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Demand and Price Elasticity Modelling

Dr. Ji Yao [a,b]

The views and opinions expressed in this presentation are independent of employer of the presenter or the Actuarial Profession

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Agenda

- **Introduction**
- **Current approaches used in the market**
- **Common pitfalls and considerations of the GLM approach**
- **Decision tree type approach**
- **Summary and Q & A**

Introduction

- The idea initiated by a CAS call for monograph in early 2015
- Purpose of this research
  - Survey of different methods of conversion and elasticity models
  - Research on new methods
  - Not limited to insurance industry

CASUALTY ACTUARIAL SOCIETY
CALL FOR MONOGRAPHS
Predictive Modeling in P&C Ratemaking and Pricing

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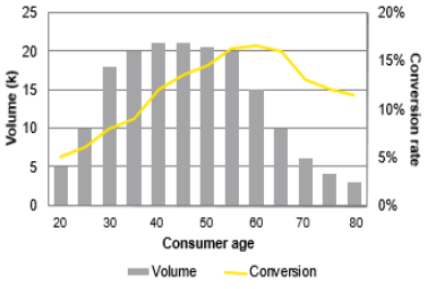
What is demand model

- Demand is defined as the number of sales divided by number of quotes/renewal invites
- Conventionally called 'conversion model' for new business and 'retention model' for renewal business
- Premium might or might not be a factor in the model



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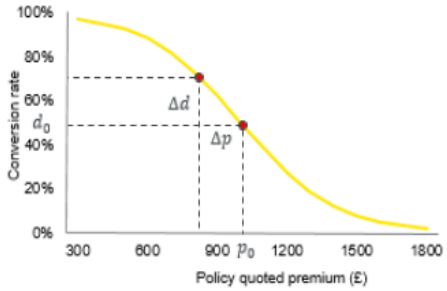
What is price elasticity model

•Price elasticity measures the change in demand divided by the change in premium, mathematically,

$$e = -\lim_{\Delta p \to 0} \frac{\Delta d / d_0}{\Delta p / p_0} = -\frac{\partial d}{\partial p}\frac{p_0}{d_0}.$$

•Conventionally add the minus sign to make it a positive number



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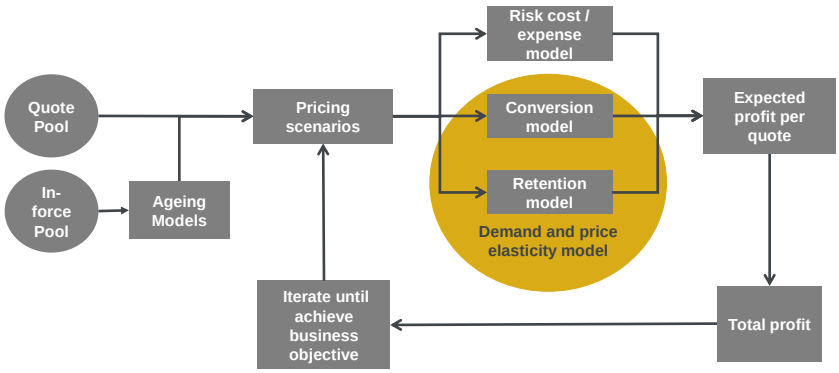
Demand and price elasticity models are important components in pricing analysis



- Price elasticity model is particularly important in price optimisation

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Current approaches used in the market

- One-way and two-way analysis
  - Easy to calculate
  - Ignore correlation in the explanatory variables
  - Not suitable for complicated analysis
- Generalised linear model (GLM)
- Generalised non-linear model
  - Guarantee that elasticity is always positive
  - Computationally intensive
- Neural networks
  - Understand the results is a challenge

The GLM approach: price elasticity derived from the demand model

Model setting

- **Logit link function** $\mu = g^{-1}(\eta) = \frac{1}{1+e^{\eta}}$
- **Binomial distribution error structure**
- **Linear component** $\eta = \mathbf{X}\boldsymbol{\beta}_d + \Delta p \mathbf{X}\boldsymbol{\beta}_e$

not *p*

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It is important to have randomised price tests

- **GLM explains the difference in demand by normal rating factors (age, area etc) and premium**
- **If the price test correlated with one rating factors, GLM will get confused whether it is the rating factor or the price difference cause the difference in demand**

Base scenario

Age	Demand
Young	10%
Old	20%

Random price test

Age	Demand - Champion	Demand - Challenge
Young	10%	20%
Old	20%	25%

Extreme scenario: Young always gets discount

Age	Demand - Champion	Demand – Challenge
Young		20%
Old	20%	

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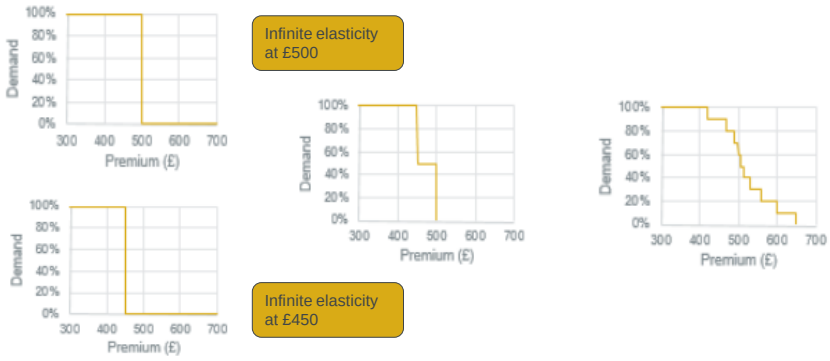
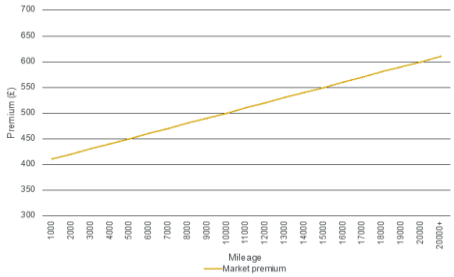
Price elasticity can only be observed for a group of risk



- **Reconciliation of price elasticity at individual level is always an approximation**

Non-linearity or break point are expected in demand model

- Demand depends on the market premium and own premium
- Even simple pricing action can give non-linearity effect in demand



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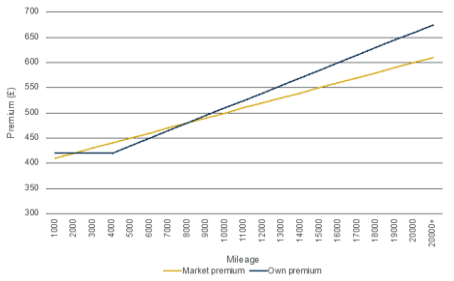

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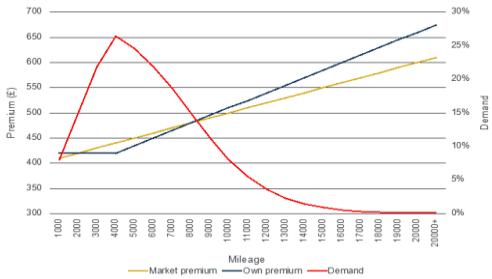

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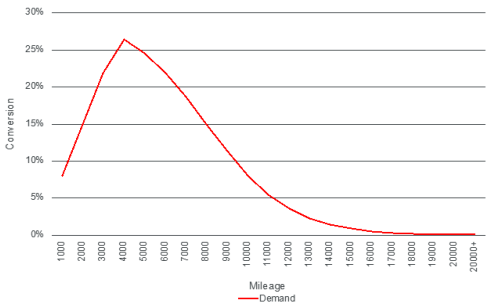
Extrapolate of model is common but much more dangerous

- **Where there is limited number of sales, the model largely depend on extrapolation of neighbouring segments**



Demand in high mileage relying on the mid-range mileage. It can't tell the difference in elasticity.

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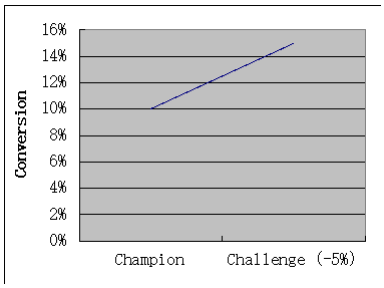
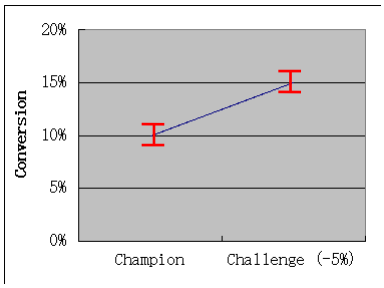
Derived elasticity has high uncertainty





Elas = (15%-10%)/10%/5% = 10

If SD of conv is 10% of conv,
SD of Elas is
(1%^2+1.5%^2)^0.5/10%/5% = 3.6,
36% of Elas

- **Uncertainty of price elasticity is compounded by uncertinty of demand**
- **And dominated by the high uncertaint point**

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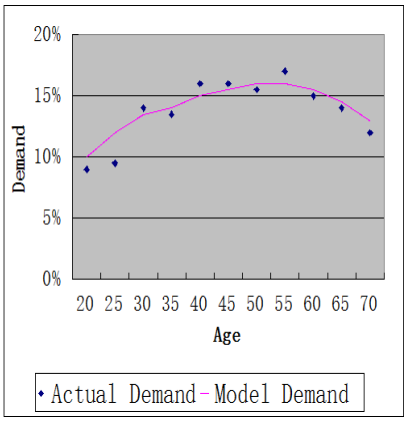
Model reconciliation

- One way chart



•How to calculate actual price elasticy? Is it possible?
•How to calculate modelled price elasticity?
•How to make them consistent and comparable?

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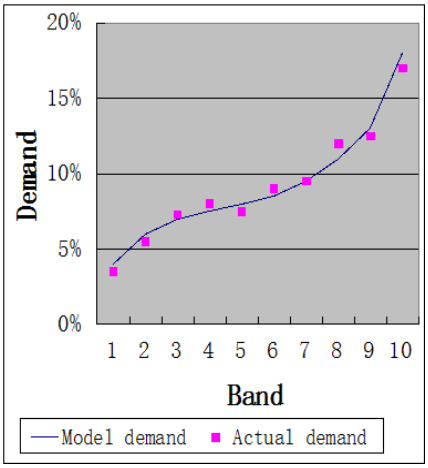
Model reconciliation

- Lift curve is even more a challenge



•How to calculate model price elasticity for individual policy? What is the price point?
•Calculate model and actual price elasticity in bands is same as one way chart

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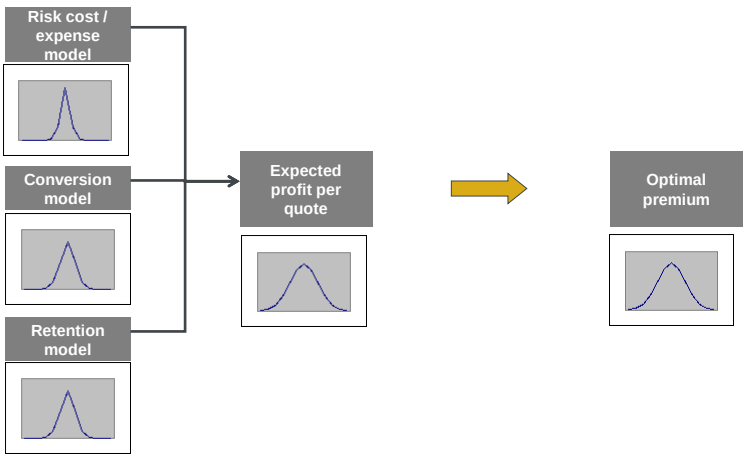
Understand the impact of model uncertainty



- **This uncertainty is compounded with winner's curse**

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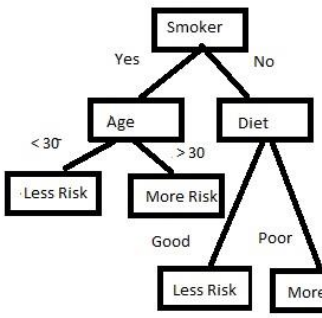
Decision tree

A normal tree

A decision tree!



A decision tree branches into two nodes. Each node is an attribute value in your dataset.

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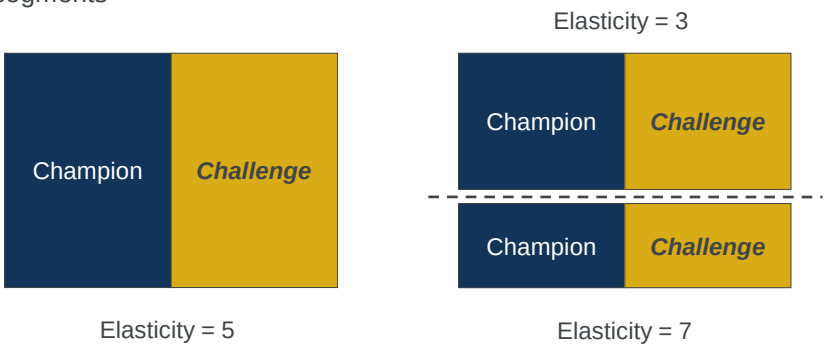
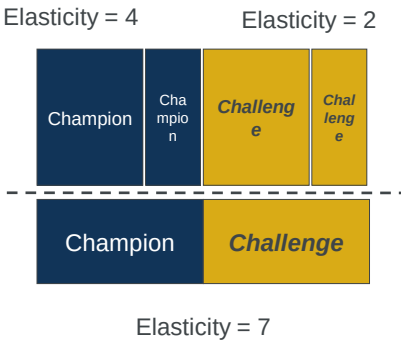
Idea of tree based approach

- Decision tree appraoch provides a top-down approach that focus on segments



- Split at a place that differentiate the price elasticity most

The idea of tree based approach



GLM could be applied to adjust the difference in mixture

- Algorithm
  - Step 1: For each possible split, build a GLM on demand including price test as a explanatory vairable. Record the impact of price test.
  - Step 2: Find the split that has the maximum impact of price test
  - Step 3: If stop criteria is not met, go to Step 1. Otherwise, stop.
  - Step 4: Build GLM in each leaf of the tree

Literatures

•Using Generalised Linear Model to Build Dynamic Pricing Systems, Karl P. Murphy, Michael J. Brockman, and Peter K. W. Lee

•Beyond the Cost Model: Understanding Price Elasticity and Its Applications, Serhat Guven, FCAS, MAAA, and Michael McPhail, FCAS, MAAA

•Real-World Uplift Modelling with Significance-Based Uplift Trees, Nicholas J. Radcliffe

•An Application of Genetic Algorithms to Uplift Modelling, David P. Hofmeyr

•Optimal personalized treatment rules for marketing interventions: A review of methods, a new proposal, and an insurance case study, Leo Guelman, Montserrat Guillén and Ana M. Pérez-Marín

•Demand Modelling Working Party report, James Tanser, John Light, Sophia Mealy and Owen Morris

Summary

- Demand and price elasticity models could be spuriously accurate
- Great attention is needed in model check and understanding uncertainty
- Decision tree type model is a top-down approach that focus on segments, that potentially reduce spurious accuracy

Expressions of individual views by members of the Institute and Faculty of Actuaries and its staff are encouraged.

The views expressed in this presentation are those of the presenter.