Modelling, Measurement and Management of Longevity and Morbidity Risk

Heriot-Watt University, Edinburgh

Actuarial Research Centre, IFoA

ARC webinar - Edinburgh - 2 October 2018

Research Project: Modelling, Measurement and Management of Longevity and Morbidity Risk

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Research Project: Modelling, Measurement and Management of Longevity and Morbidity Risk

The Research Team:

Andrew Cairns	Principal investigator	Heriot-Watt Univ.
Angus Macdonald	Co-investigator	HWU
George Streftaris	Co-investigator	HWU
Torsten Kleinow	Co-investigator	HWU
David Blake	Co-investigator	Cass Bus. Sch.
Erengul Dodd	Co-investigator	U. Southampton
Stephen Richards		Longevitas

Plus: 2 postdoctoral researchers; 3 PhD students

Plus: Aarhus, Durham, U. California.

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Mortality and Deprivation

Torsten Kleinow
joint work with Jie Wen and Andrew J.G. Cairns

Heriot-Watt University, Edinburgh

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Index of Multiple Deprivation

The IMD is a weighted combination of seven indices of deprivation:

- Income (22.5%)
- Employment (22.5%)
- Education (13.5%)
- Health (13.5%)
- Crime (9.3%)
- Barriers to Housing and Services (9.3%)
- Living environment (9.3%)

source: GOV.UK

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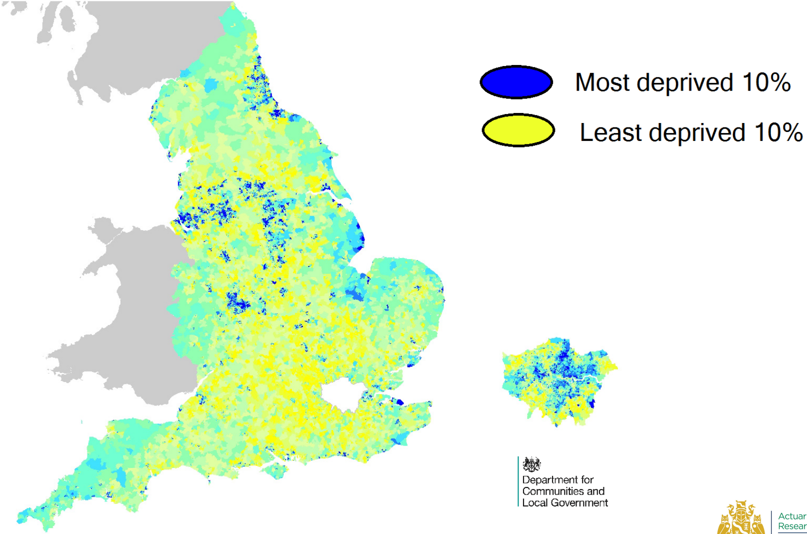
- just over 30,000 LSOAs (Lower Layer Super Output Area) in England
- ordered and split into ten deciles:

  10% most deprived, ..., 10% least deprived

Index of Multiple Deprivation (IMD) areas



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Data

- We consider mortality data for males in England for the ten IMD deciles (2015).
- ages: 40-89, years: 2001-2015
- source: Office for National Statistics

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  The death rate is the number of deaths per 1,000 lives
- We observe different death rates at different ages, in different years and in different IMD deciles
- Death rates for most deprived are higher than death rates for least deprived.
- So, the ratio of deaths rates in most deprived areas compared to least deprived areas is greater than one,

$$\frac{\text{deaths per 1,000 lives in } \textbf{most} \text{ deprived areas}}{\text{deaths per 1,000 lives in } \textbf{least} \text{ deprived areas}} > 1$$

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Poll 1: Death rates by IMD decile in 2001 (age 65)

What is the ratio of death rates in the most deprived areas compared to the least deprived in England in 2001 (males, age 65)?

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What is the ratio of death rates in the most deprived areas compared to the least deprived in England in 2001 (males, age 65)?

A) Ratio ≤ 1.5, (50% extra mortality compared to least deprived)

B) Ratio is between 1.5 and 2

C) Ratio is between 2 and 3

D) Ratio is between 3 and 4

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	Deaths per 1,000 lives		
	most deprived	least deprived	ratio
2001	25.3		

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	Deaths per 1,000 lives		
	most deprived	least deprived	ratio
2001	25.3	11.4	2.219

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Death rates by IMD decile

- roughly linear in age (Gompertz line)
- mortality differentials are decreasing with age

Death rates by IMD decile

- similar shape as male log mortality, but lower level, slightly smaller differences
- again, mortality differentials are decreasing with age

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Poll 2: Death rates by IMD decile fourteen years later

What is the ratio of death rates in the most deprived areas compared to the least deprived in England in 2015 (males, age 65)?

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2015	22.3	6.8	3.279

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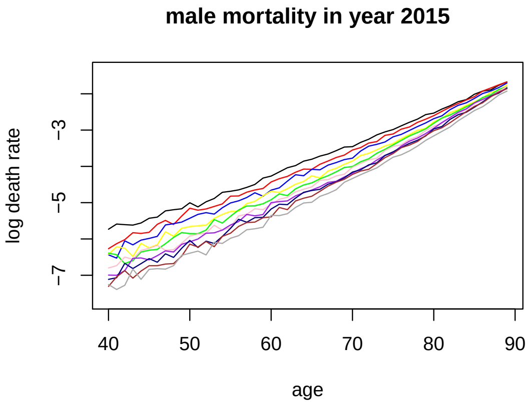
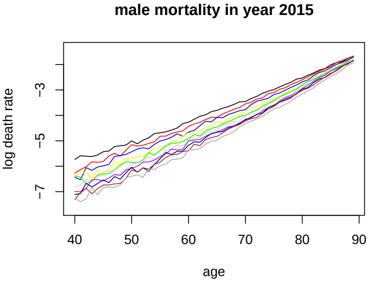
Death rates by IMD decile



- similar shape as in 2001
- differences at high ages are larger

Death rates by IMD decile



- downward shift from 2001 to 2015
- differences between most deprived and least deprived have increased since 2001
- higher differences at high ages

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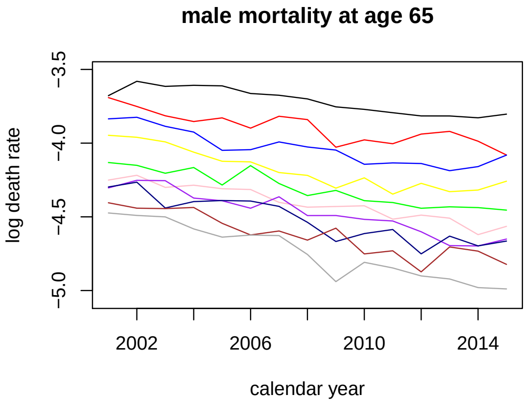
Death rates by IMD decile - Change over time

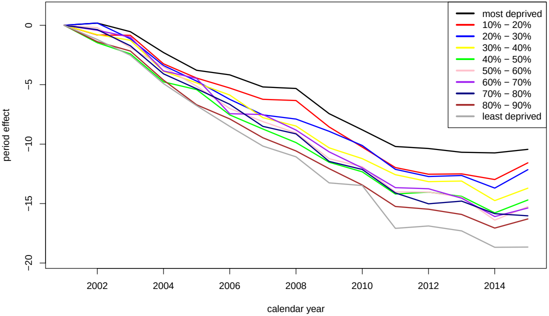
	Deaths per 1,000 lives		
	most deprived	least deprived	ratio
2001	25.3	11.4	2.219
2005	27.0	9.7	2.784
2010	23.0	8.2	2.805
2015	22.3	6.8	3.279

Death rates by IMD decile



- downward trend strongest for least deprived

Period effect in Lee-Carter model by IMD decile



- downward trend strongest for least deprived
- no improvements for most deprived since 2011
- slowdown of improvements for least deprived since 2011

Focus of ARC research - Models

Focus of our research:

- Stochastic models that describe mortality experiences in all socio-economic groups simultaneously.
- Model uncertainty addressed by comparing a wide variety of models (Goodness of fit, robustness, ...)
- Leading to projections, and more importantly, **mortality scenario generation** allowing us
  - to put probabilities on certain scenarios and ...
  - then use those for Value at Risk calculations, annuity pricing, etc.

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Model for the Number of Death in Different Groups

$$D_{xti} \quad \sim \quad \text{Poisson}\,(m_{xti} E_{xti})$$

For each period (calendar year) t, age x and IMD decile i we have

D_{xti}: Number of deaths,

E_{xti}: Central exposure-to-risk

m_{xti}: force of mortality

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So, expected number of deaths, $\text{E}[D_{xti}] = m_{xti} E_{xti}$

Aim or our research: compare different models for the force of mortality m_{xti}.

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Models

All considered models are variants of group specific Lee-Carter type models with the extension to a second age-period effect by Renshaw & Haberman (2003):

$$\log m_{xti} = \alpha_{xi} + \beta^1_{xi}\kappa^1_{ti} + \beta^2_{xi}\kappa^2_{ti} + \gamma_{ci}$$

where $c = t - x$ is the cohort (year of birth).

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where $c = t - x$ is the cohort (year of birth).
Specific versions include models with:

common age effect : $\alpha_{xi} = \alpha_x$

non-parametric common age effects : $\beta^k_{xi} = \beta^k_x$ (Kleinow, 2015)

fixed age effects : constant $\beta^1_{xi} = 1$ and linear $\beta^2_{xi} = x - \bar{x}$, where $\bar{x}$ is the mean age in the data set. (Plat, 2009)

common period effects : $\kappa^k_{ti} = \kappa^k_t$ (Li and Lee, 2005)

group specific trends in common period effects : $\kappa^k_{ti} = \kappa^k_t + \eta_i(t - \bar{t})$

and variations with and without cohort effects.

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Some research questions

$$\log m_{xti} = \alpha_{xi} + \beta^1_{xi}\kappa^1_{ti} + \beta^2_{xi}\kappa^2_{ti} + \gamma_{ci}$$

- What parameters should be chosen to be group specific and which parameters are common?
- Should age-effects be estimated?
- Should we include cohort effects (common or group specific)?
- What parameters show the greatest differences between IMD groups?
- Are the groups clustered?

Our conclusions so far...

- There are clear differences between the death rates for the ten IMD deciles.
- The improvement rates (from 2001 – 2015) are also different.

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- For a wider age range, models with common non-parametric age effects (Kleinow (2015) + common α) produce a good fit in terms of BIC, heatmaps ...
- However, for a narrower age range (65-89), models with constant/linear β's, (Plat (2009) + common α) are better.

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- However, for a narrower age range (65-89), models with constant/linear β's, (Plat (2009) + common α) are better.
- Cohort effects do not improve the fit for those models
- If a cohort effect is included it should be a common cohort effect

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Thank You!

Questions and Comments

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Critical illness insurance rates and related morbidity trends

Dr George Streftaris

Joint work with
Chunxiao Xie (PhD, HWU)
Dr Erengul Dodd (Southampton U)
Dr Ayse Arik (HWU)

The 'Modelling, Measurement and Management of Longevity and Morbidity Risk' research programme is being funded by the Actuarial Research Centre, Society of Actuaries, and the Canadian Institute of Actuaries.

Critical illness insurance: Policy description

- Fixed term policy, usually ceasing at age 65
- A fixed sum insured payable on the diagnosis of one of a specified list of critical illnesses
- Covers: Cancer; *Death*; Heart attack; Stroke; Multiple Sclerosis; Total & permanent disability; Coronary artery bypass graft; Kidney failure; Major organ transplant etc.
- Policies are often sold together with term or endowment insurance
- Benefit type: Full Accelerated (FA) or Stand Alone (SA)

Data
Provided by the CMI Assurances Committee (UK)

- 1999-2005
  - Details of policies inforce at the start and end of each year
  - 19,127 claims settled
- 2007- 2010
  - Grouped by various risk factors
  - 20,487 claims settled

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Data:

- Claims
- Exposures
- Risk factors:

Risk factor (covariate)	1999 – 2005	2007 – 2010
Age (last birthday)	√	√
Gender	√	√
Smoker	√	√
Policy duration	√	√
Office	√	
Distribution channel	√	√
Benefit type (accelerated, standalone)	√	√
Benefit amount	√	√
Policy type (single, joint)	√	
Settlement year	√	√
Cause	√	
Product category	√	√
Date of diagnosis	√	

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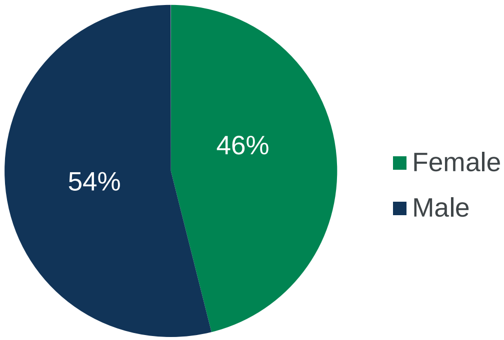
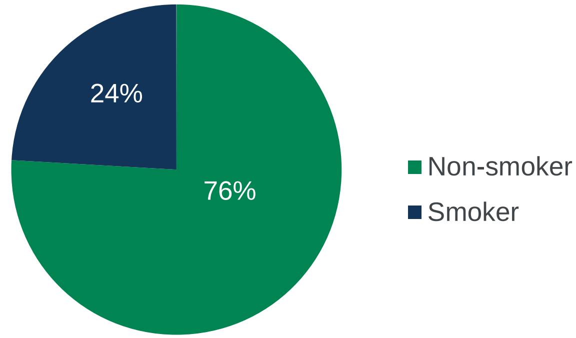
Data: 2007 - 2010

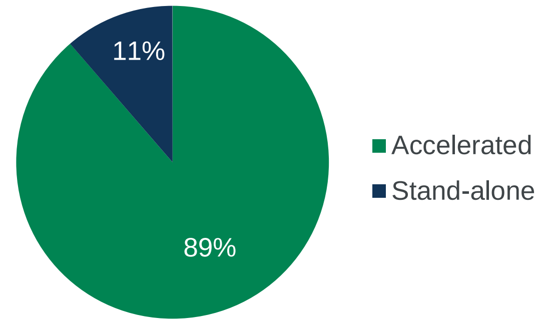
Gender



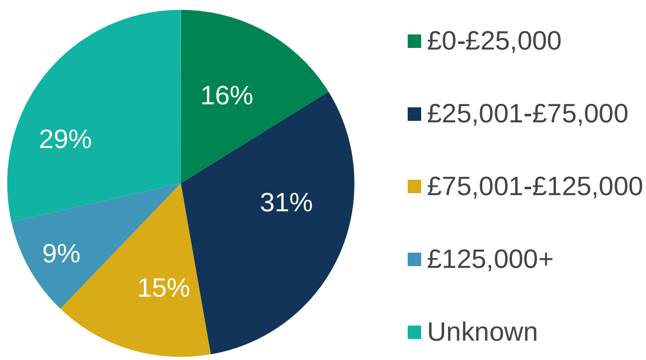
Smoker Status



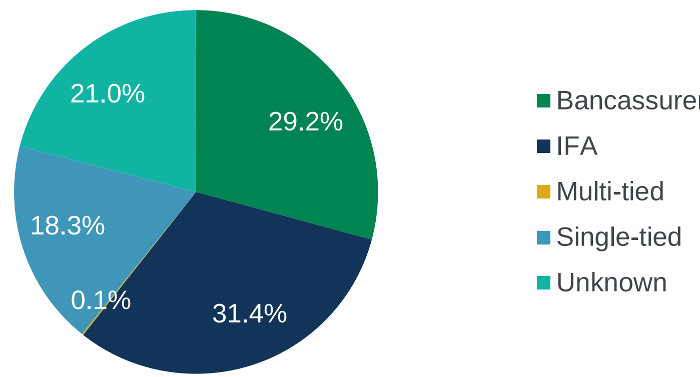
Benefit Type



Sum Assured



Distribution Channel



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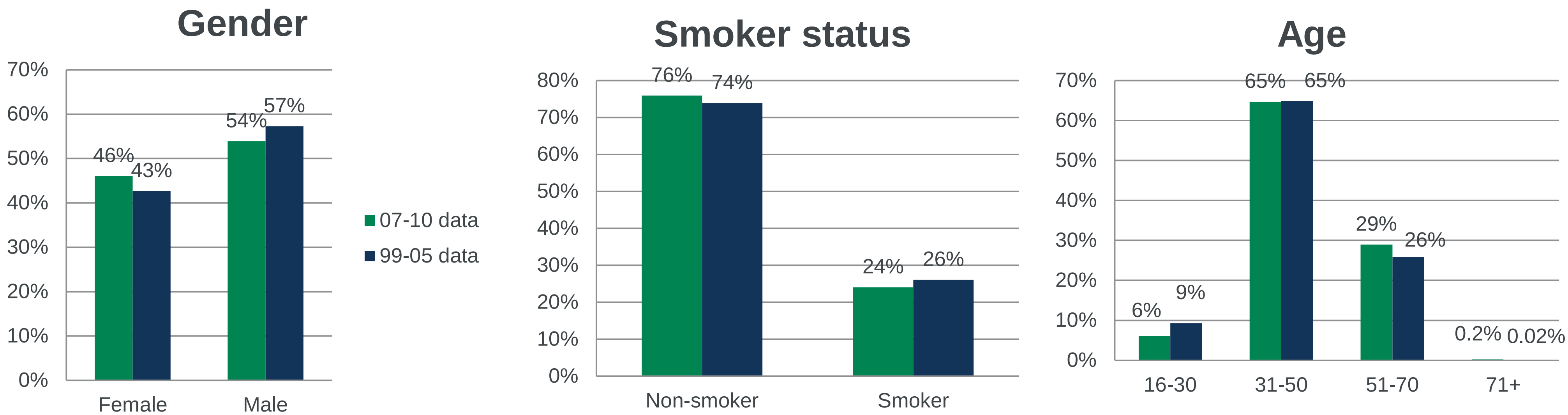
Claims edata: 2007 – 2010 v 1999 – 2005



- Distributions very similar between 2007 – 2010 & 1999 – 2005
- Slightly higher proportion of **F** and **NS** in 2007 – 2010
- Lower proportion of **age 16-30** in 2007 – 2010

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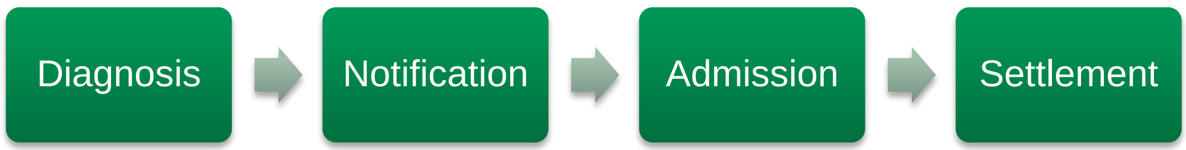
Poll 3

UK CII claim rates in 2007-2010 (as compared to 1999 – 2005):

(a) have gone considerably **up**;
(b) have gone considerably **down**;
(c) have stayed roughly **unchanged**;
(d) I don't know.

Modelling: mostly Bayesian stochastic

- Estimation & smoothing of CI diagnosis rates
  - – how do these depend on **risk factors?**
- Diagnosis is the insured event and there is a delay between diagnosis and settlement



- For 1999- 2005 data:
  - exposure corresponds to claims settled, not to claims diagnosed
  - we have made adjustments by fitting a delay distribution (Bayesian Generalised Beta 2 model)

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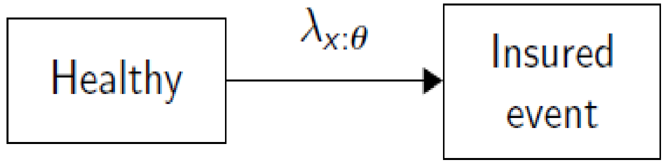
Stochastic modelling: Claim rates

Model:



Fit Bayesian model:

Adjusted exposure

$$N^{(j)}(x;\theta) \sim \text{Poisson}\left(\lambda^{(j)}_{x;\theta} \int_{u=0}^{4} \overbrace{E(u:x;\theta)\, F^{(j)}(4-u:x;\theta)\, du}^{\text{Adjusted exposure}}\right)$$

- $\lambda^{(j)}{}_{x,\theta}$: **diagnosis (claim) rate** for cause *j* at age *x* with risk factors θ

$$\lambda_{x,\theta} \sim LN(\delta x + \beta\theta, \sigma^2)$$

- normal priors for coefficient vectors δ and β.

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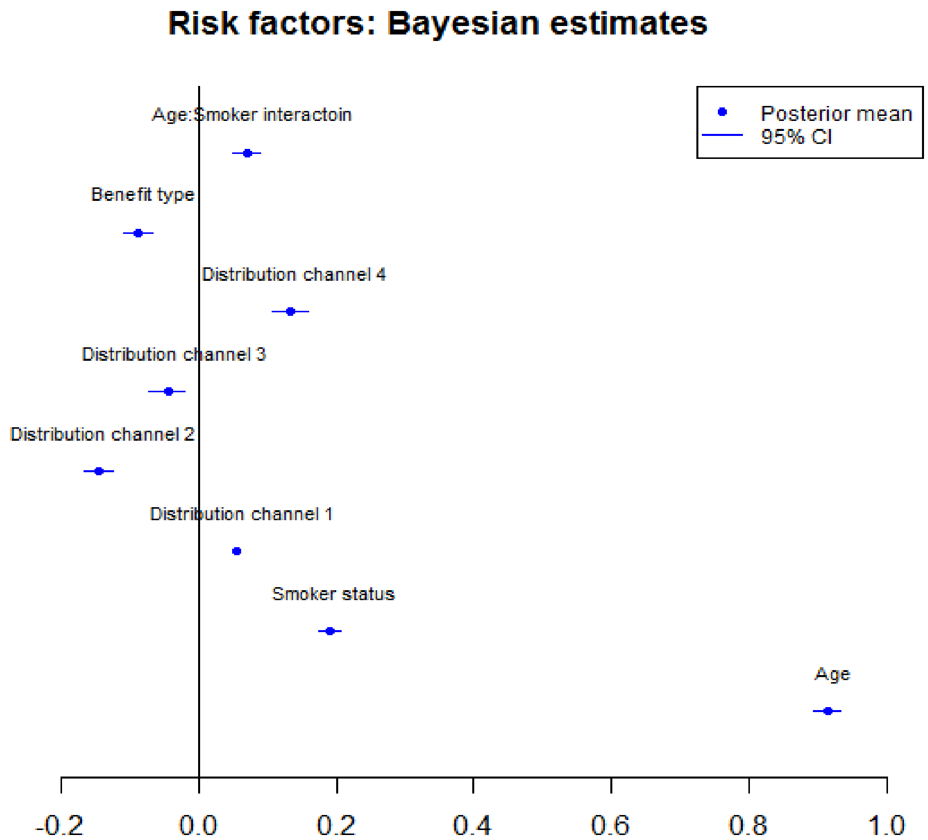
Stochastic modelling:
Risk factor estimates for claim rates (2007 – 2010)



Perform variable (factor) selection

Selected model includes:

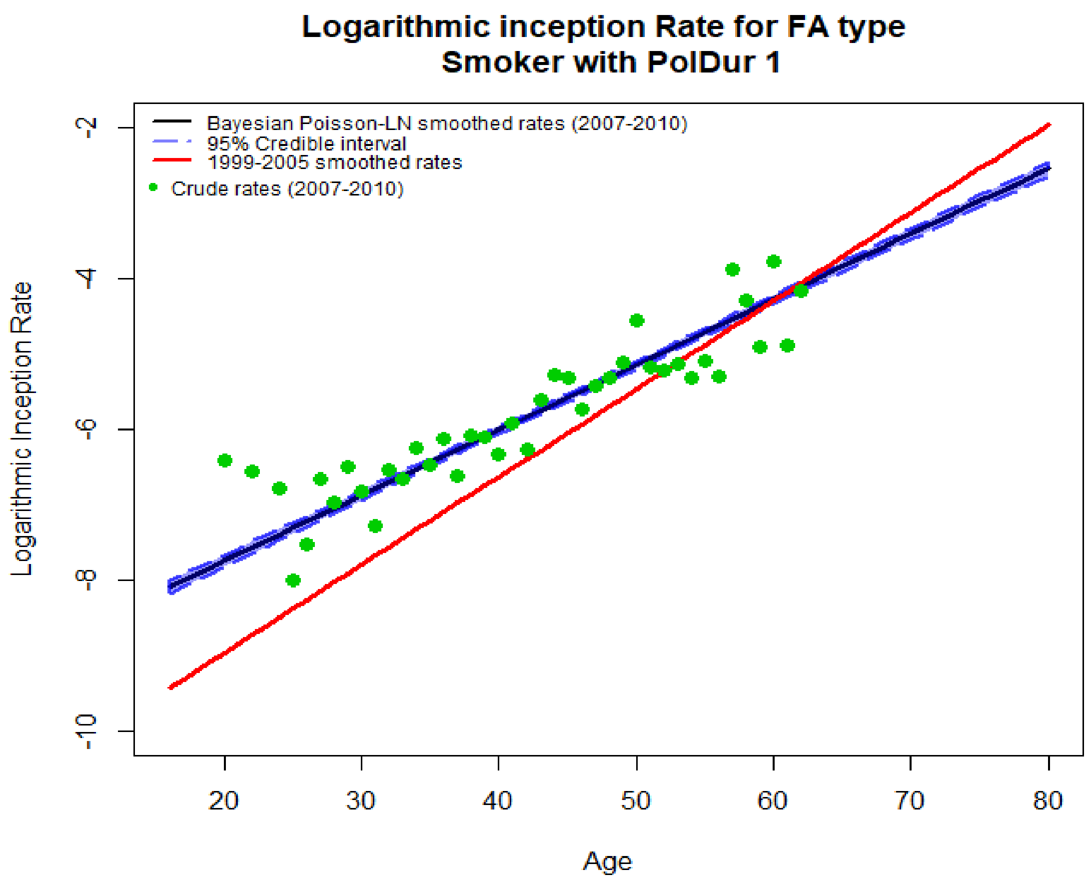
- ✓ age (older ↑)
- ✓ smoker status (S ↑)
- ✓ distribution channel
- ✓ benefit type (stand-alone ↓)
- ✓ age x smoker

Also (not shown here):

- ✓ policy duration (longer ↑)
- ✓ benefit amount (mid ↑)

Fitted claim rates (and intervals)

2007-2010 v 1999 – 2005, Accelerated, Smoker, Pol Duration 1



- Model fits crude rates (2007 – 2010) well
- 2007 – 2010 rates significantly higher
- Gap wider at younger ages
- Similar trends for other profiles

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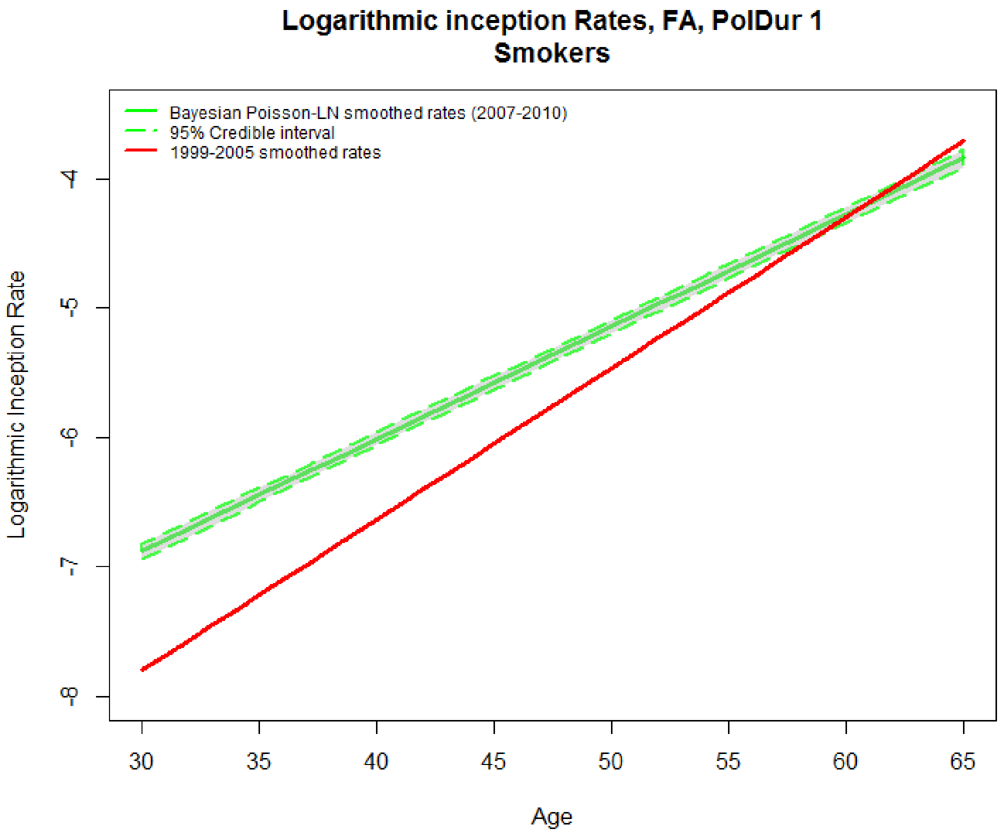
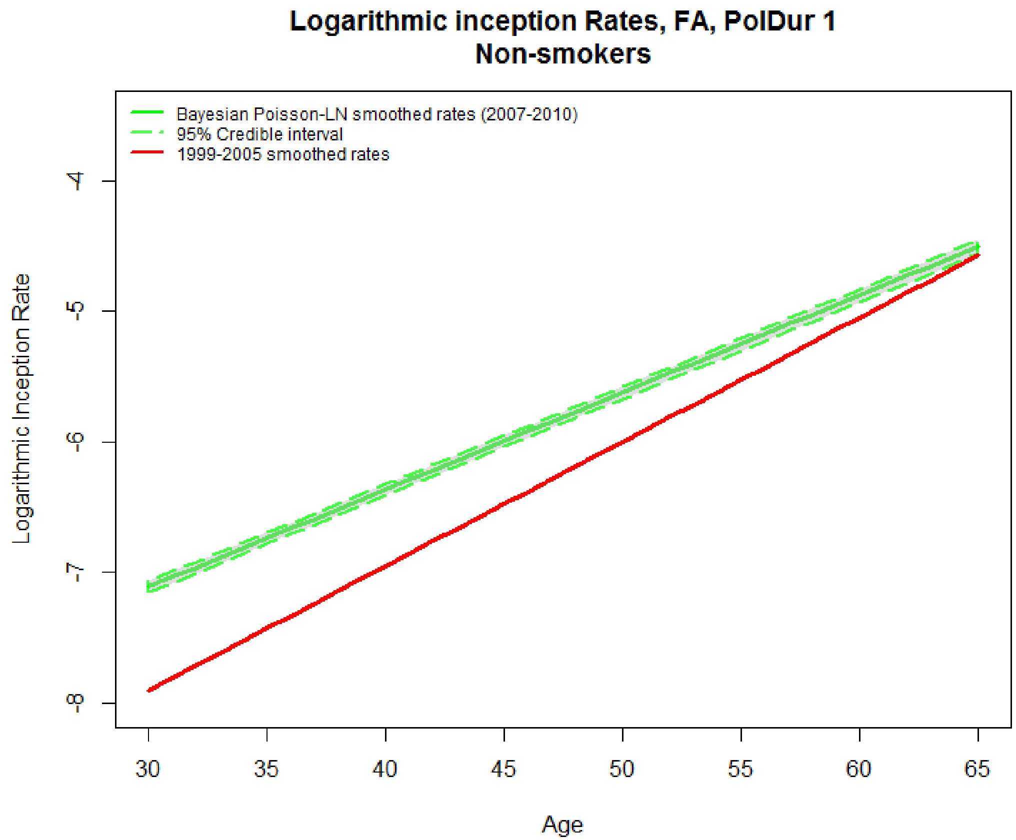
Fitted claim rates

Smokers & non-smokers (Accelerated, Pol Duration 1)





- 2007 – 2010 rates significantly higher, both S & NS

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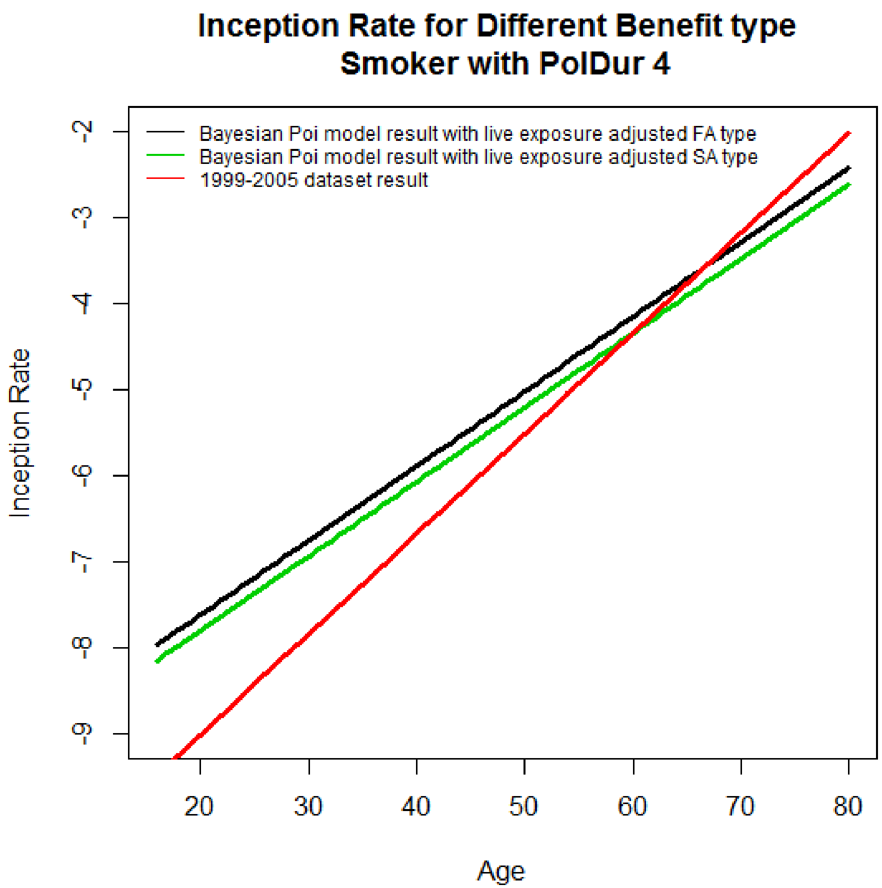
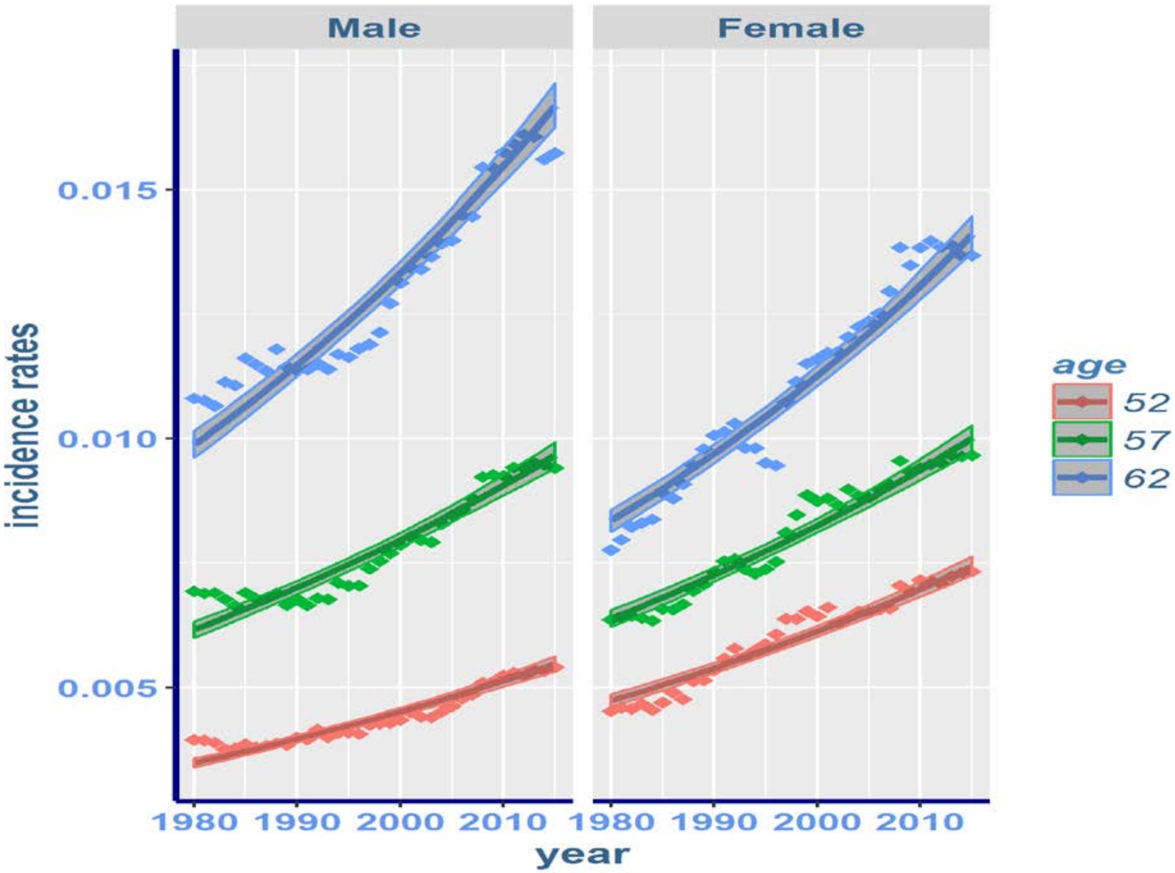
Fitted claim rates

Accelerated v Stand alone (2007 – 2010) & 1999 – 2005



- Accelerated 2007 -2010 (black) higher than stand-alone (green)
- Both significantly higher than 1999 – 2005

UK population cancer rates (ONS data)
All cancers



Fitted: —— ; Observed: ▪ ▪ ▪

- Bayesian GLM with: age, year, gender
- Incidence rates increasing with time
- Higher rates for older ages

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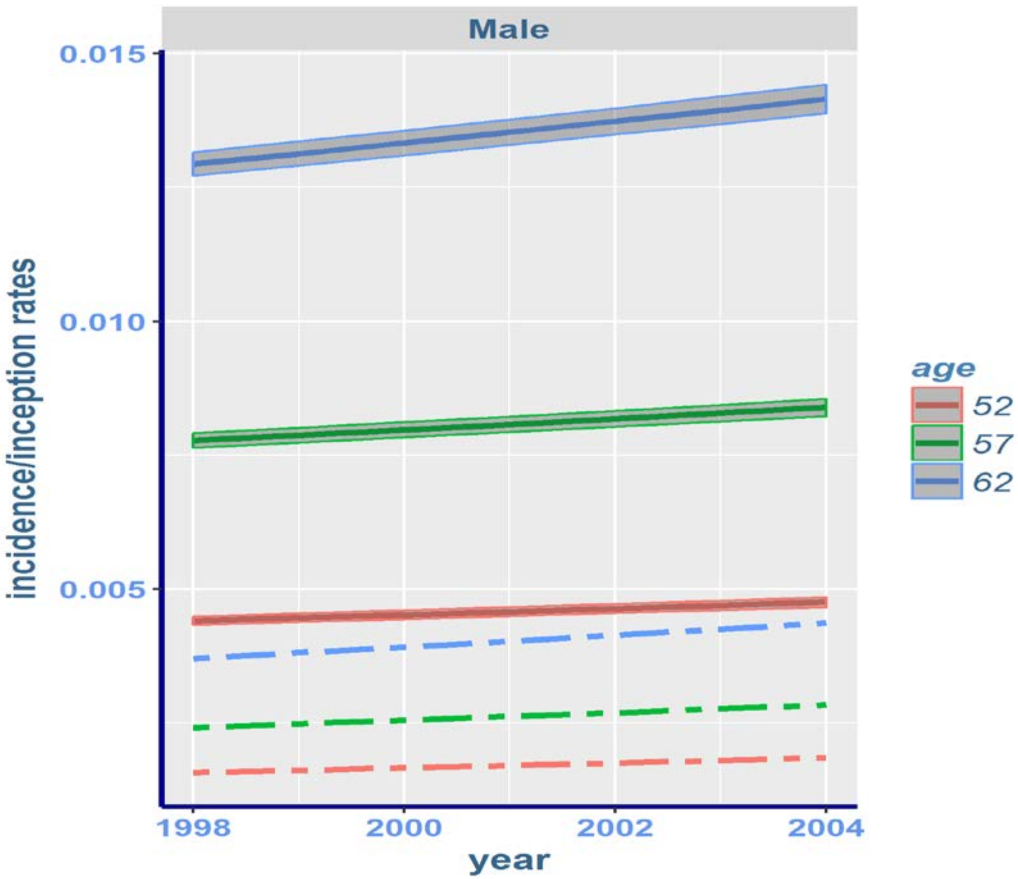
Poll 4

Insured population cancer rates in 1999-2005 (as compared to general population cancer rates):

(a) are at the **same level**;
(b) are considerably **higher**;
(c) are considerably **lower**;
(d) I don't know.

Population cancer rates v insurance rates

Males - All cancers

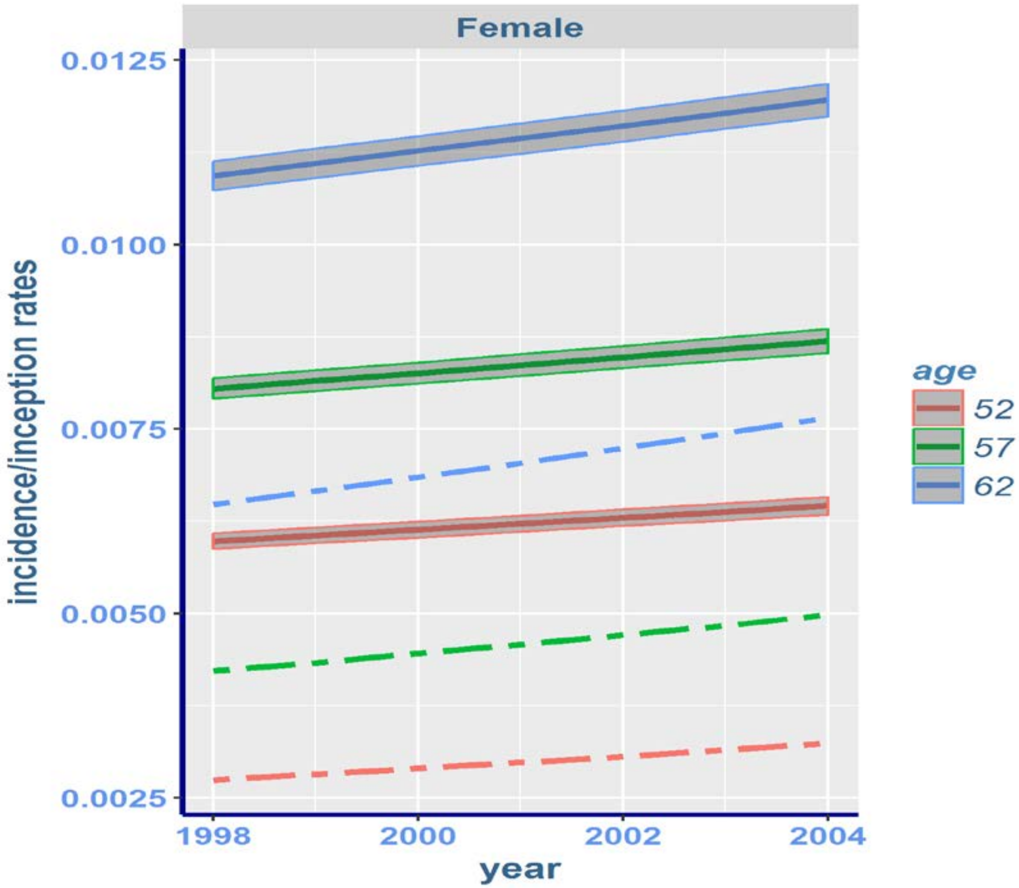


Population ——; CII – – -

- Experience for the insured population is different
- CII rates significantly lower than population rates
- Why?
  -- Differences between those who can/cannot afford CII?
  -- Rates lower in most affluent groups? (but not for all types of cancer)
  -- Underwriting effect?

Population cancer rates v insurance rates

Females - All cancers



- Gap smaller than for males (for older ages)
- Effect of breast cancer? (same for all socio-economic groups)

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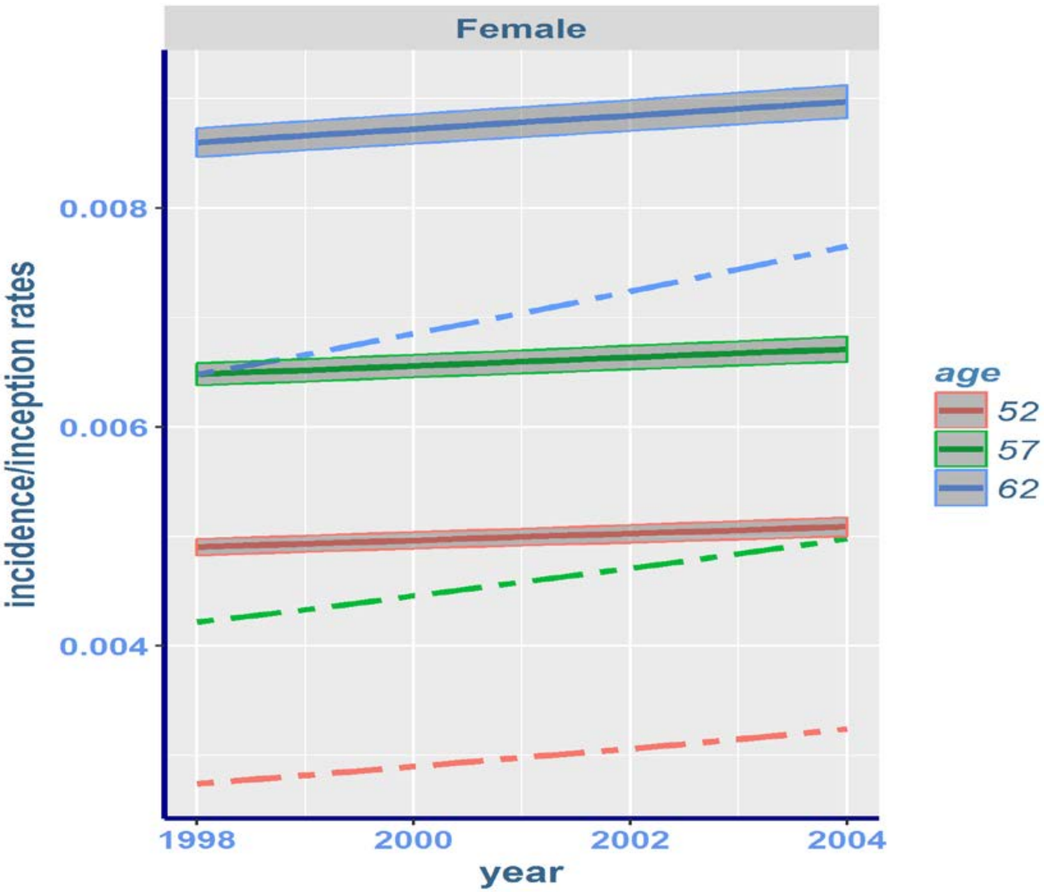
Population cancer rates v insurance rates

Females – Excluding melanoma skin cancer



- Some cancers not covered by CII
- Exclude skin cancer from population rates:
  - gap now smaller
  - CII rates increasing faster that population rates?

Summary

- CII claimants distribution similar between 1999-2005 & 2007-2010
- Claim rates (2007-2010) depend on a number of risk factors:
  - age, smoker status, distribution channel, policy duration, benefit amount and benefit type, etc.
- Analysis suggests **increase of CII claim rates over time**
  - especially at younger ages
- **Cancer: insurance rates much lower than population rates**
- But **trends could be different** (worse for CII)?

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Questions

Comments

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

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