq x Dur x Amt = Hospital cost

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Combining claim elements

Cons Freq x Amt = Cost 1

OP Freq x Amt = Cost 2

IP Freq x Amt = Cost 3

Psyc Freq x Amt = Cost 4

Dent Freq x Amt = Cost 5

- Claim models can be combined by individual claim type
  - where products are modular
  - or when separate components can be calculated at the point of sale

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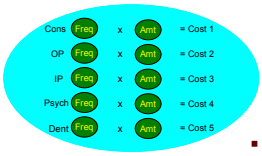
Combining claim elements



- Claim models can be combined across claim types
  - where the product (or part of the product) is a package across covers
  - for ease of understanding even when premiums can be priced by component at point of sale
- Claim types combined by using GLM to average relativities implicit in fitted values from other GLM results

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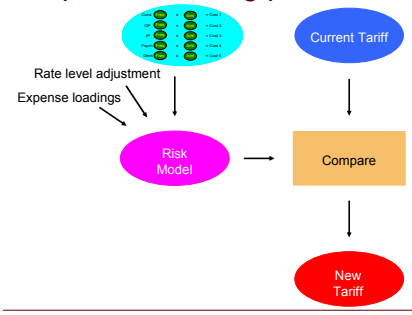
The premium rating process



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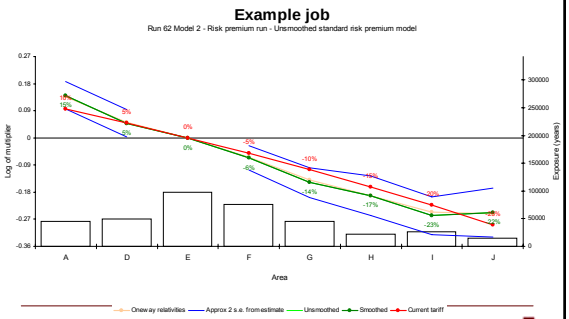
Factor effect analysis – individual factors



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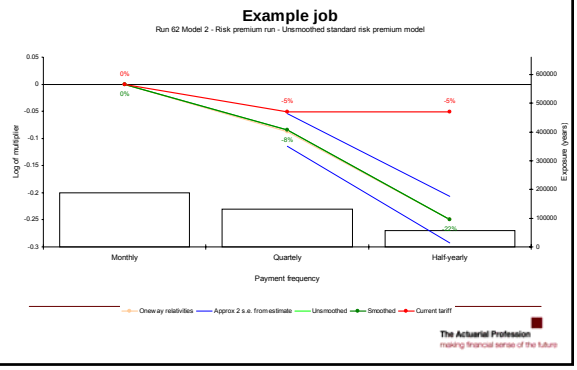
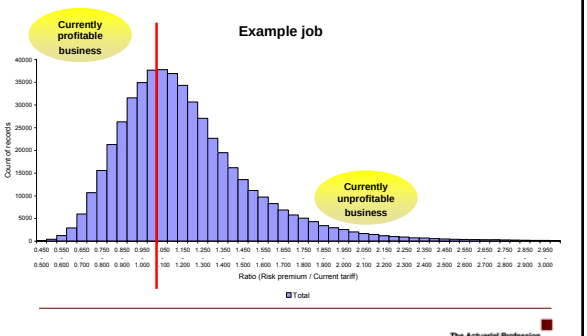


Impact analysis – all factor changes



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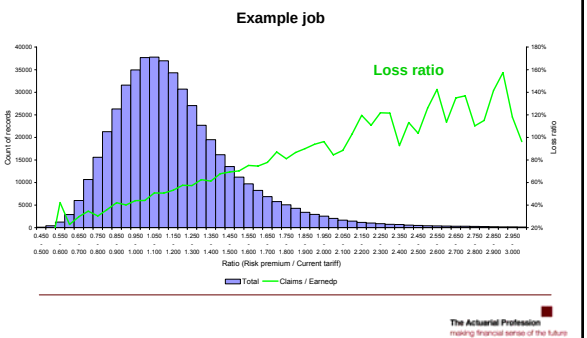

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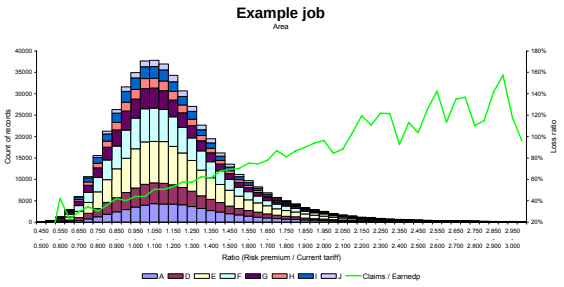

Impact analysis – all factor changes

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- Overview of application areas
- Healthcare claims analysis
- Life portfolio analysis - annuities
- Other uses of GLMs

Using GLMs on annuity blocks

- What is the aim of the investigation?
  (Do we need – eg – postcodes?)
- Amount of data (typically 1,000 + deaths)
- Use of multiple calendar years
- Amounts-based calibration v lives-based
- Mathematics – Poisson and/or binomial?
- Subjectivity of the iterative process
- External data sources?

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Effect on cash flow valuation

- What is the aim of the investigation?
  - help with new business pricing?
  - help with general understanding?
  - help with 'classical' basis?
  - help with more accurate portfolio cash flow valuation?
- Factor results help greatly with general understanding of the portfolio's mortality dynamics
- Help inform choice of mortality table & year of birth effect
- Factor information relating to amounts (including escalation) may have a substantial effect on cash flow valuations

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Effect on cash flow valuation

- What is the effect on a cash flow valuation if we discover that the population should be segmented?
  - eg our analysis says population should be split between blue-collar group +20% to mortality and a white-collar group -20%
  - $\Sigma\ CF_t^{all} \cdot v^t\ p^{all}(t) \approx \Sigma\ CF_t^{bc} \cdot v^t\ p^{bc}(t) + \Sigma\ CF_t^{wc} \cdot v^t\ p^{wc}(t)$ - *no difference*
  - if amount is already taken account of in the model, this is just an amount-neutral (ie cost-neutral) redistribution into subsets
  - also, what seems to have a substantial effect on death probability *q* has very little effect on survival probability *p*
  - eg if *q* moves from 0.01 to 0.012 (+20%), *p* moves from 0.99 to 0.988 (ie -0.2%) – and it is *p* which is the cash flow 'driver'
  - segregation will not have a material effect on the cash flow valuation unless segregating by amount bands (or amount escalation)
  - … & complex output likely to lead to interpretation/implementation errors

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Efficient use of calendar years

- GLMs viable with eg 20,000 annuities × 5 years observation
- Use many years and have calendar year as a factor
- Empirical reasoning: testing results against an independent part of the data

TEST OF PREDICTIVENESS		Variation
Predicted deaths 2004 using model from many years (1995-2003)	1,341	-0.8%
Predicted deaths 2004 using model from one year (2003)	1,441	6.6%
Actual deaths in 2004	1,352	

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Using GLMs on annuity blocks

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Multifactor analysis – public domain

- Interpretation
  - *eg* London earnings 29% above average
  - mortality should be 4% below average
  - crude regional mortality is 2% above average
  - so adjusted regional mortality is 7% above average

Combined results	Wales	Scot-land	West Mid'nds	East of England	London	South East
Relative earnings	88%	94%	89%	113%	129%	116%
Implied amounts factor	105%	103%	104%	98%	96%	98%
Raw regional mortality factor	103%	126%	103%	86%	102%	86%
Real regional mortality factor	99%	123%	100%	87%	107%	88%

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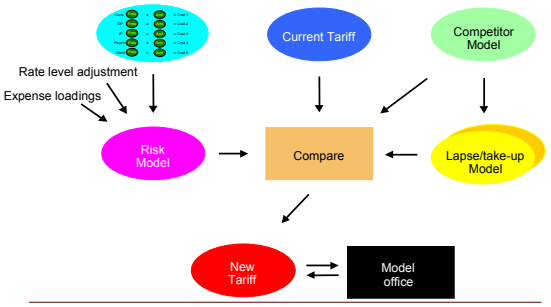

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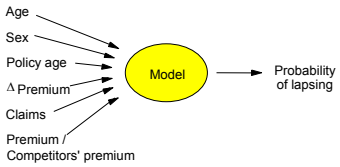
Modelling retention



- Model
  - rating factors
  - payment method
  - NCD expectation
  - source
  - claims history
  - other products held
  - change in cover

  plus…
  - change in premium
  - competitiveness

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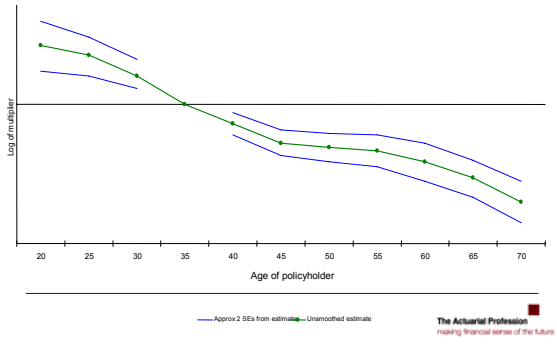
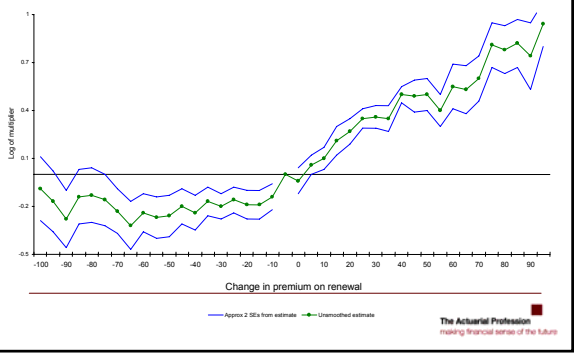
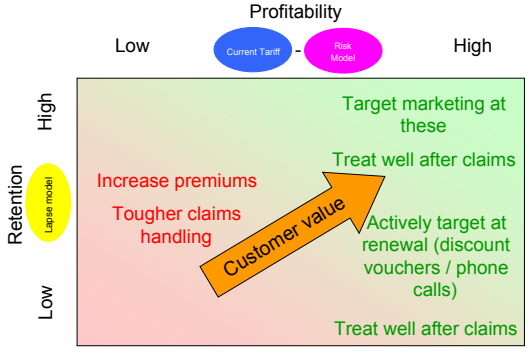
Lapse model – Effect of age



Lapse model - Change in premium



Customer value



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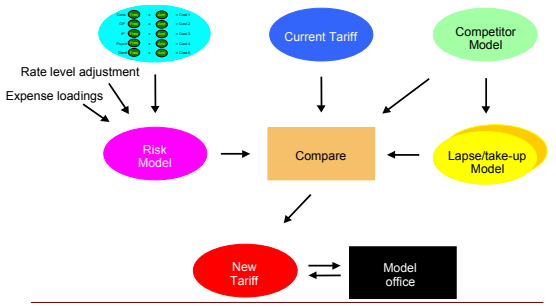

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Optimisation techniques

	Exposure	Age of driver	Gender	Marital status	Territory	Credit score	Earned Premium	# claims BI	Incurred losses BI	# claims PD	Incurred losses PD	Optimal premium
1	1.00	22	M	S	12	178	2,331	0	-	0	-	2,651
2	0.65	39	F	D	2	569	512	0	-	1	650	561
3	0.35	39	F	D	4	569	440	0	-	0	-	412
4	1.00	58	F	M	6	715	968	0	-	0	-	745
5	0.66	47	M	M	19	202	760	1	16,138	0	-	699
6	1.00	35	M	M	32	550	815	0	-	0	-	894
7	1.00	46	M	S	17	420	1,012	0	-	0	-	1,242

- For each policy, optimise the chosen success criteria (eg function of profit next 2 yrs + EV per IF policy in 2 yrs)
- Result is individual premium for each renewal
- For new business and amendments, and if required for renewals, can approximate results with a single structure by fitting GLM to optimised individual rates

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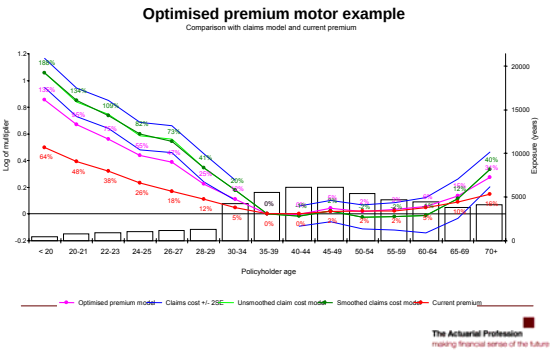
Optimised rating structure



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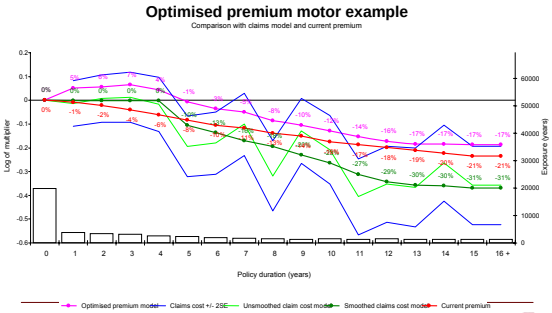
Optimised rating structure



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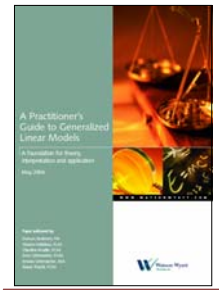
"A Practitioner's Guide to Generalized Linear Models"



- CAS 2004 Discussion Paper Program
- Copies available at www.watsonwyatt.com/glm
- Parts of it now in the CAS Exam 9 syllabus in 2006

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Improving portfolio analyses: GLMs in life and health insurance

Life Convention 2006
Ryan Warren
Matthew Edwards
Watson Wyatt Limited