Modelling of Cancer Morbidity Risk in a Bayesian Framework

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Outline

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Aim of the Study

The main purpose of the study

1. Investigate the dynamics of various types of population cancer risk
   - under a Bayesian setting by employing generalised linear model structures
   - using cancer registration numbers in England
2. Compare population incidence rates with the CII rates

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Data

Cancer registration data for England provided by Office for National Statistics (ONS)

1. International Statistical Classification of Diseases (ICD): ICD 8, ICD 9 and ICD 10
2. age from zero to 95+
3. year from 1971 through 2015
4. region ?
5. gender

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All Cancer Incidences in England

$\Rightarrow$ Bayesian model

$$C_i|\theta_i \sim \text{Poisson}(E_i\theta_i)$$

$$\theta_i \sim \text{Lognormal}(\mu_i, \sigma^2)$$

$$\boxed{\mu_i = \beta_0 + \beta_{1,j}x_j + \beta_{2,k}y_k + \beta_{3,g}x_g + \beta_{4,j,g}x_jx_g}$$

$$\sigma^2 \sim \text{Inv.Gamma}(1, 0.001)$$

$$\beta\text{'s} \sim \text{Normal}(0, 10^4),$$

$$i = 1, \ldots, 1080;\ k = 1, \ldots, 36;\ j = 1, \ldots, 15 \text{ and } g = 1, 2.$$

Model	age	year	age:year	gender	age:gender	BIC
1	cont.	cont.	✗	factor	✗	1131204
2	cont.	cont.	✓	factor	✗	1130858
3	cont.	factor	✗	factor	✗	1126715
4	cont.	factor	✓	factor	✗	1126402
5	factor	cont.	✗	factor	✗	360975
6	factor	cont.	✓	factor	✗	355419
7	factor	cont.	✓	factor	✓	350386
8	cont.	factor	✓	factor	✓	817914
9	factor	factor	✗	factor	✓	37229
10	factor	factor	✓	factor	✗	351360

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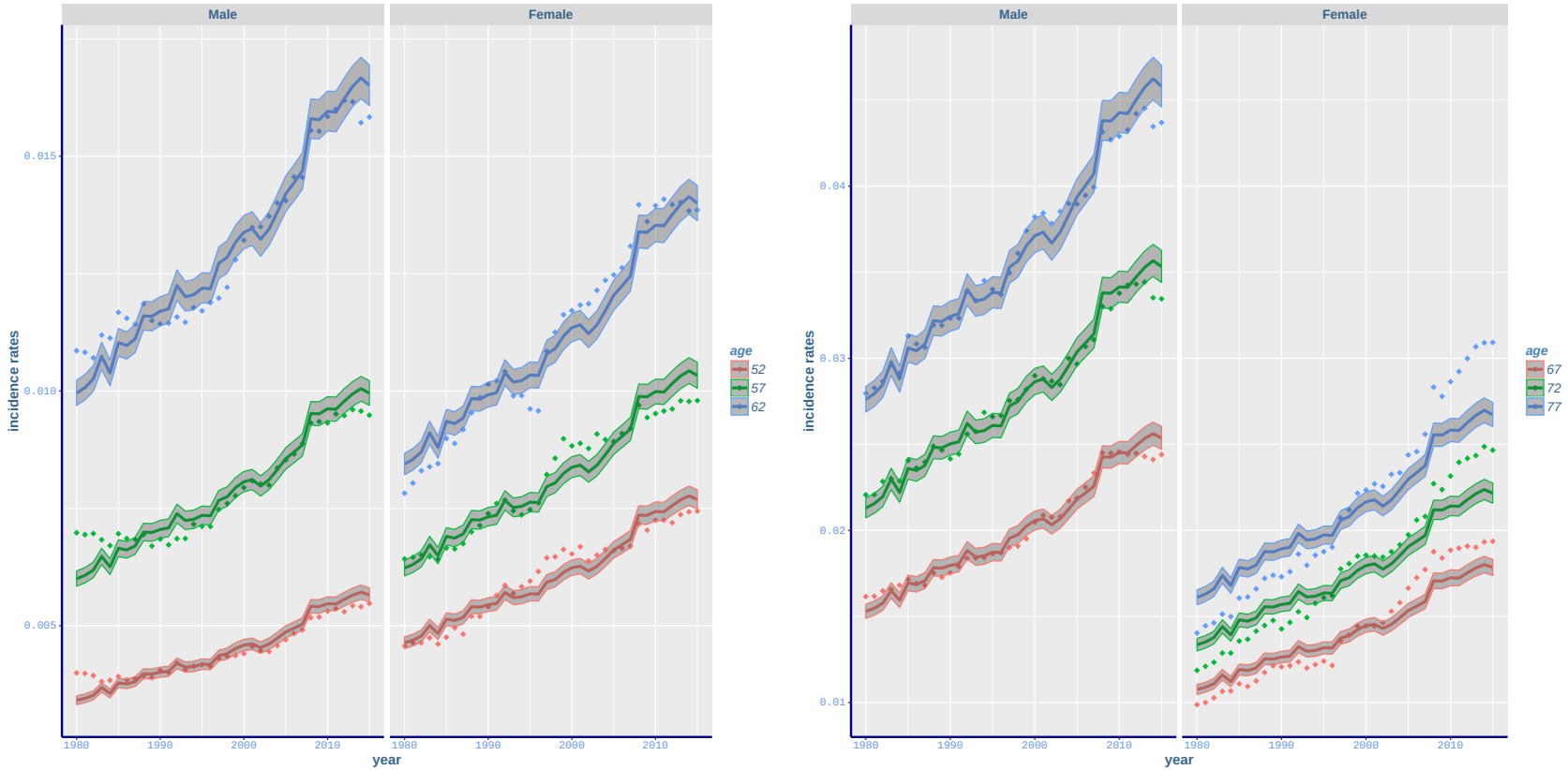
All Cancer Incidences in England



Actual and fitted incidence rates of all cancer types without carcinoma in situ
fitted incidence rates as solid lines & crude rates as dots

- An increasing trend for all ages.

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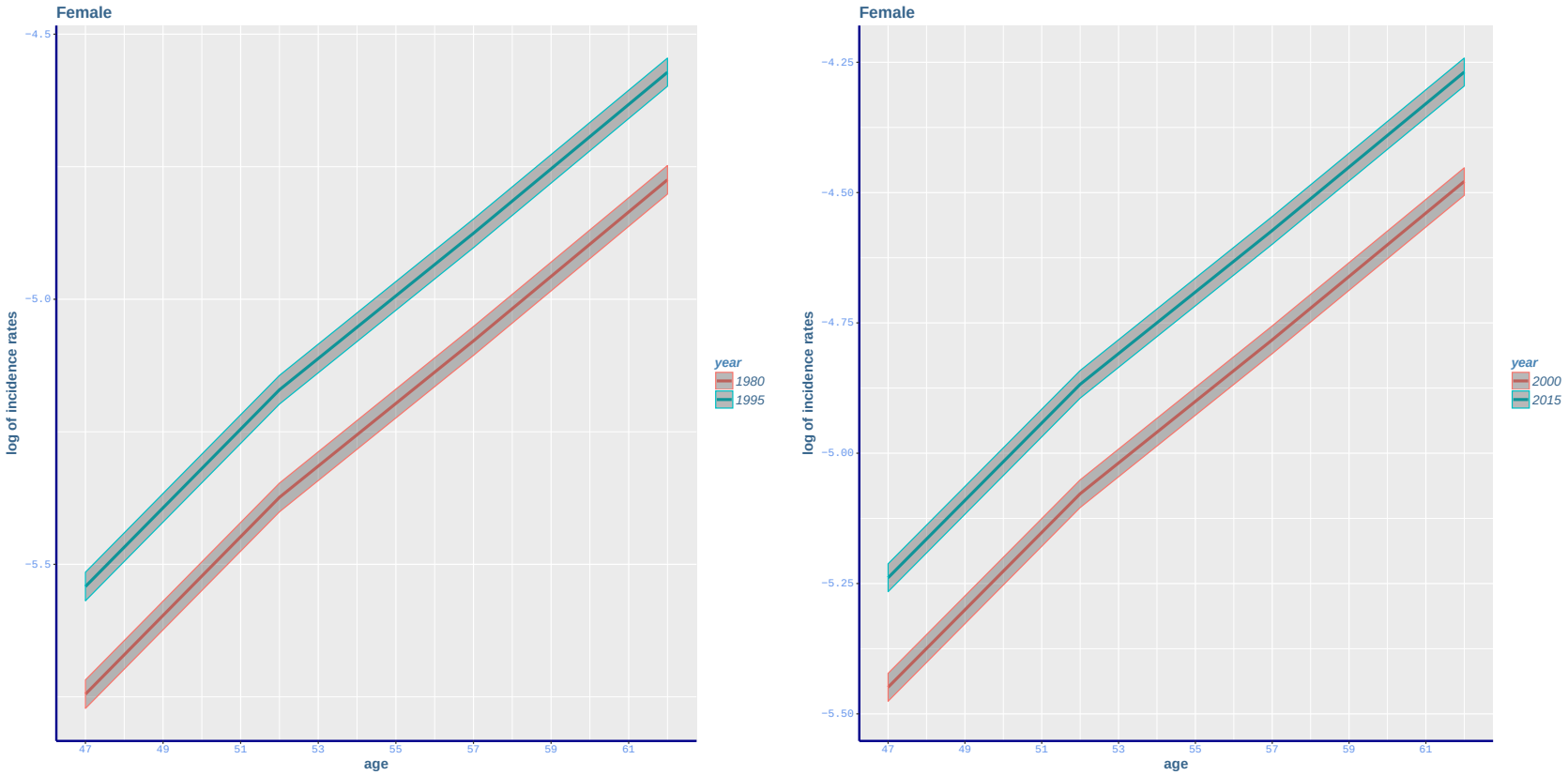
All Cancer Incidences in England



incidence rates for females from ages 47 to 62
for years 1980, 1995, 2000 and 2015
fitted incidence rates as solid lines

- Ageing is a fundamental factor for cancer.

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Lung Cancer in England

$\Rightarrow$ Bayesian model

$$C_i|\theta_i \sim \text{Poisson}(E_i\theta_i)$$

$$\theta_i \sim \text{Lognormal}(\mu_i, \sigma^2)$$

$$\boxed{\mu_i = \beta_0 + \beta_1 x + \beta_2 x^2 + \beta_3 x^3 + \beta_4 y + \beta_5 xy + \beta_{6,g} x_g + \beta_{7,g} x_g y + \beta_{8,g} x_g x}$$

$$\sigma^2 \sim \text{Inv.Gamma}(1, 0.001)$$

$$\beta\text{'s} \sim \text{Normal}(0, 10^4),$$

$i = 1, \ldots, 648$ and $g = 1, 2$.

Model	age	year	age:year	gender	gender:year	age^2	age^3	gender:age	DIC
12	Cont.	Cont.	✓	Factor	✓	✓	✓	✓	7148

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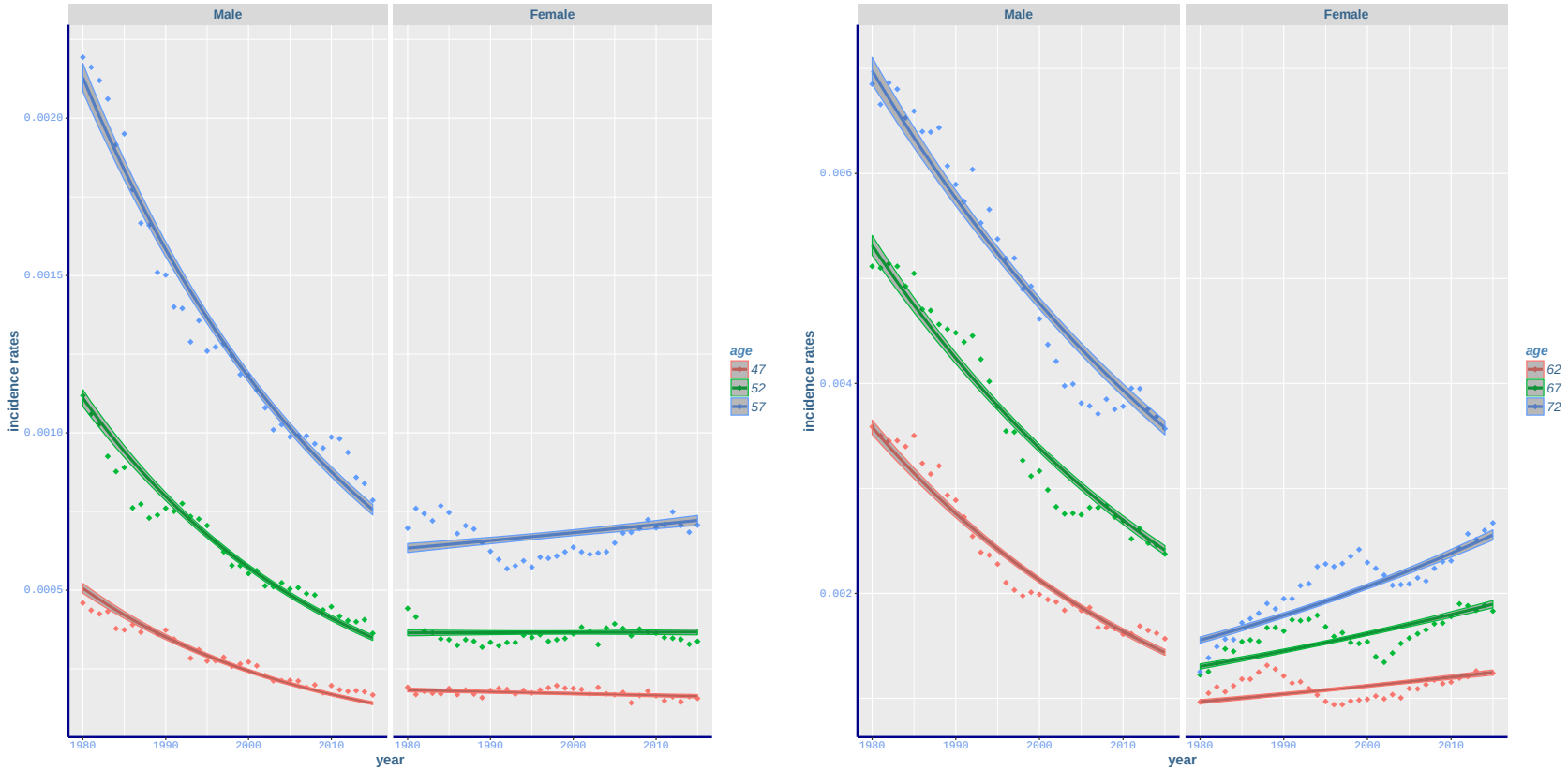
Lung Cancer in England



Actual and fitted incidence rates of malignant neoplasm of trachea, bronchus and lung

fitted incidence rates as solid lines & crude rates as dots

- A narrowing gap bw males & females with different trends due to different smoking patterns.

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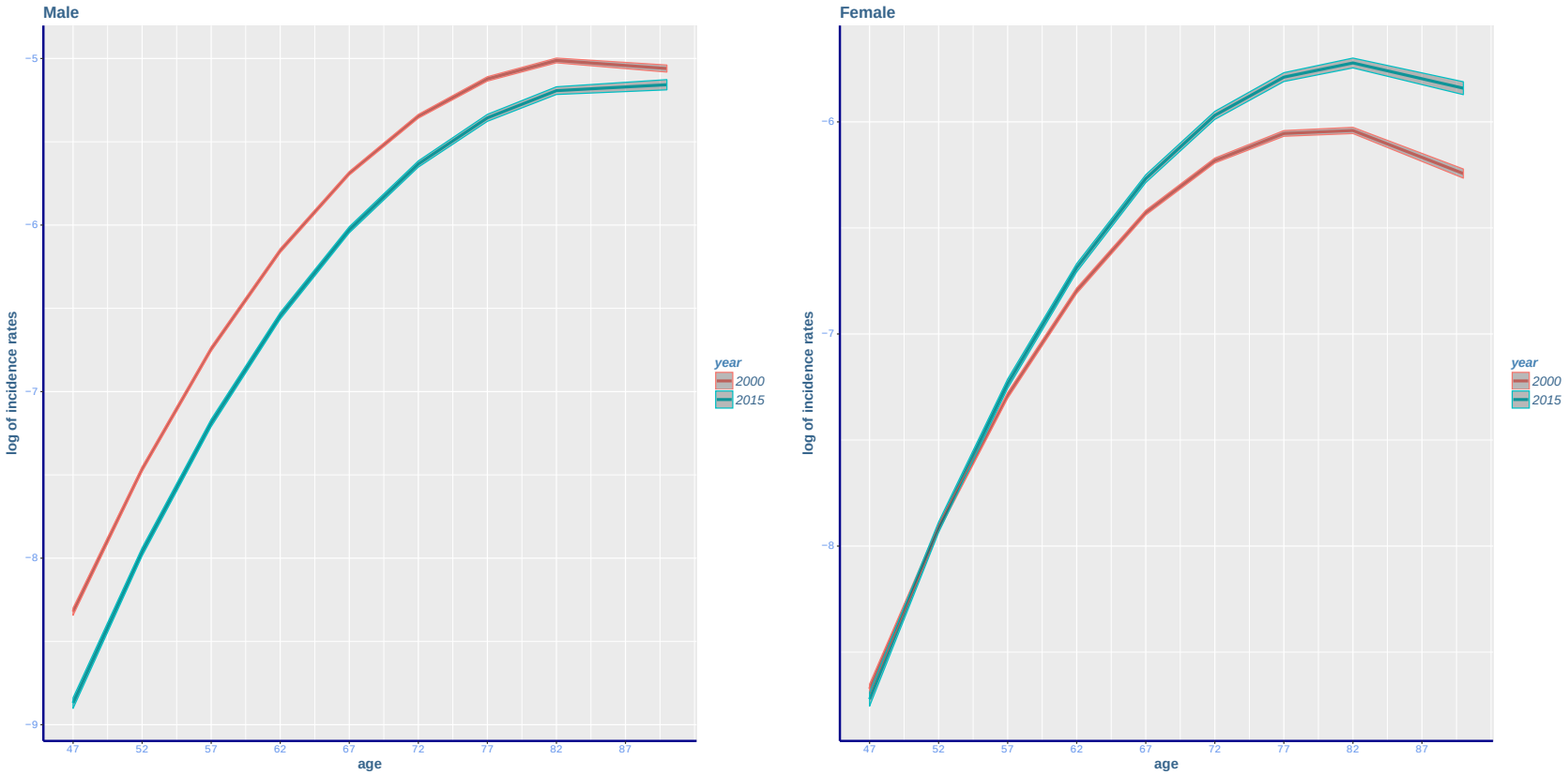
Lung Cancer in England



fitted incidence rates as solid lines

- An opposite trend for males and females.

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Prostate Cancer in England

$\Rightarrow$ Bayesian model

$$C_i|\theta_i \sim \text{Poisson}(E_i\theta_i)$$

$$\theta_i \sim \text{Lognormal}(\mu_i, \sigma^2)$$

$$\boxed{\mu_i = \beta_0 + \beta_1 x + \beta_2 x^2 + \beta_3 x^3 + \beta_4 y + \beta_5 y^2 + \beta_6 y^3 + \beta_7 y^4 + \beta_8 xy}$$

$$\sigma^2 \sim \text{Inv.Gamma}(1, 0.001)$$

$$\beta\text{'s} \sim \text{Normal}(0, 10^4),$$

$i = 1, \ldots, 324.$

Model	age	year	age:year	$year^2$	$year^3$	$year^4$	age^2	age^3	DIC
14	cont.	cont.	✓	✓	✓	✓	✓	✓	3580

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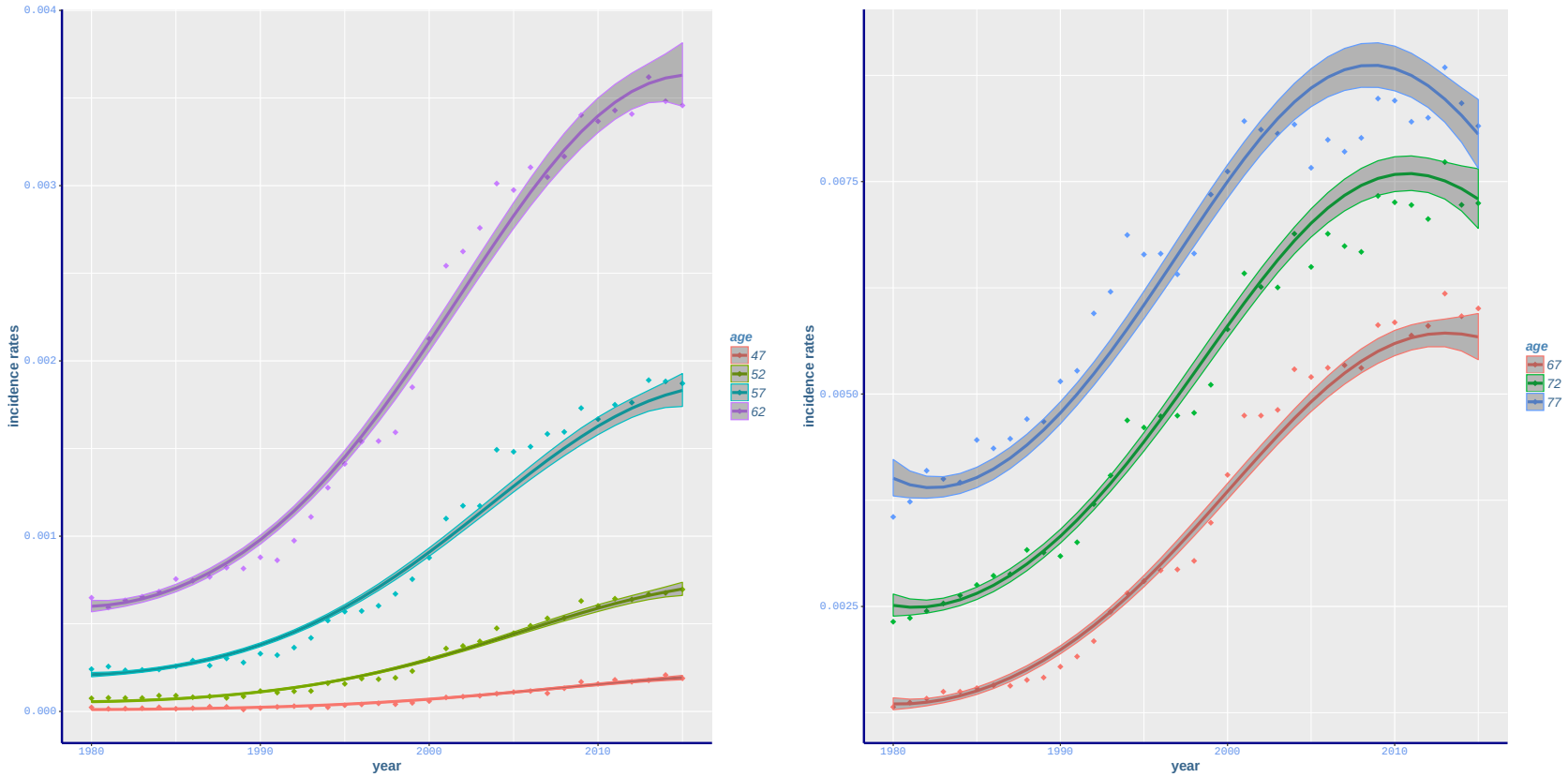
Prostate Cancer in England



Actual and fitted incidence rates of malignant neoplasm of prostate
fitted incidence rates as solid lines & crude rates as dots

- PSA testing started to be used in the UK in the early 1990s.
- The second increase after 2006 with a peak in 2013.

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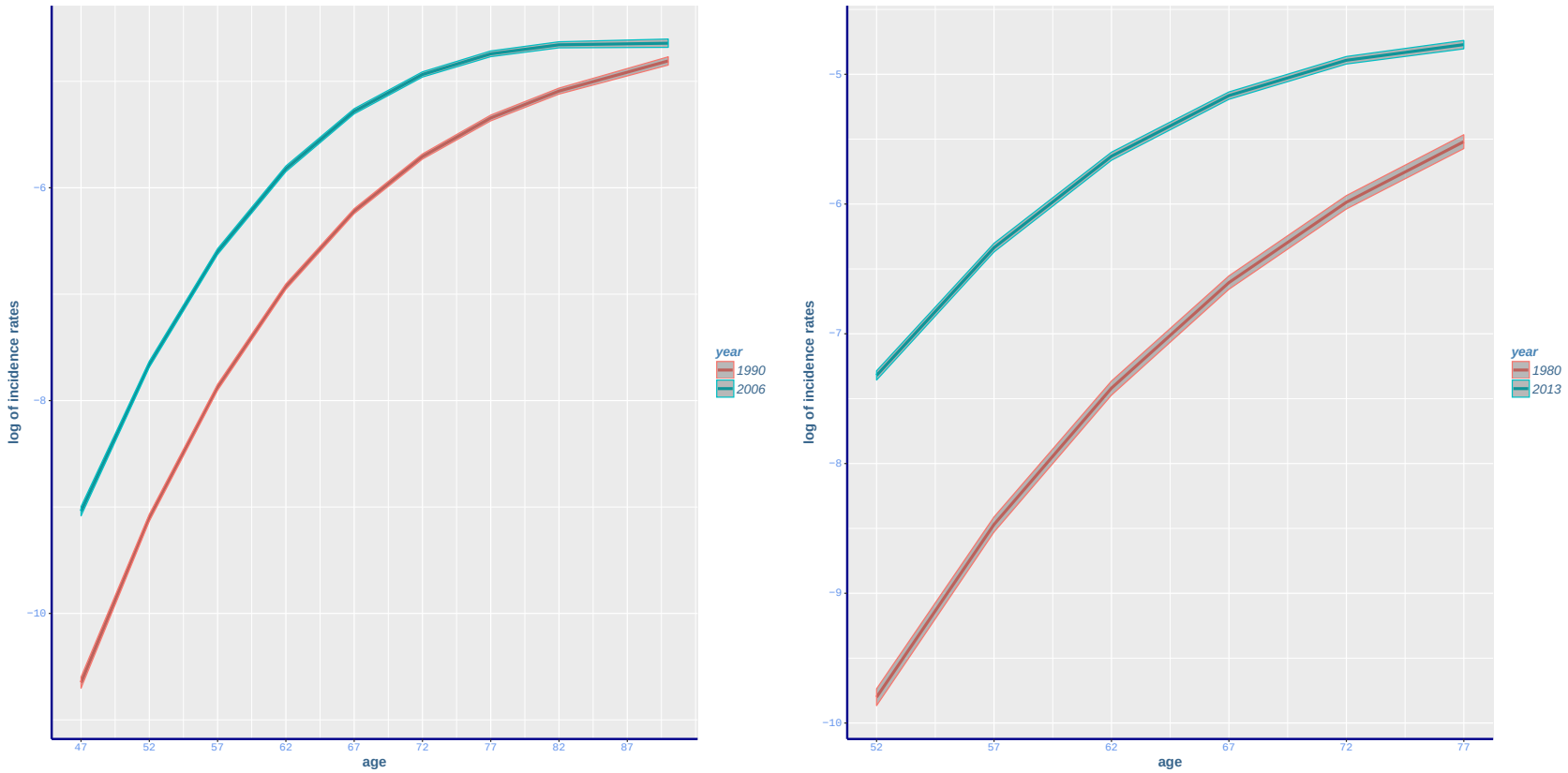
Prostate Cancer in England



Actual and fitted incidence rates of malignant neoplasm of prostate
for years 1980, 1990, 2006 and 2013
fitted incidence rates as solid lines

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Breast Cancer in England

$\Rightarrow$ Bayesian model

$$C_i|\theta_i \sim \text{Poisson}(E_i\theta_i)$$

$$\theta_i \sim \text{Lognormal}(\mu_i, \sigma^2)$$

$$\boxed{\mu_i = \beta_0 + \beta_{1,j}x_j + \beta_2 y + \beta_{3,j}x_j y}$$

$$\sigma^2 \sim \text{Inv.Gamma}(1, 0.001)$$

$$\beta\text{'s} \sim \text{Normal}(0, 10^4),$$

$i = 1, \ldots, 540$ and $j = 1, \ldots, 15$.

Model	age	year	age:year	DIC
6	factor	cont.	✓	5616

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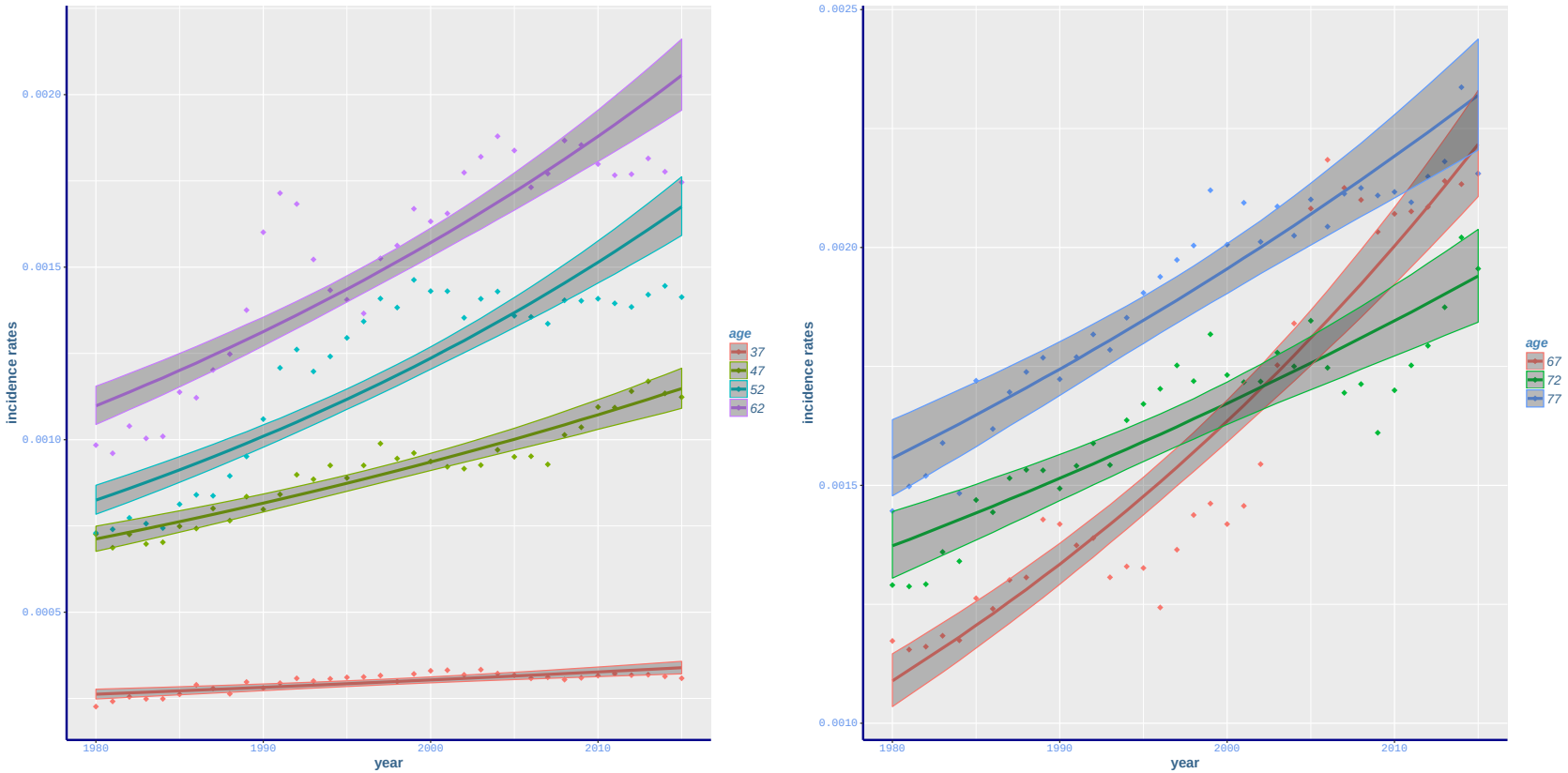
Breast Cancer in England



Actual and fitted incidence rates of malignant neoplasm of breast fitted incidence rates as solid lines & crude rates as dots

- NHSBSP began in 1988, targeted women between ages 50 and 64.
- After 2005, screening offered for women between ages 50 and 70.

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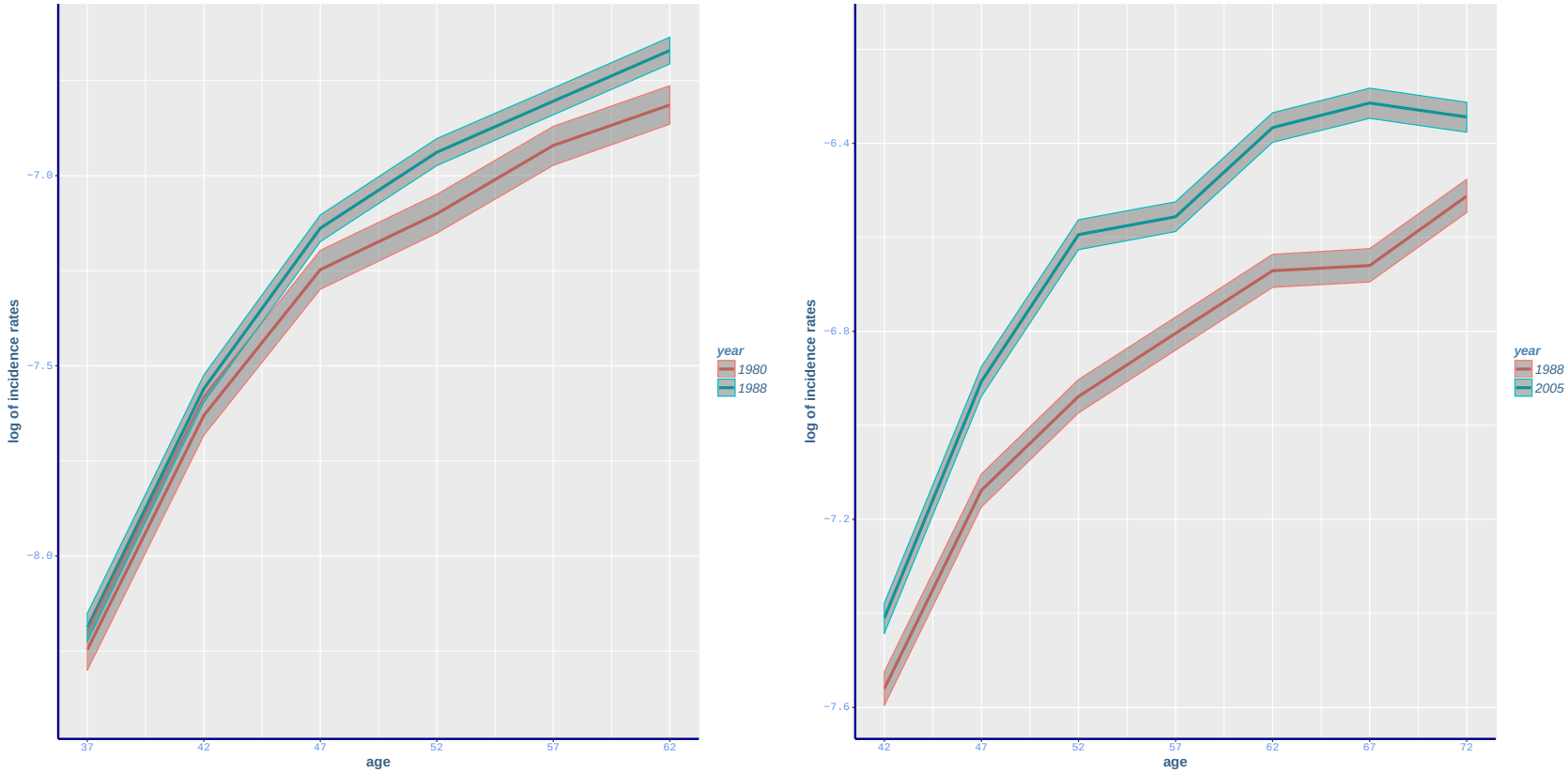
Breast Cancer in England



Actual and fitted incidence rates of malignant neoplasm of breast
for years 1980, 1988 and 2005
fitted incidence rates as solid lines

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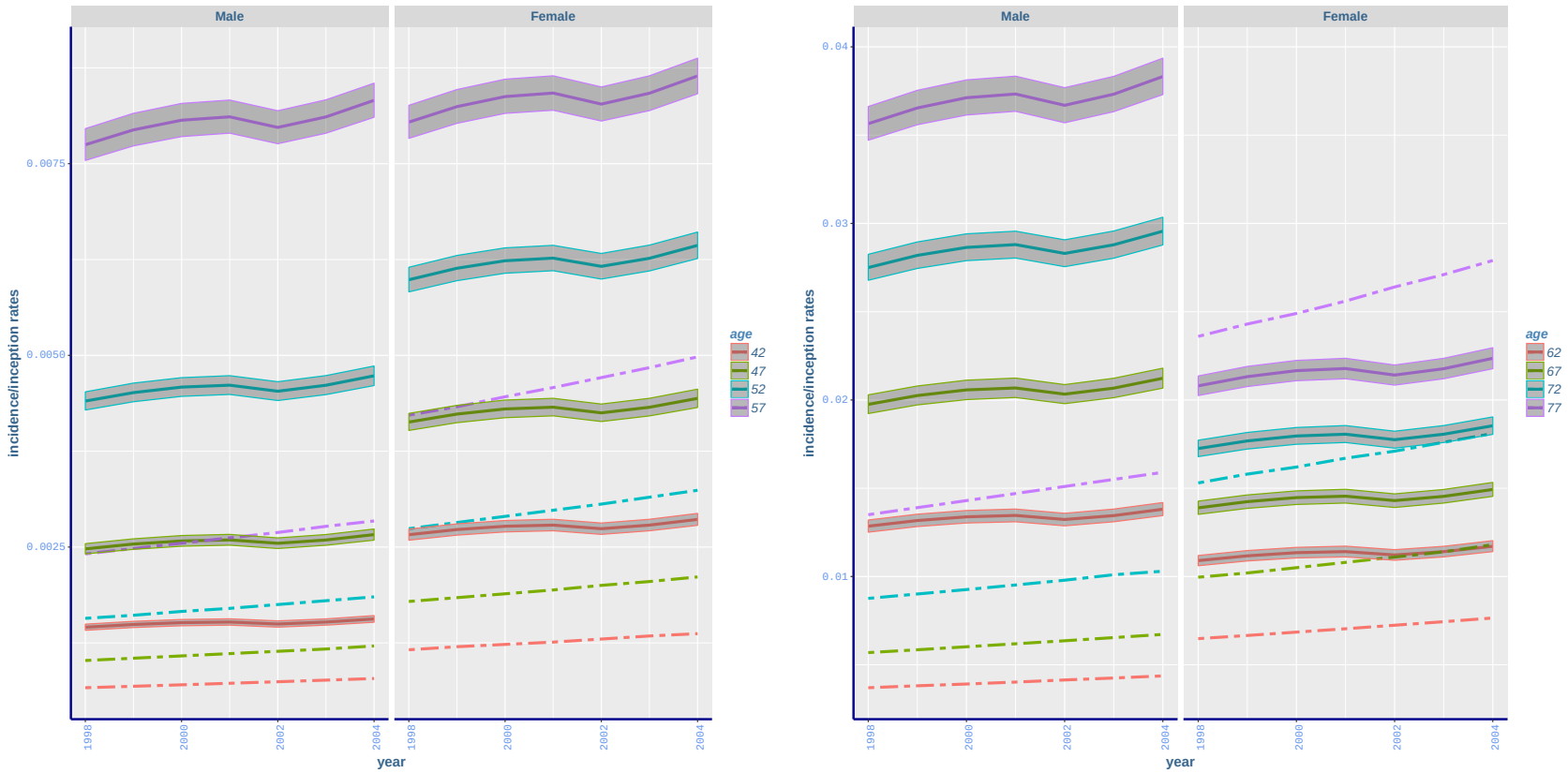
A Comparison between Population Incidence Rates and CII Rates



fitted population incidence rates (ONS data) as solid lines &
fitted CII rates (CMI data) as dashed lines

- incidence rates $>$ CII rates
- Cancer rates are higher for socio-economically deprived groups.

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Summary

- An increasing trend for all cancer types for all age groups.
- An adverse trend in lung cancer for different genders.
- An increasing trend both in prostate and breast cancers.
- Population incidence rates are higher than the insurance rates.

Sources

1. CII claims settled bw 1999 and 2005 by Continuous Mortality Investigation (CMI) in the UK.
2. Office for National Statistics. Cancer registration statistics, England, 2008, 2009, 2011, 2013 and 2016.
3. E. Ozkok, G. Streftaris, H.R. Waters, and A.D. Wilkie. Modelling critical illness claim diagnosis rates I: Methodology. Scandinavian Actuarial Journal, Vol:5, pp 43-457, 2014a.
4. E. Ozkok, G. Streftaris, H.R. Waters, and A.D. Wilkie. Modelling critical illness claim diagnosis rates II: Results. Scandinavian Actuarial Journal, Vol:5, pp 458-482, 2014b.

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Thank You!

Questions?

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