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Cancer morbidity risk modelling – regional variation over time

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Joint work with
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.

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- ARC is the IFoA's network of actuarial researchers around the world.
- ARC seeks to deliver cutting-edge research programmes that address some of the significant, global challenges in actuarial science, through a partnership of the actuarial profession, the academic community and practitioners.
- The **'Modelling, Measurement and Management of Longevity and Morbidity Risk'** research programme is being funded by the ARC, the SoA and the CIA.
- This work is under theme on:
  Stochastic models for critical illness insurance

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Outline

- Cancer morbidity risk
- Data
- Stochastic modelling
- Incidence rates
  - time trends
  - regional variation
- Comparisons with cancer mortality risk
- Population cancer rates *v* rates in insured population

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Cancer morbidity risk

- Important for insurance purposes
- Can impact pricing and reserving in related health insurance fields
  - e.g. critical illness insurance and care provision
- Want to identify
  - temporal trends
  - regional variations

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Data

Provided by the Office for National Statistics (ONS)

Data

ONS Cancer registration data

- International Statistical Classification of Diseases
  - ICD 9, ICD 10
- Age groups 0, 1-4, 5-9, ..., 95+
- Gender
- Years from 1981 to 2016
- Regions (England):
  - North East, North West, Yorkshire and the Humber, East Midlands, West Midlands, East, London, South East, South West

Regions

Scotland
North East
North West
Yorkshire & Humberside
East Midlands
West Midlands
East
London
South East
South West

Data (cont.)

Also available:

- ONS cancer mortality data
  - ICD 10
  - Age groups 20-24, 25-29, ..., 85-89
  - Years **2001 – 2016**

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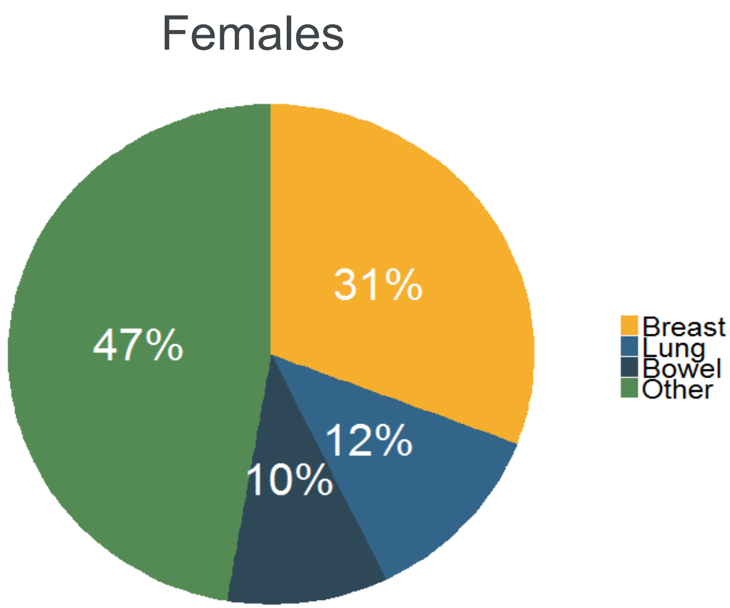
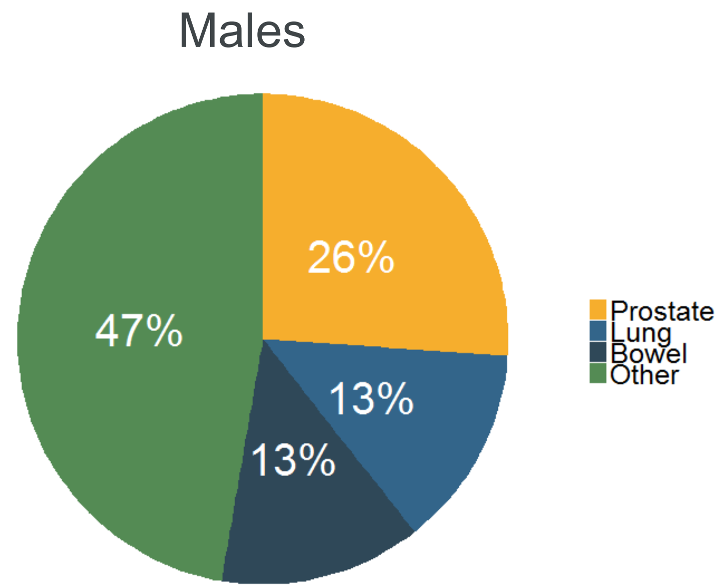
Most common cancer types (2016)

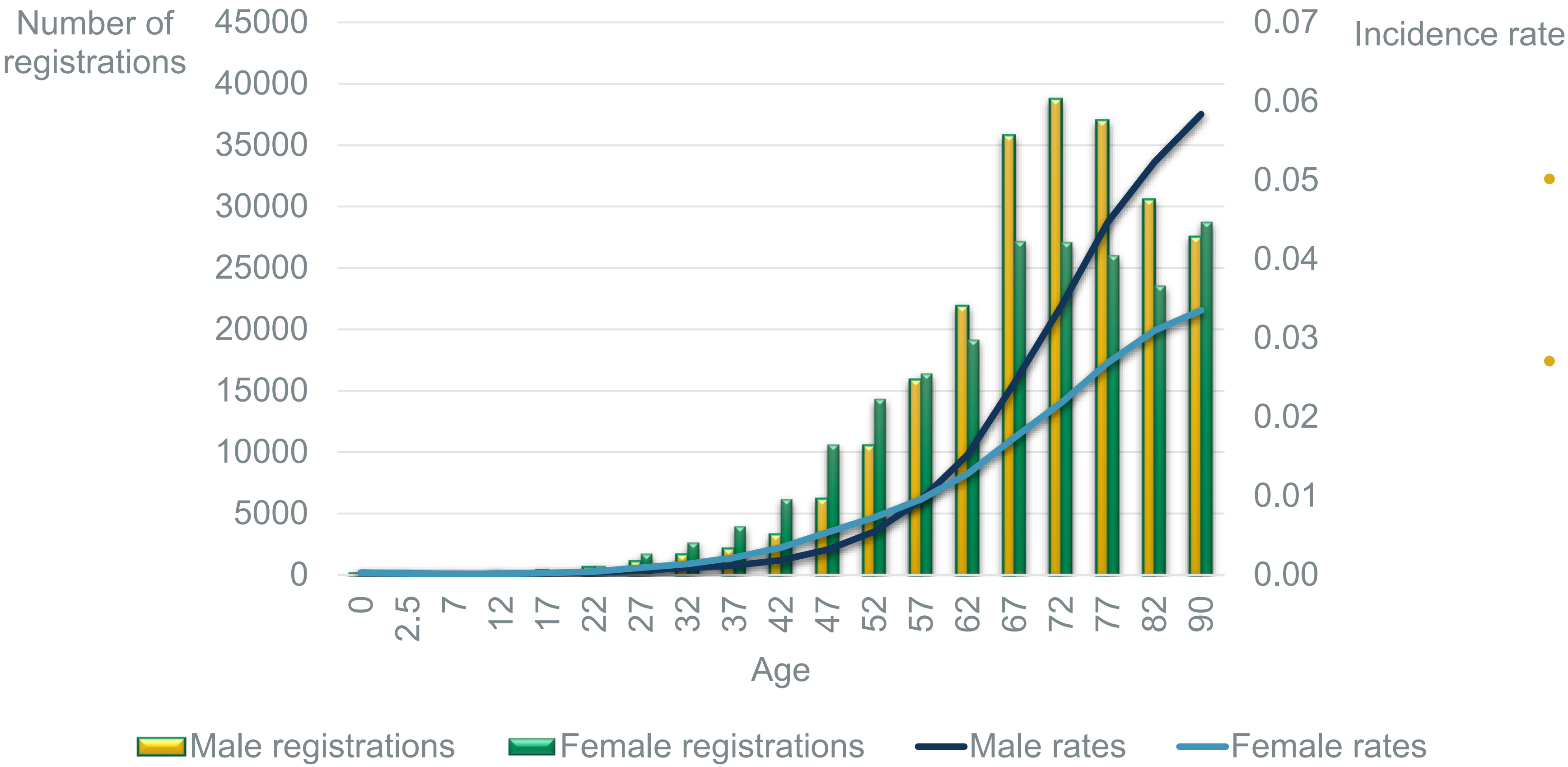




- Focus on all cancers,

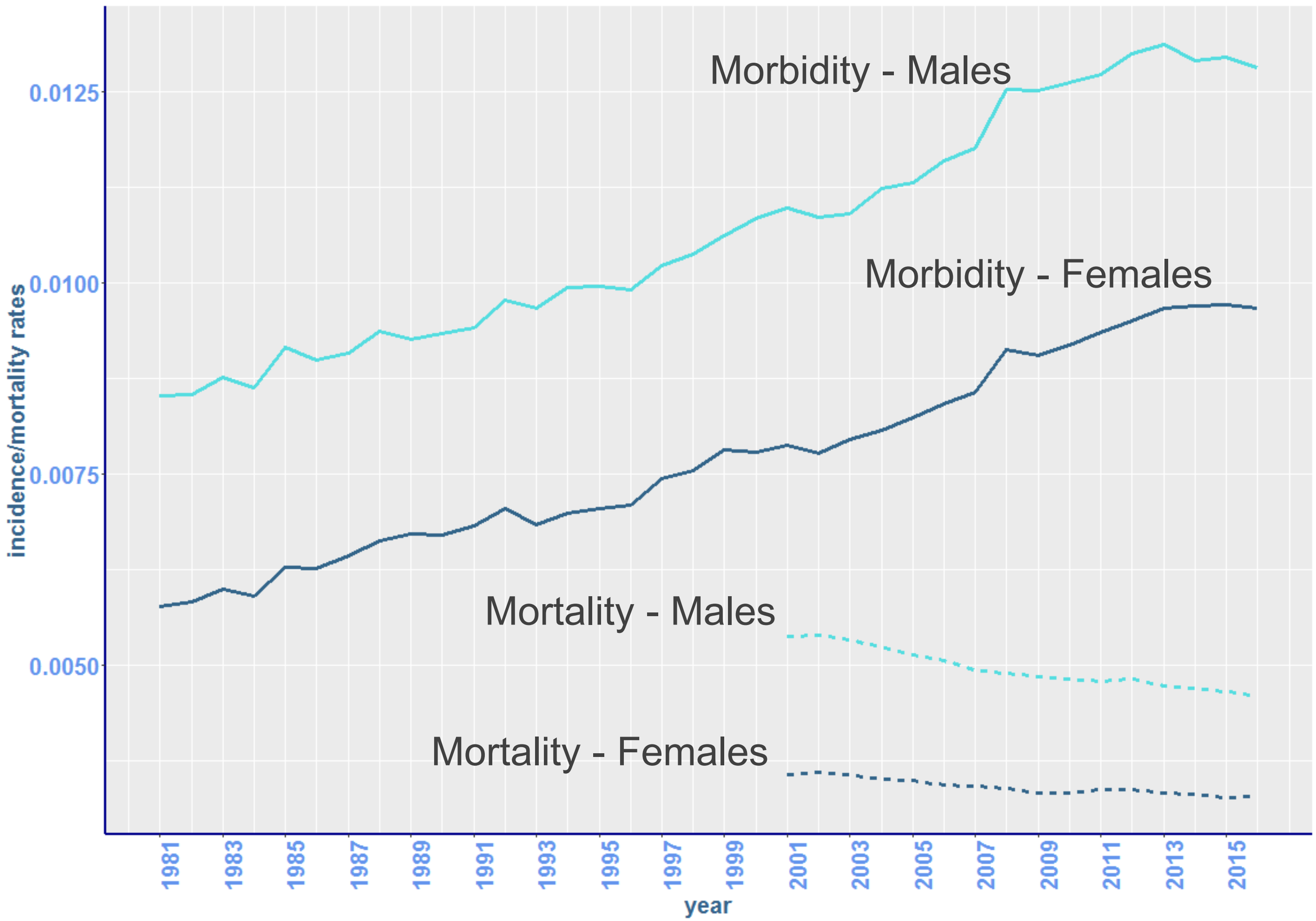
  breast, prostate, lung and colorectal (bowel) cancer

New diagnoses (2016) by age group



- Affects mostly older ages
- Male numbers and rates higher

Age-standardised incidence rates
All cancers 1981 – 2016, Females & Males



- Based on European Standard Population (ESP) 2013
- Increasing trends for morbidity incidence
- Decreasing trends for mortality

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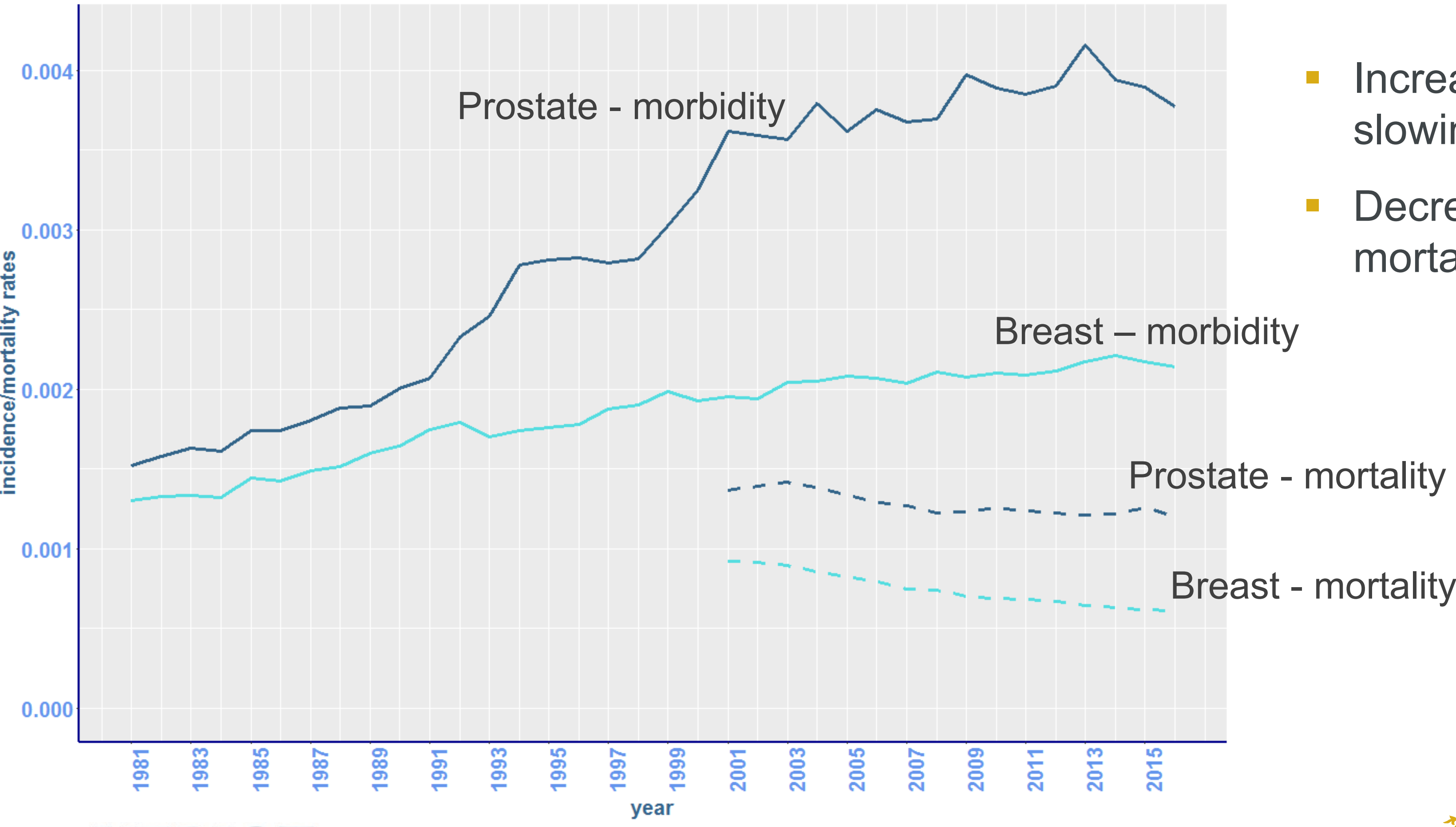
Age-standardised incidence rates
Breast, prostate cancer 1981 – 2016



- Increase in morbidity slowing down
- Decreasing trends for mortality

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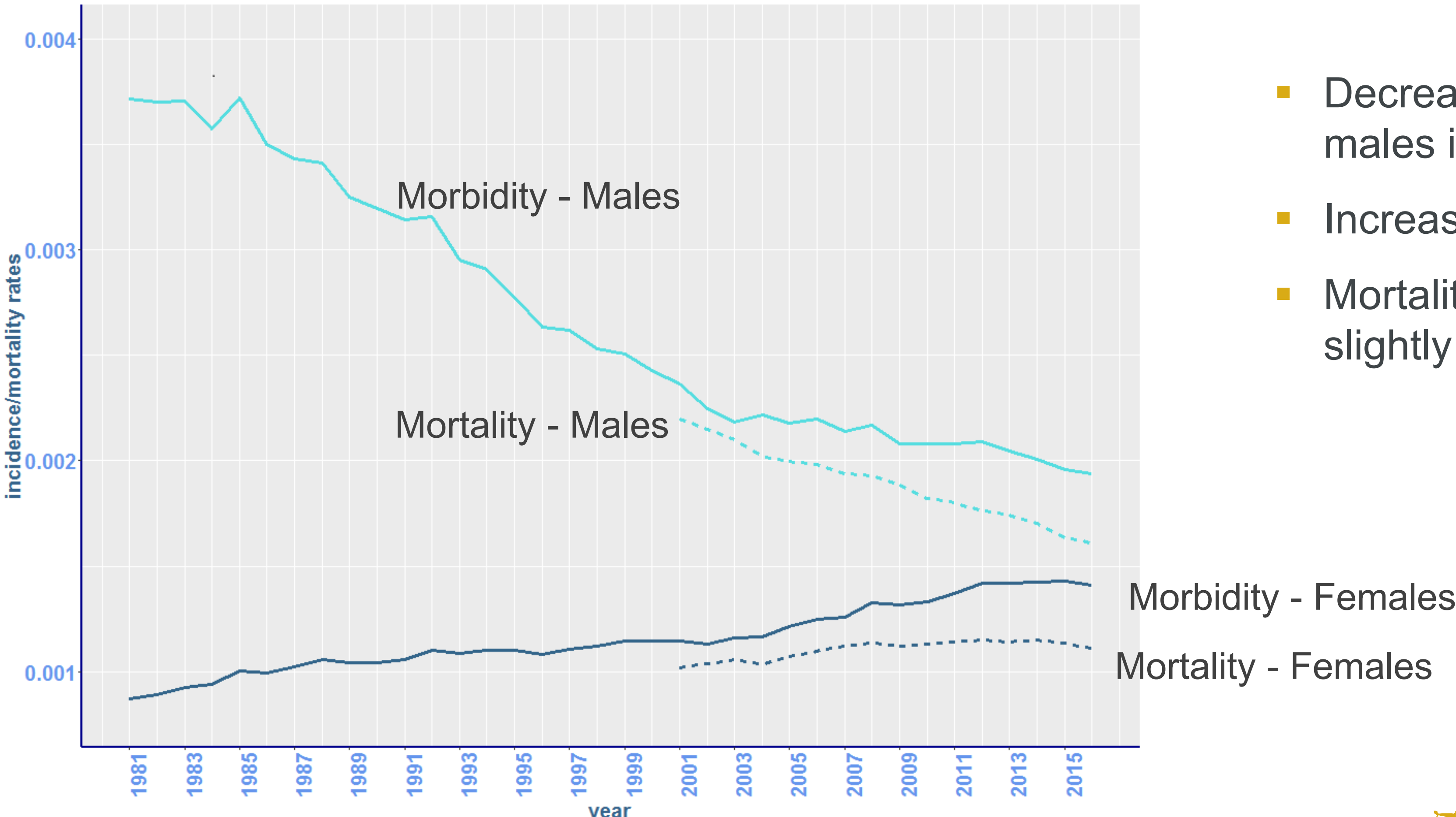
Age-standardised incidence rates
Lung cancer 1981 – 2016



- Decreasing trend for males incidence
- Increasing for females
- Mortality rates only slightly lower

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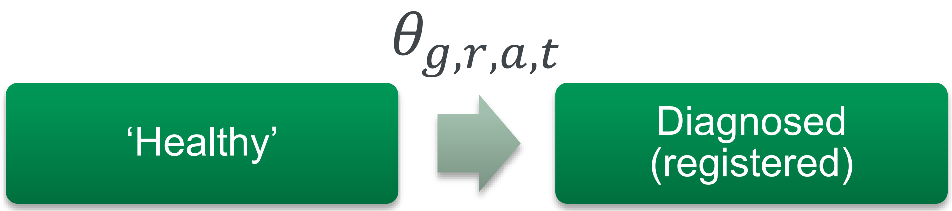
Modelling

Mostly Bayesian stochastic

Stochastic modelling

- Estimation & smoothing of cancer diagnosis (incidence) rates
  - how do rates depend on **risk factors?**
  - gender, region, age, time



- Transition characterised by underlying incidence rate $\theta_{g,r,a,t}$
  - depending on **g**ender, **r**egion, **a**ge, **t**ime

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Bayesian modelling

- Fit hierarchical Poisson model (GLM-type)

$$C_{g,r,a,t} \mid \theta_{g,r,a,t} \sim Poisson\left(E_{g,r,a,t}\theta_{g,r,a,t}\right)$$
$$\theta_{g,r,a,t} \sim Lognormal(\mu_{g,r,a,t}, \sigma^2)$$
$$\mu_{g,r,a,t} = \beta' X$$

with independent priors

$$\beta \sim N\left(0, 10^4\right)$$
$$\sigma^2 \sim \text{InvGamma}(1, 10^{-3})$$

- $C_{g,r,a,t}$: number of new registrations for … *g*, *r*, *a*, *t*
- $E_{g,r,a,t}$: corresponding mid-year populations (ONS)
- *X*: risk factors (*g*, *r*, *a*, *t*) and possible interactions
- *β*s: corresponding coefficients

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Model selection

- Bayesian variable selection methodology used
- Chooses the ‘best’ model for

$$\mu_{g,r,a,t} = \beta' X$$

according to model fitting criteria

(here marginal likelihood, deviance information criterion)

- Results suggest that all 4 main effects (gender, region, age, time) are important
- But various different interactions between them, and polynomials are significant when modelling different cancers

Change points

- Allow for change point(s) in time trends (and age)

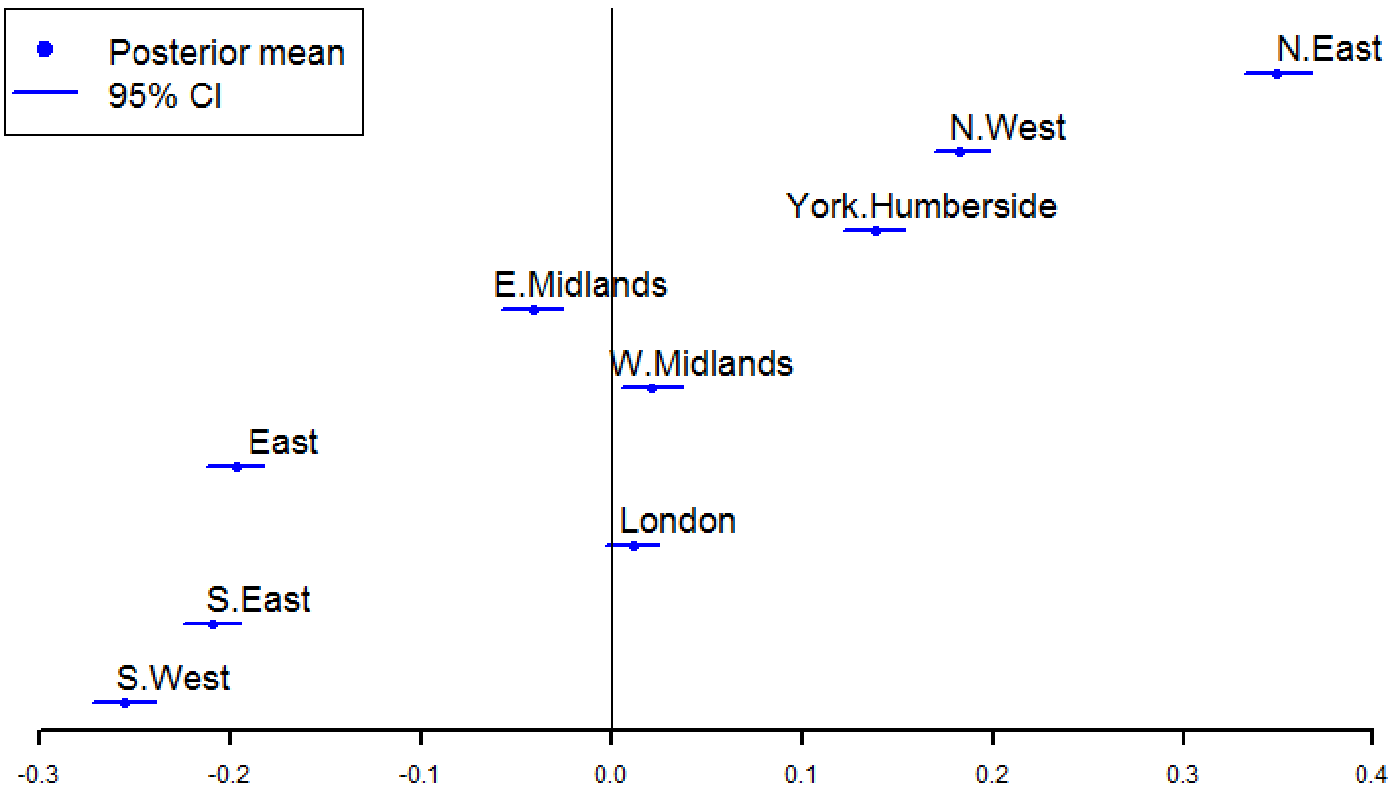
$$\mu_{g,r,a,t} = \beta_0 + \beta_1 \times Year$$

may become

$$\mu_{g,r,a,t} = \beta_0 + \beta_{1,1} \times Year_{<1989} + \beta_{1,2} \times Year_{\geq 1990}$$

- E.g. new trend after new screening policy introduced
- or after a certain age

Stochastic modelling:
Risk factor estimates for lung cancer



Perform variable (factor) selection

Selected model includes:

- ✓ Age (older: ↑)
- ✓ Year (↑)
- ✓ Gender (M: ↑)
- ✓ Region (see plot)
- ✓ Interactions

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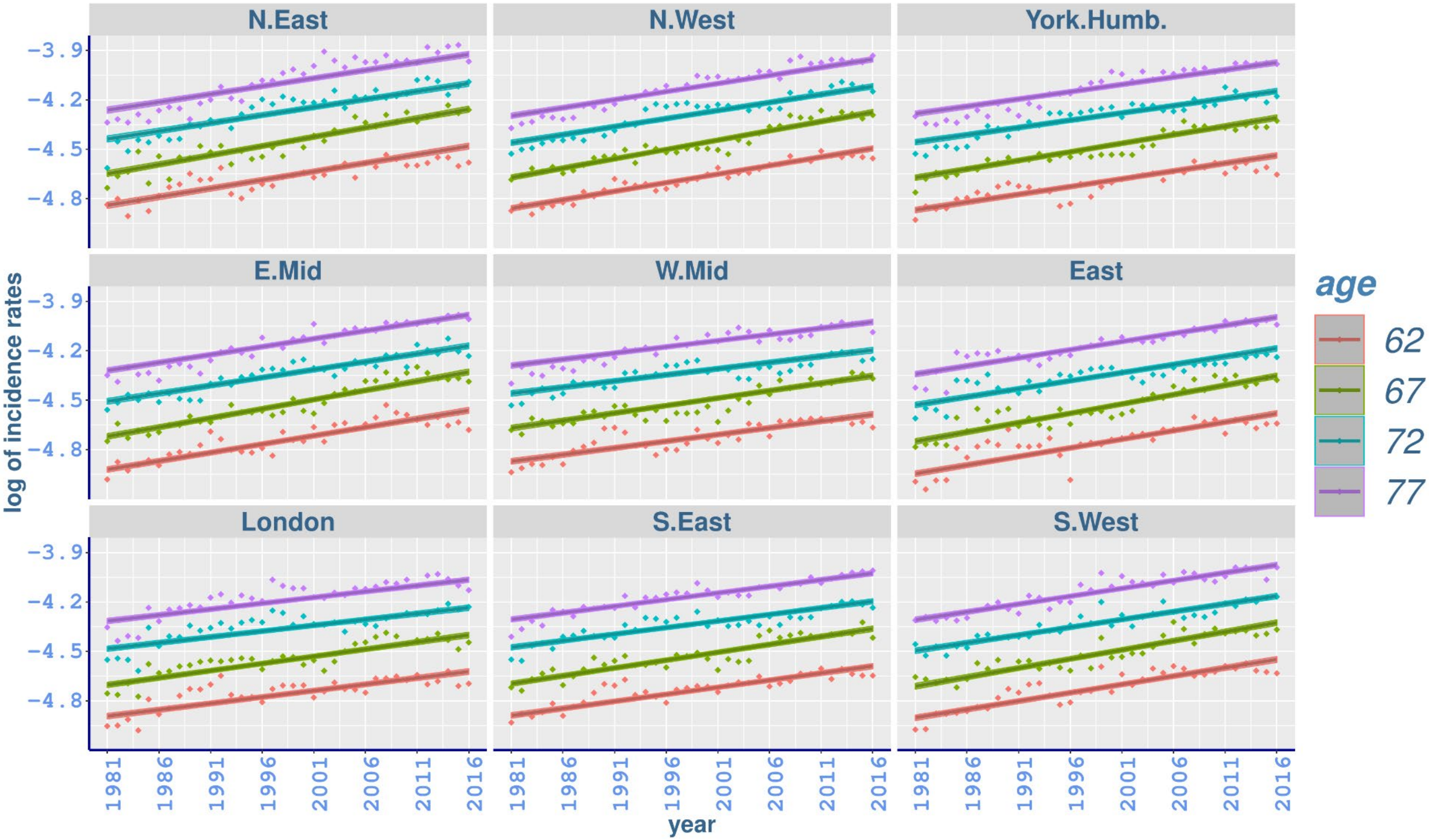
Incidence rates

Smoothed estimates, probability intervals

All cancers incidence – Females (1981-2016)



- Generally increasing over time
- Higher at older ages
- Higher rates for males (not shown)
- Regional variation?

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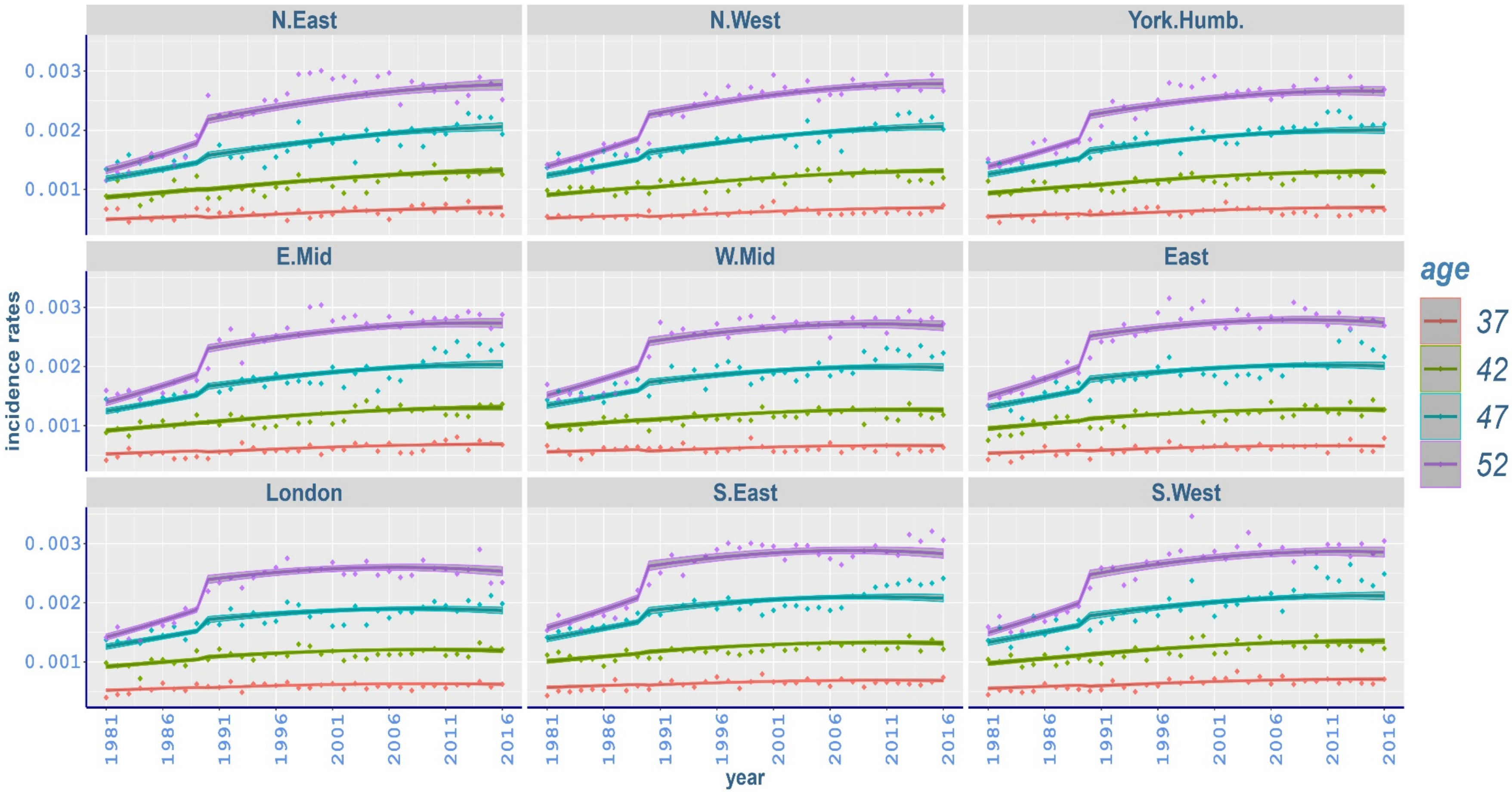
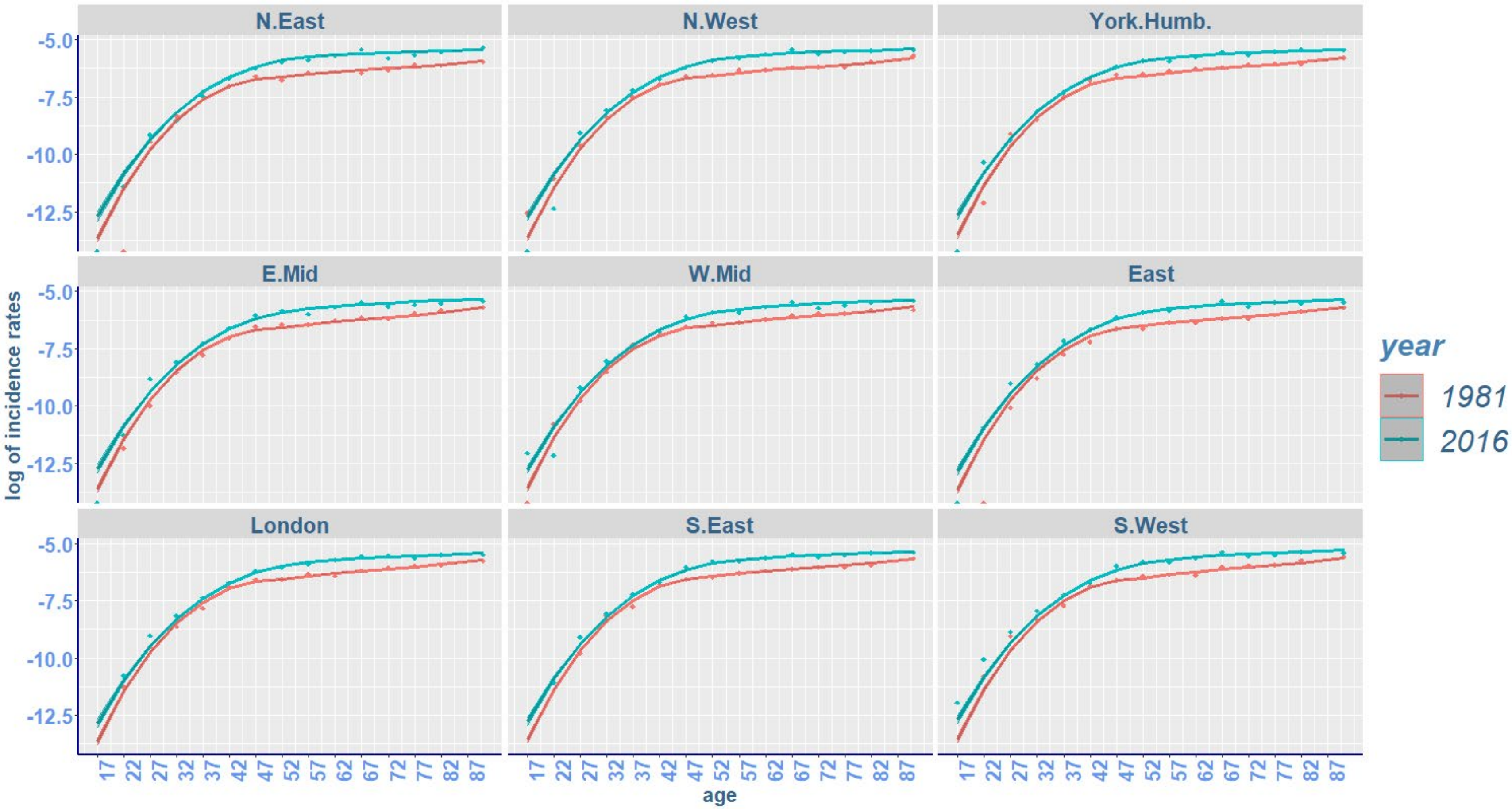
Breast cancer incidence (1981-2016)



- NHS screening introduced in 1988
- Model includes change point in 1989

Breast cancer incidence – by age



- Screening implemented from age 50
- Model change point at 50
- Incidence slows down after ages 45-55

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Lung cancer incidence – Females (1981-2016)

- Increasing rates
- Steeper for older ages

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Lung cancer incidence - males

- Decreasing incidence for males
- Linked to smoking patterns (?)

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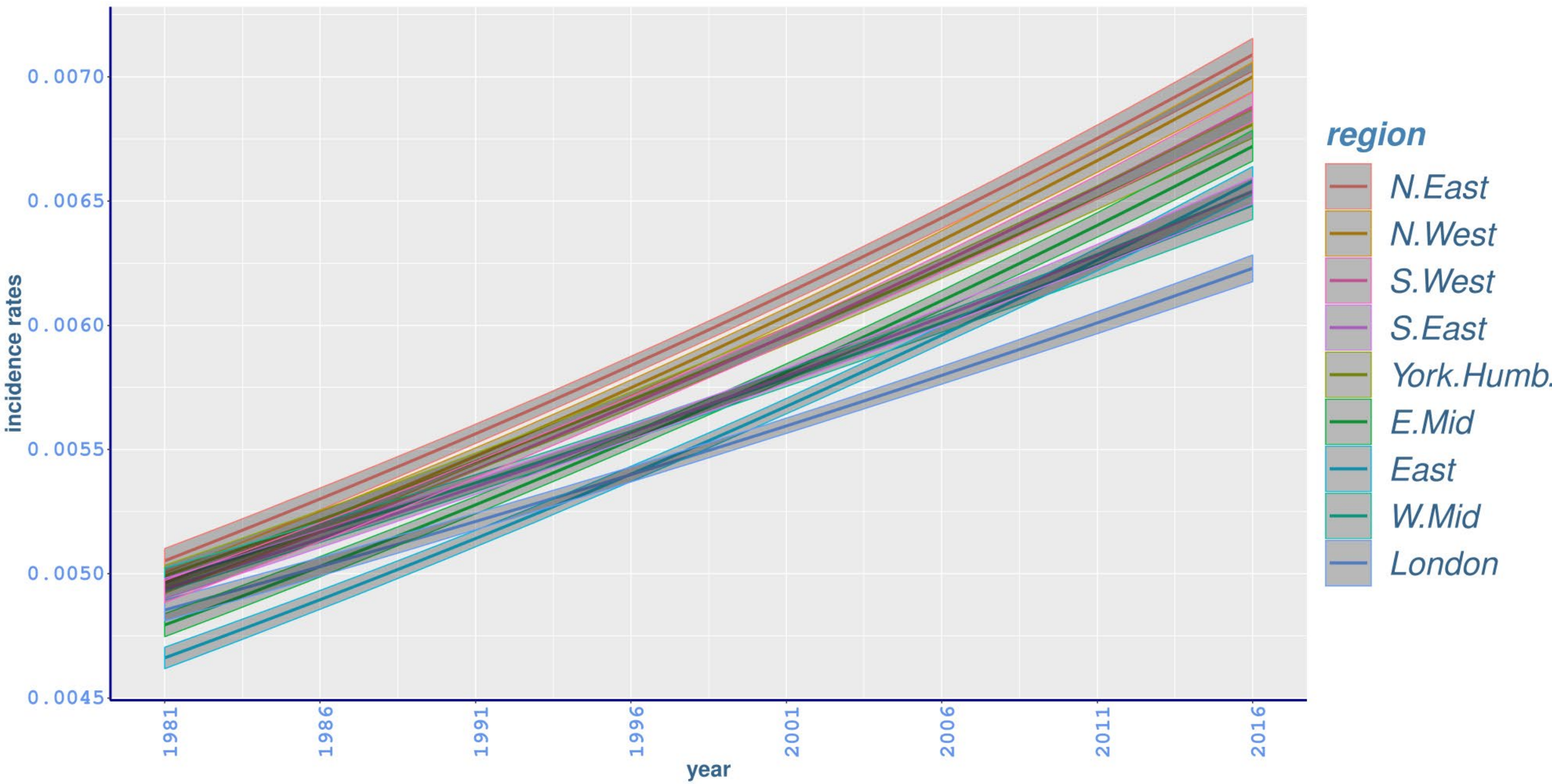
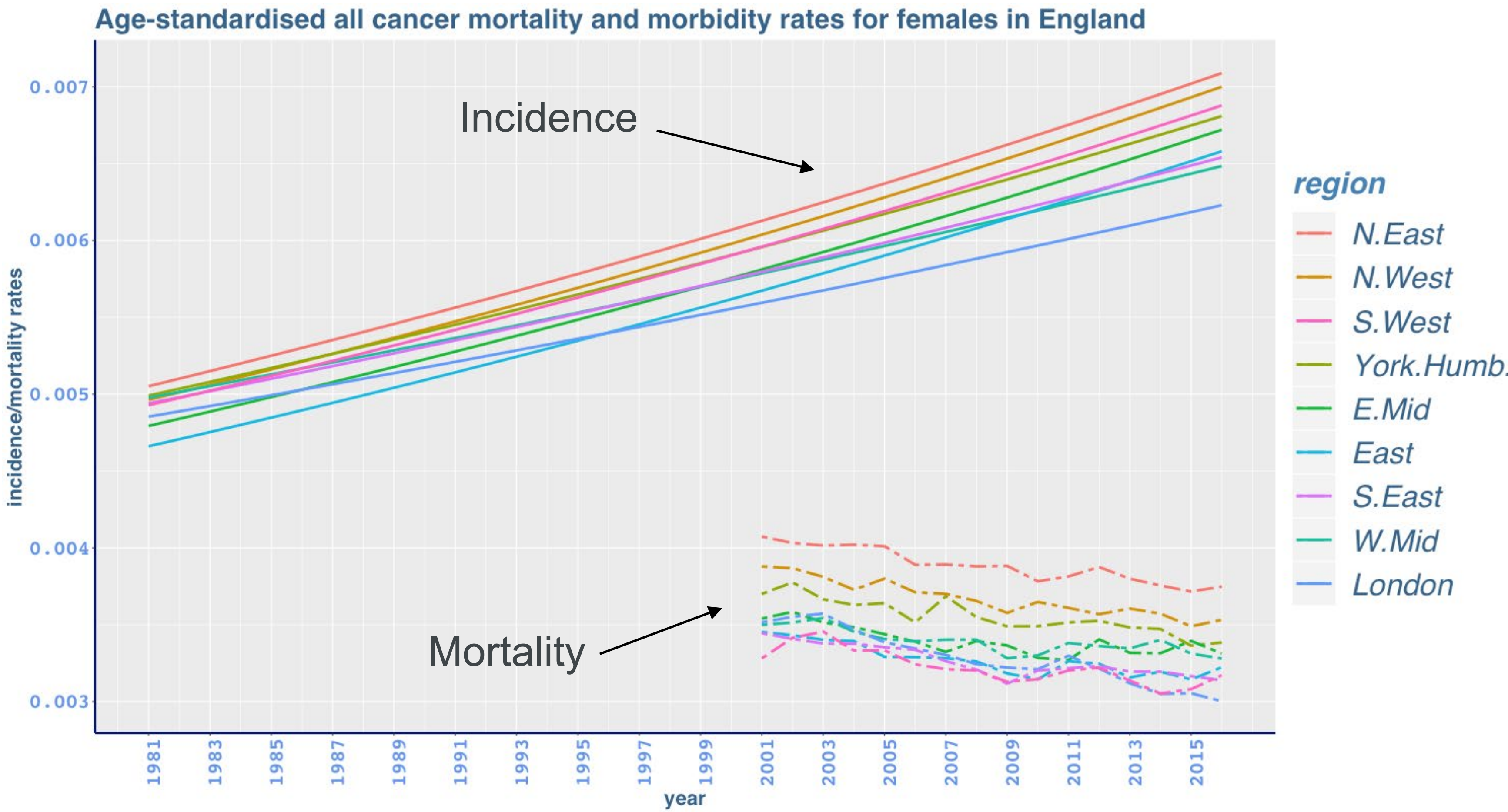
Regional variation

Regional variation - All cancers – Females
Age-standardised fitted incidence (1981-2016)



- Generally increasing over time
- Regional variation getting wider

Regional variation - All cancers – Females



- Different trends in morbidity, mortality
- Regional variation
- London?

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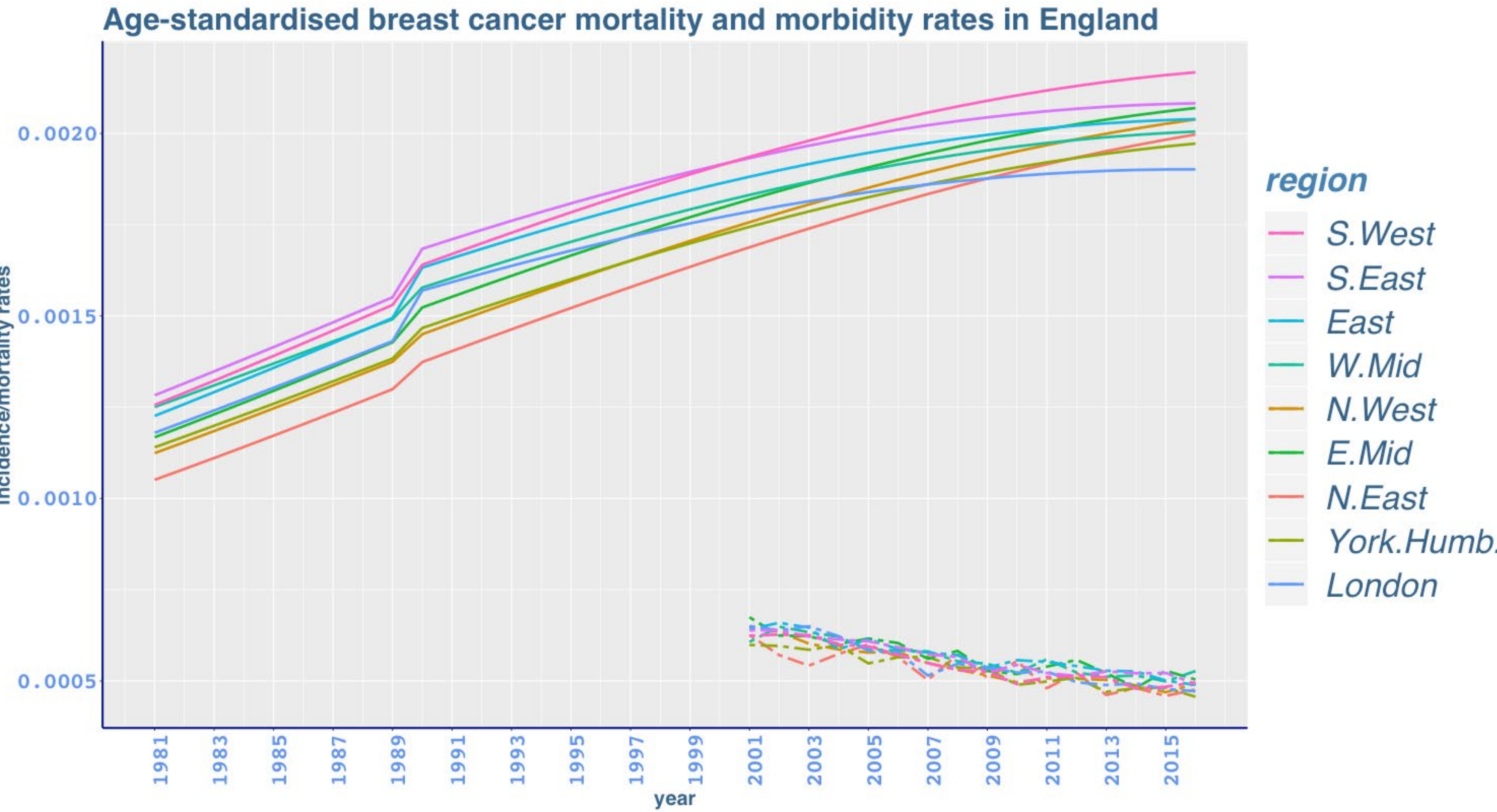
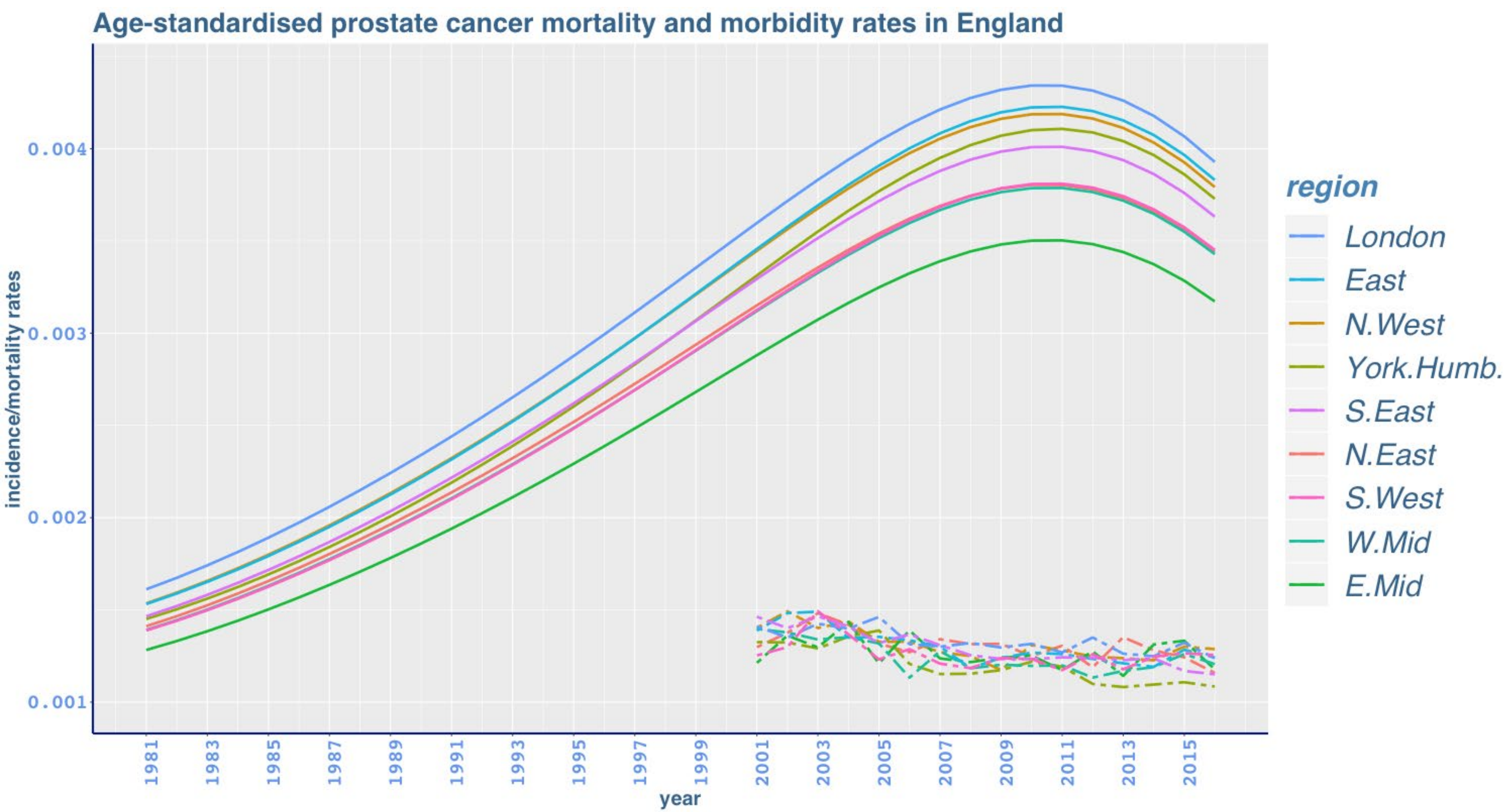
Regional variation – Breast cancer



- Regional variation smaller than for all cancers
- Morbidity *v* mortality trends

Regional variation – Prostate cancer



- Regional variation getting wider
- Morbidity slowing down since c. 2010?
- London?

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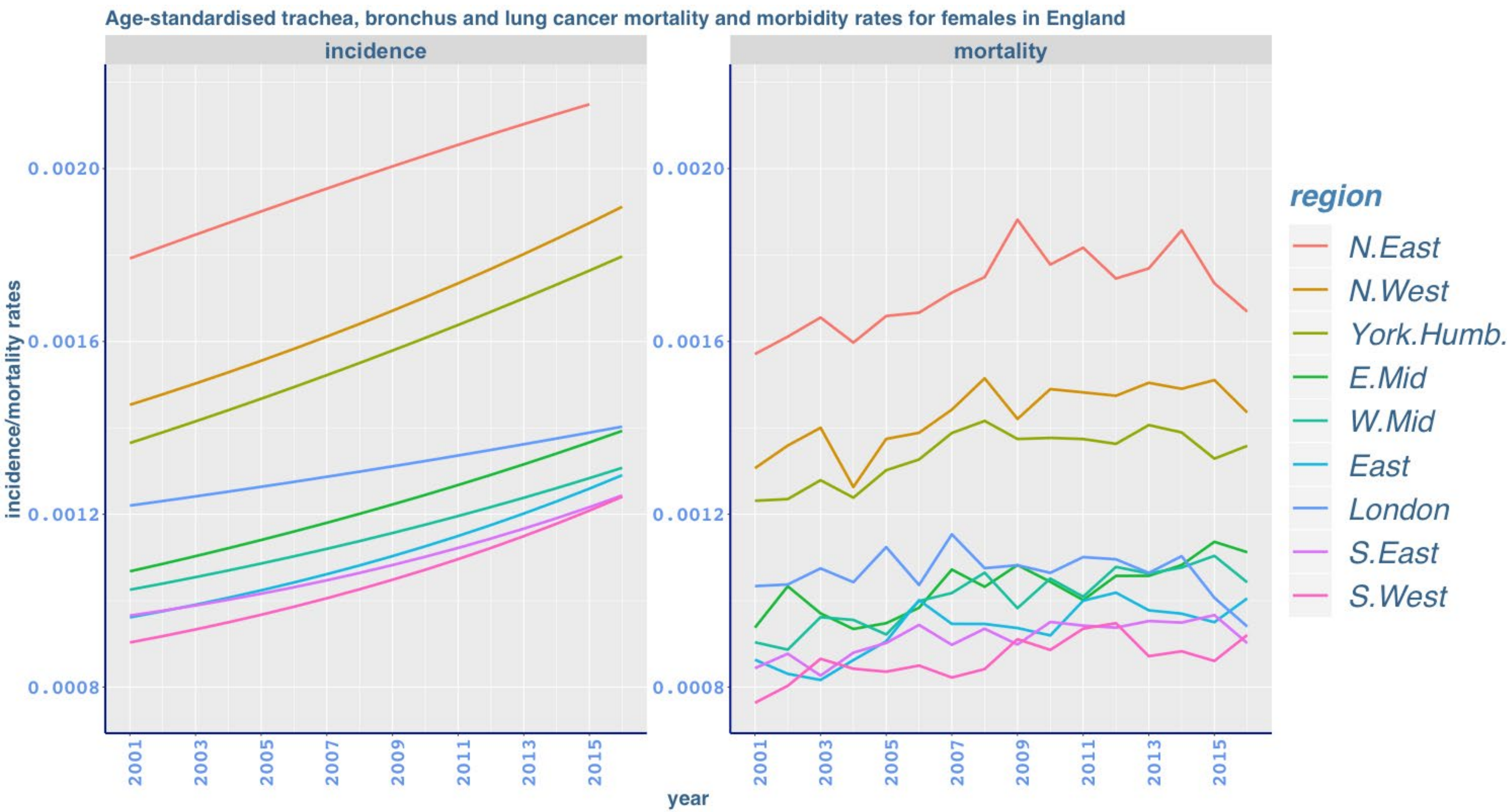
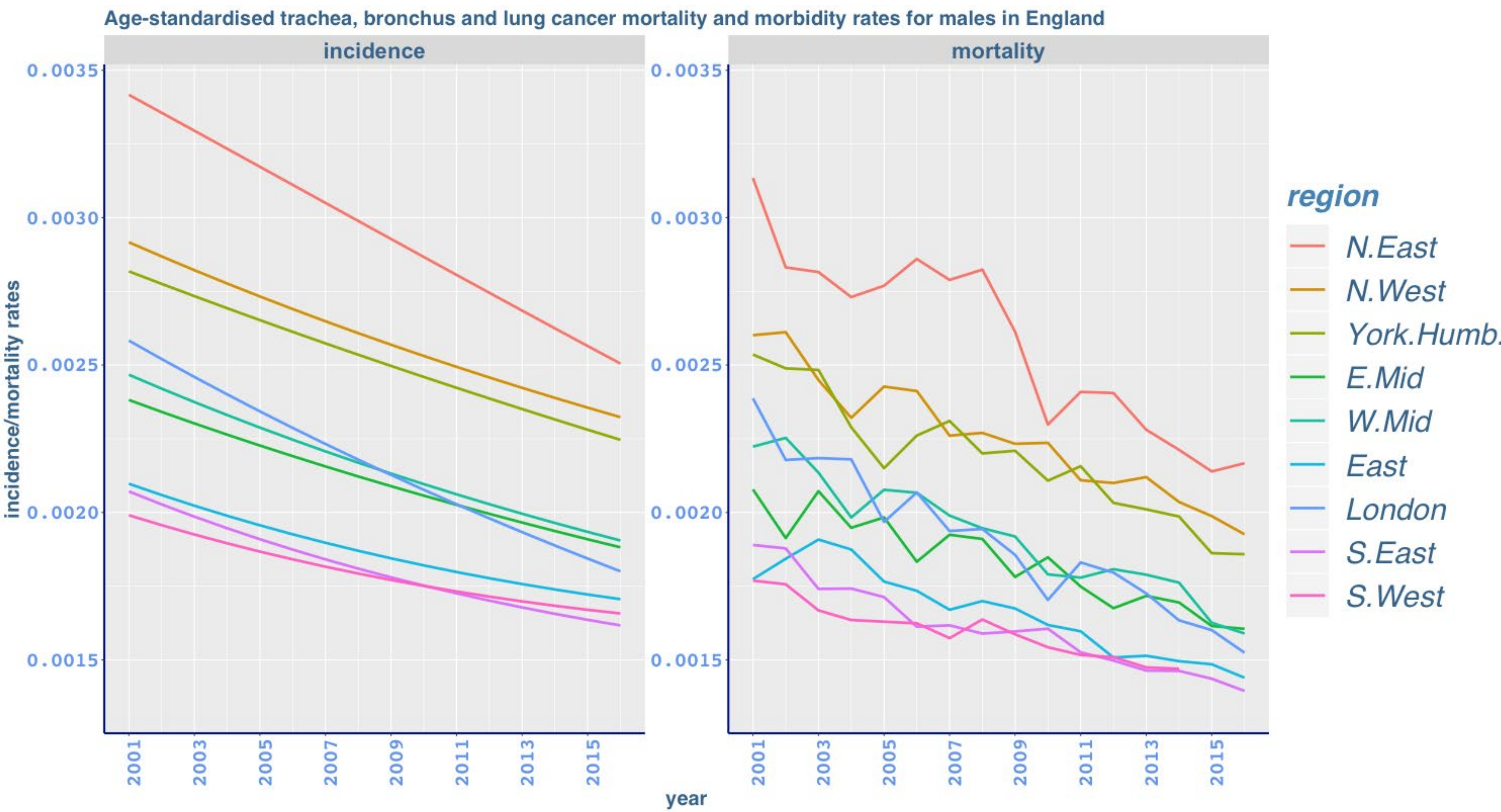
Regional variation – Lung cancer – Females (2001-2016)



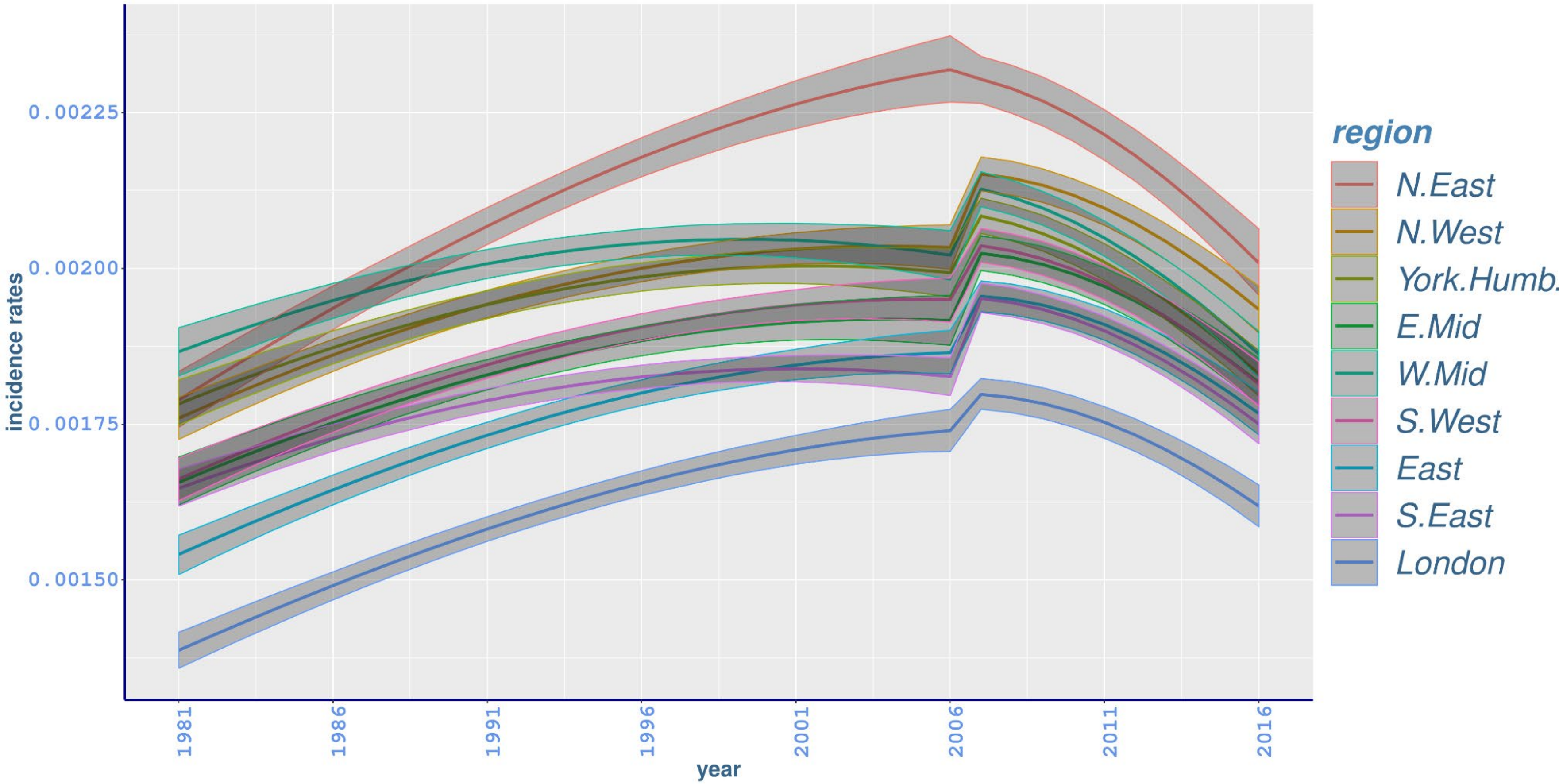
- Increasing trends
- North – South effect
- Mortality at high levels

Regional variation – Lung cancer – Males (2001-2016)



- North – South effect
- Decreasing trends

Regional variation – Bowel cancer – Males (1981-2016)



- Regional effect
- Change point in 2006
- Higher rates than females

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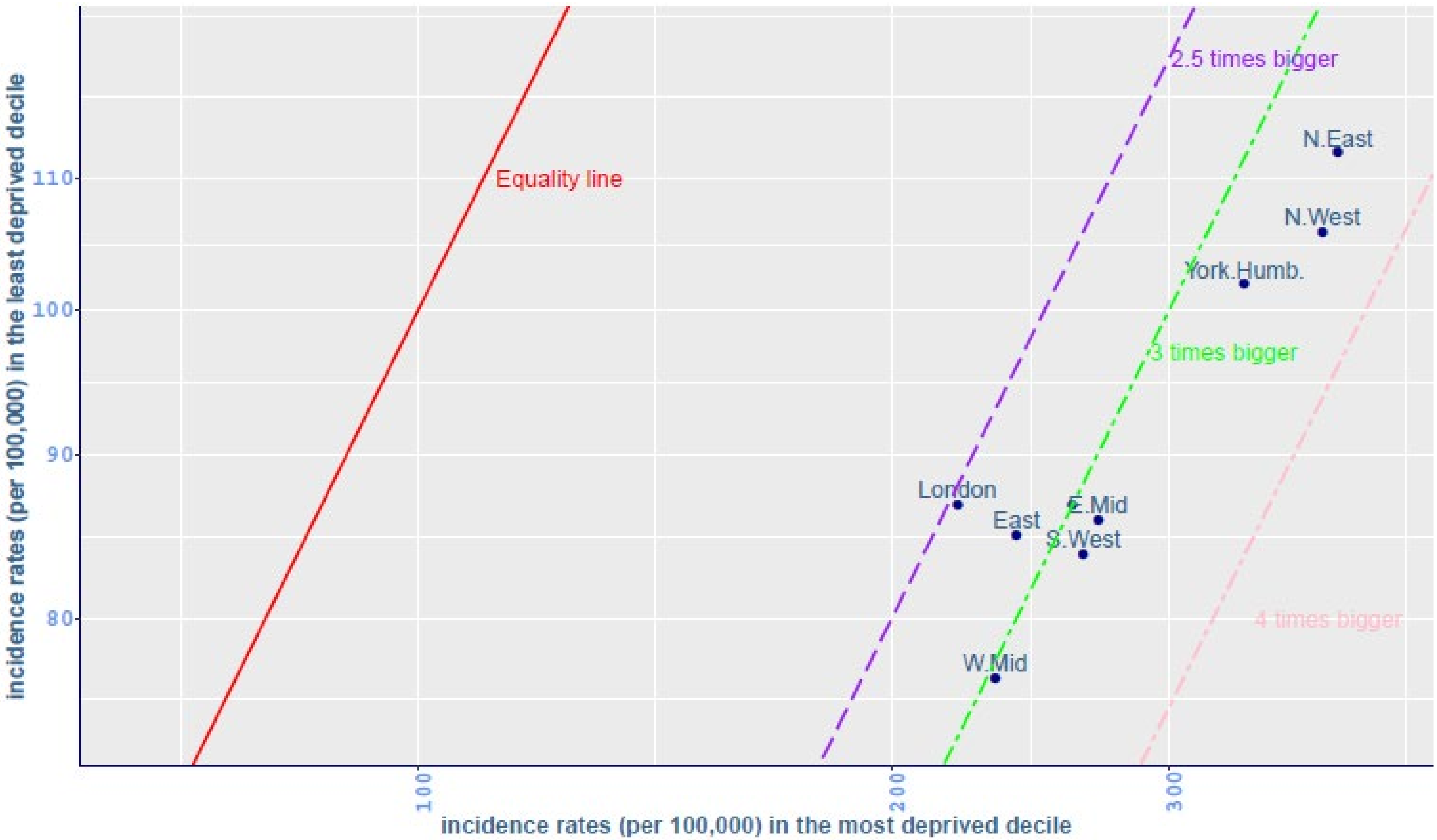
Including Index of Multiple Deprivation (work in progress)

Lung cancer morbidity rates, females (2016)
Most v. least deprived by region



- Incidence for most deprived much higher (by factor 2.5 – 3.5)
- Regional variation

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Comparisons with insured population incidence

Data

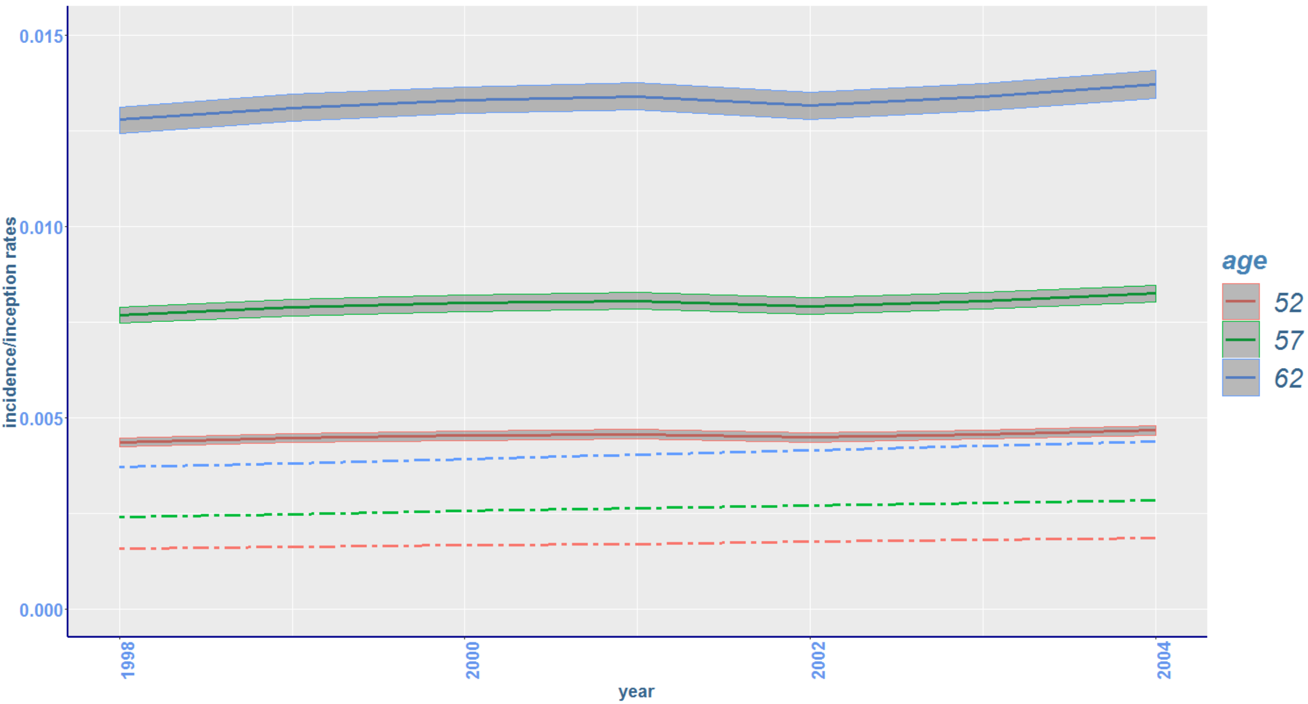
Also available:

- CMI Critical Illness Insurance (CII) data
  - here for 1999-2005
  - policies inforce, 19127 claims settled
  - Cause of claim available (incudes cancer)

Population cancer rates v insurance rates

Males - All cancers

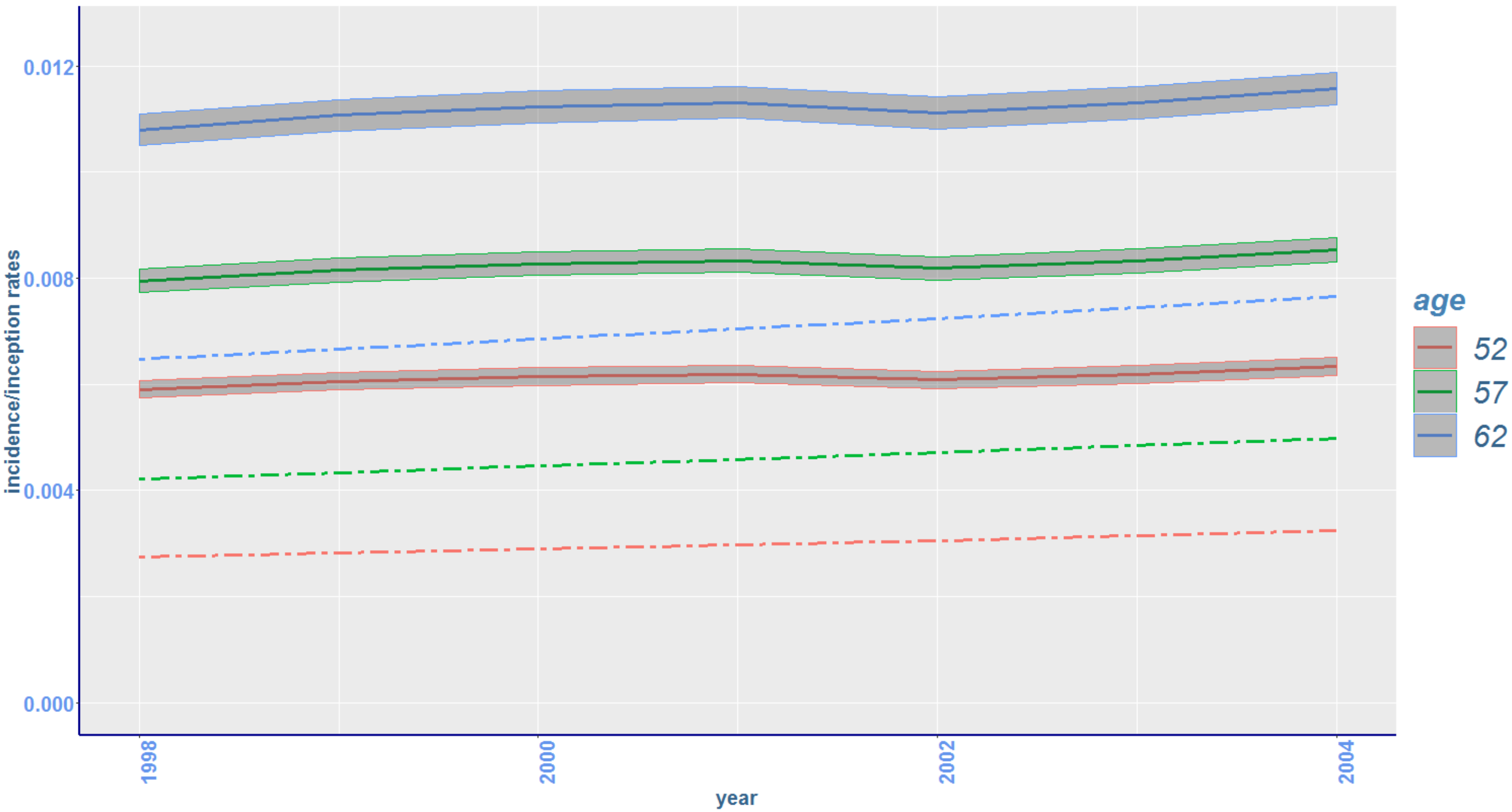
Population ——— ; CII – – –



- Experience for 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 cancers)
  - Underwriting effect?

Population cancer rates v insurance rates

Females - All cancers



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

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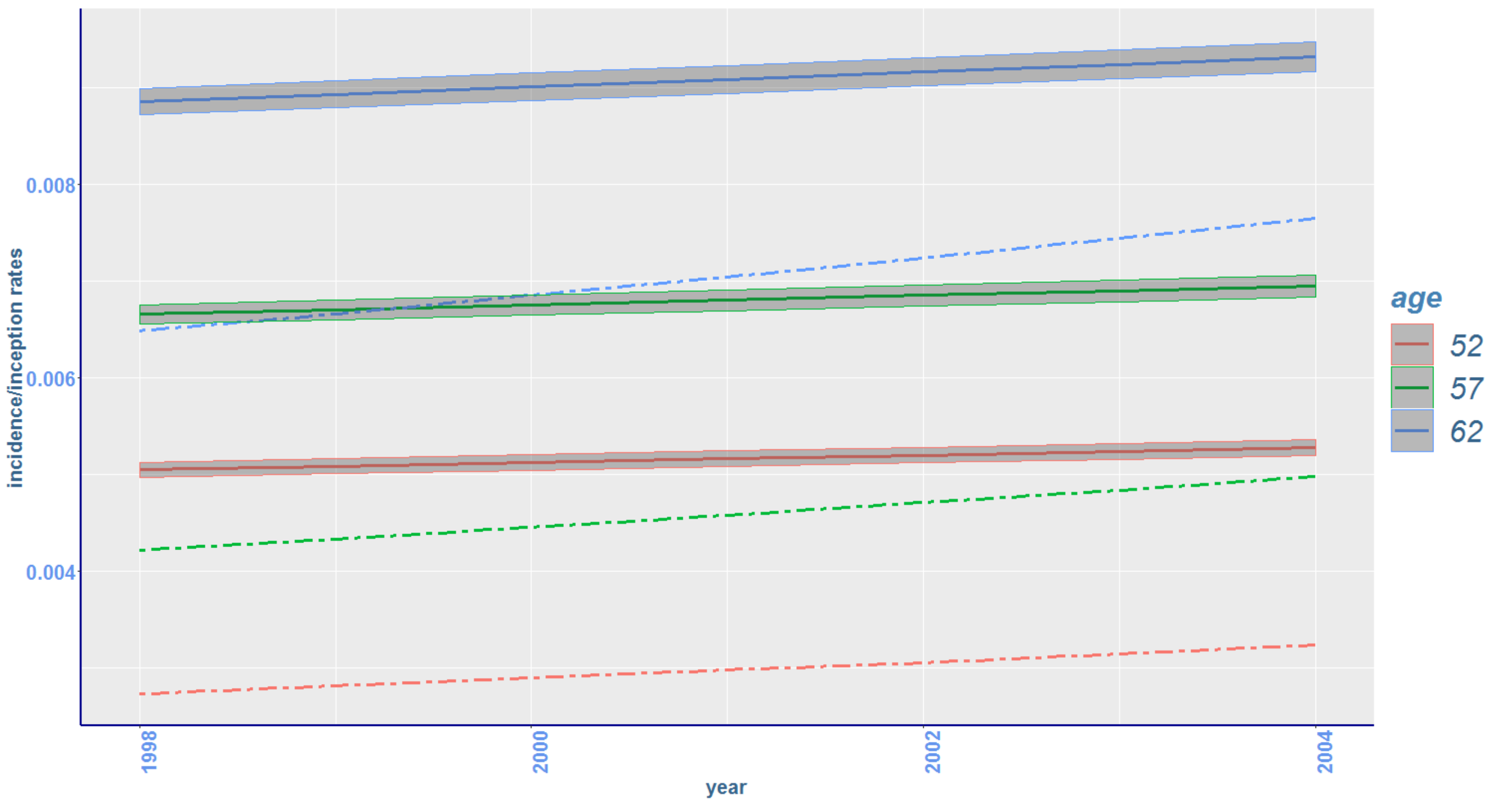
Population cancer rates v insurance rates

Females – Excluding melanoma skin cancer



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

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Conclusions

Conclusions

- Cancer morbidity incidence mostly increasing
- Notable exception: lung cancer for men
- Significant regional (and socio-economic) differences
  - Mostly in ‘life-style’ cancers
- Regional differences higher in 2016 compared to 1981 (mostly)
- Mortality rates falling
  - Are mortality regional differences smaller?
- Insured population incidence lower compared to general population
  - But trends could be different (steeper increase for CII)?

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Continuing work

- Include deprivation factor in the analysis
- Investigate associations between morbidity and mortality
- Investigate other types of cancer
- Compare with more recent critical illness rates
- Build geographical dependence into modelling

Questions

Comments

Work published in:

Arık A., Dodd E., Streftaris G. (2020) Cancer morbidity trends and regional differences in England – A Bayesian analysis. PLoS ONE 15(5): e0232844.

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

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