Trends and Differences in Cancer Morbidity and Mortality Risk in England

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Outline

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Purpose of the study

The main purpose of the study

1. Identify the trends of the more common cancers at different ages and different regions
2. Modelling of regional cancer morbidity risk by deprivation index over time using a Bayesian framework
3. Identify morbidity inequalities between different regions and deprivation levels
4. Compare cancer incidence rates with cancer death rates

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Cancer morbidity risk data groupings

Cancer registration data and cancer cause of death data for England provided by the Office for National Statistics (ONS)

- International Statistical Classification of Diseases (ICD): ICD 10
- Age groups: 0, 1-4, 5-9, ..., 95+
- Single years: 2001 - 2016
- The Index of Multiple Deprivation (IMD)
- Regions of England: North East, North West, Yorkshire and the Humber, East Midlands, West Midlands, East, London, South East and South West
- Gender

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The 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%)

Deprivation	
Level 1	The most deprived group
...	...
Level 10	The least deprived group

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Cancer cause of death data groupings

1	Cancer: mouth, gullet, stomach	2	Cancer: gut, rectum
3	Cancer: larynx	4	Cancer: trachea
5	Cancer: lung and bronchus	6	Cancer: breast
7	Cancer: uterus, cervix	8	Cancer: ovary
9	Cancer: prostate	10	Cancer: other male genital
11	Cancer: skin, bones and certain organs	12	Cancer: lymphatic

- Age groups: 20-24, 25-29, ..., 85+
- Age-standardisation based on European Standard Population (ESP) 2013

Models for incidence rates

$$C_{a,t,d,g,r} \sim \text{Poisson}(\theta_{a,t,d,g,r}\ E_{a,t,d,g,r})$$
$$\theta_{a,t,d,g,r} \sim \text{Lognormal}(\mu_{a,t,d,g,r}, \sigma^2)$$
$$\mu_{a,t,d,g,r} = \boldsymbol{\beta}' \boldsymbol{X}$$
$$\boldsymbol{\beta}\text{'s} \sim \text{Normal}(0, 10^4)$$
$$\sigma^2 \sim \text{Inv.Gamma}(1, 0.001),$$

1. $C_{a,t,d,g,r}$: number of cancer registrations of a given malignant neoplasm at age a in year t for gender g in deprivation level d and region r of England
2. $E_{a,t,d,g,r}$: mid-year population estimates
3. $\theta_{a,t,d,g,r}$: incidence rates of a given malignant neoplasm
4. $\boldsymbol{X}$: vector of covariates, specifically age, year, deprivation, gender and region, in addition to potential interaction(s)
5. $\boldsymbol{\beta}$: appropriate coefficients
6. Bayesian variable selection methodology to decide the best model for $\mu_{a,t,d,g,r} = \boldsymbol{\beta}' \boldsymbol{X}$ based on marginal likelihood & deviance information criterion

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Change points

1. Allow change point(s) in time trends (and age)
2. The pruned exact linear time (PELT) method is considered for detection of changes

$$\mu_{a,t,d,g,r} = \beta_0 + \beta_1 \text{ year} + \dots$$

may become

$$\mu_{a,t,d,g,r} = \beta_0 + \beta_{1,1} \text{ year}_{<2006} + \beta_{1,2} \text{ year}_{\geq 2007} + \dots$$

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

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All cancer incidence

$$\mu_{a,t,d,g,r} = \beta_0 + \beta_{1,a} + \beta_2 t + \beta_3 t^2 + \beta_4 t^3 + \beta_{5,g} + \beta_{6,r} + \beta_{7,d}$$
$$+ \beta_{8,a,g} + \beta_{9,a,d} + \beta_{10,a} t + \beta_{11,g} t + \beta_{12,a,r}$$
$$+ \beta_{13,g,d} + \beta_{14,r} t + \beta_{15,g,r} + \beta_{16,r,d}$$
$$+ \beta_{17,a} t^2 + \beta_{18,a} t^3 + \beta_{19,r} t^2$$

- age is a categorical variable with $a = 1, 2, \ldots, 14$
- year, denoted by t, is a numerical variable with $t \in \{2001, \ldots, 2016\}$
- gender is a categorical variable with $g = 1, 2$
- region is a categorical variable with $r = 1, \ldots, 9$
- deprivation is a categorical variable with $d = 1, \ldots, 10$

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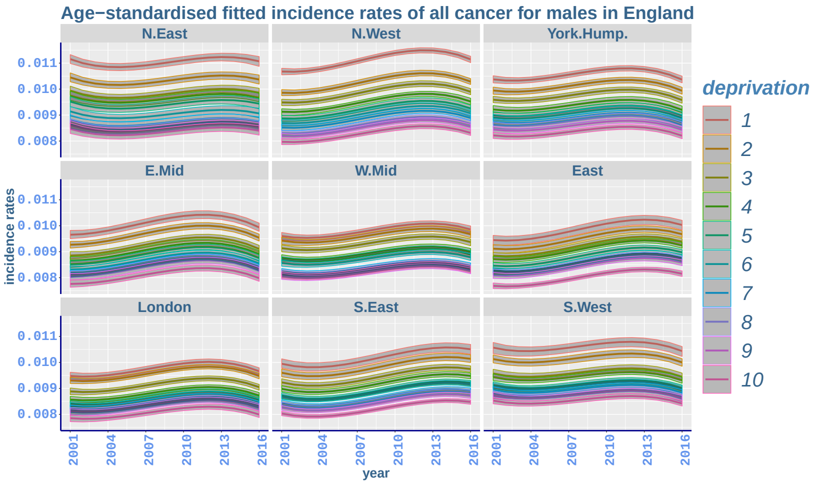
All cancer incidence: males

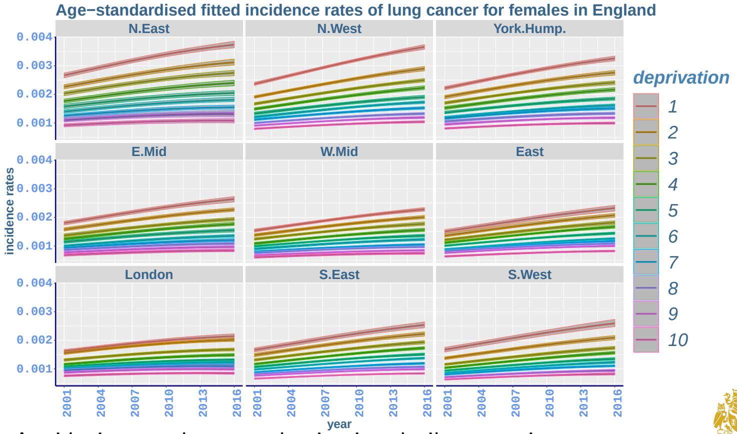


- Pronounced differences between deprivation deciles
- Regional differences ?

Trachea, bronchus and lung cancer incidence: females

$$\mu_{a,t,g,r} = \beta_0 + \underbrace{\boxed{\beta_{1,a}}}_{a=1,\ldots,9} + \underbrace{\boxed{\beta_{.}\, t^m}}_{m=1,\,2}$$

$$+ \text{gender} + \text{region} + \text{deprivation} + \text{interactions}$$



- A widening gap between deprivation deciles over time

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Colorectal (bowel) cancer incidence

- The National Bowel Cancer Screening Programme began in 2006, targeted population between ages 60 and 69
- We have a break point in 2006

$$\mu_{a,t,g,r} = \beta_0 + \underbrace{\boxed{\beta_{1,a}}}_{a=1,\dots,9} + \underbrace{\boxed{\beta_{.,1} t_1^m + \beta_{.,2} t_2^m}}_{m=1,\dots,3}$$

$$+ \text{gender} + \text{region} + \text{deprivation} + \text{interactions}$$

Table 1: Bayesian variable selection based on marginal likelihood&DIC for main effects in bowel cancer when age is categorical&year is numerical

	variable added	marginal lik.	diff of mlik	DIC
1	null	-276904.21		553736.35
2	age	-85942.14	190962.06	171805.90
3	gender	-74600.86	11341.28	149119.36
4	region	-74238.50	362.35	148340.49
5	deprivation	-74120.32	118.18	148043.63
	When we consider change points			
6	year with break point	-73976.24	119.48	147739.43

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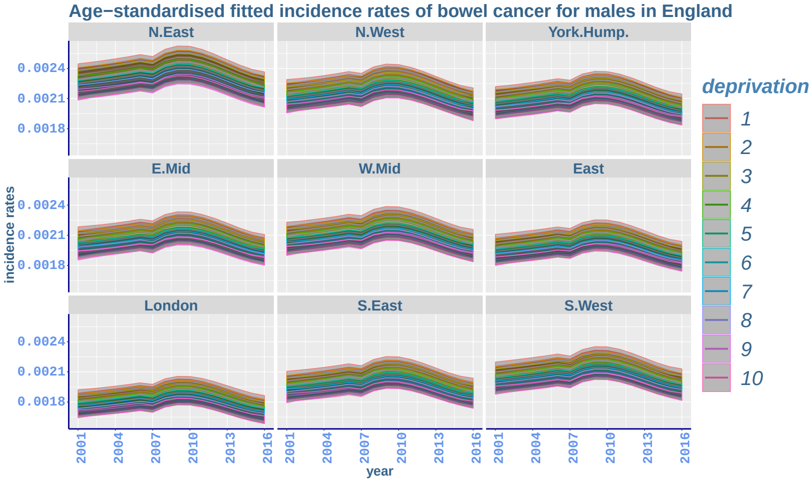
Colorectal (bowel) cancer incidence: males



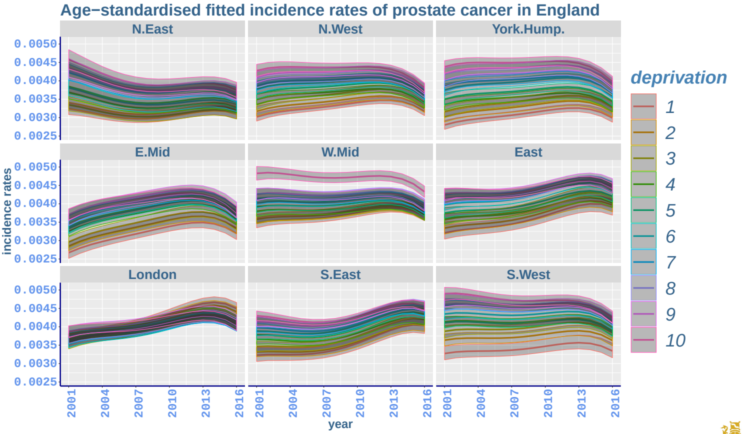
- In 2010, screening was extended to aged 74
- The rates are dropping in the most recent years

Prostate cancer incidence

$$\mu_{a,t,g,r} = \beta_0 + \boxed{\beta_{1,a}} + \boxed{\beta_{.} t^m} + \text{region}$$

a=1,. . . ,9 m=1,. . . , 4

$$+ \text{deprivation} + \text{interactions}$$



- Less deprivation inequality yet bigger regional inequality

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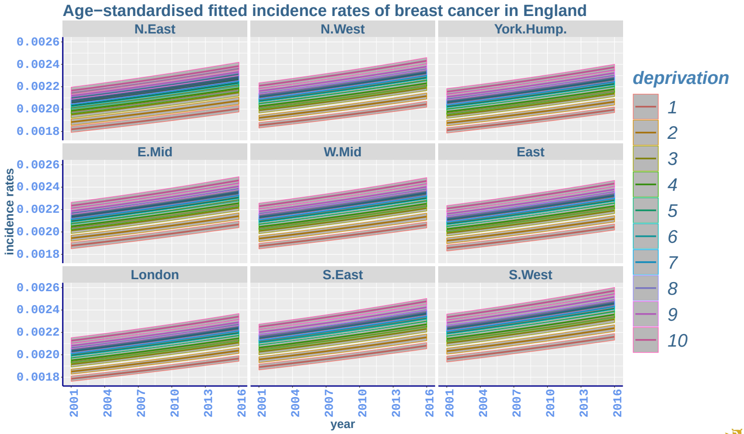
Breast cancer incidence

$$\mu_{a,t,g,r} = \beta_0 + \boxed{\beta_{1,a}} + \text{year} + \text{region}$$

a=1, . . . ,14

$$+ \text{deprivation} + \text{age:year}$$



- An increasing trend in all regions

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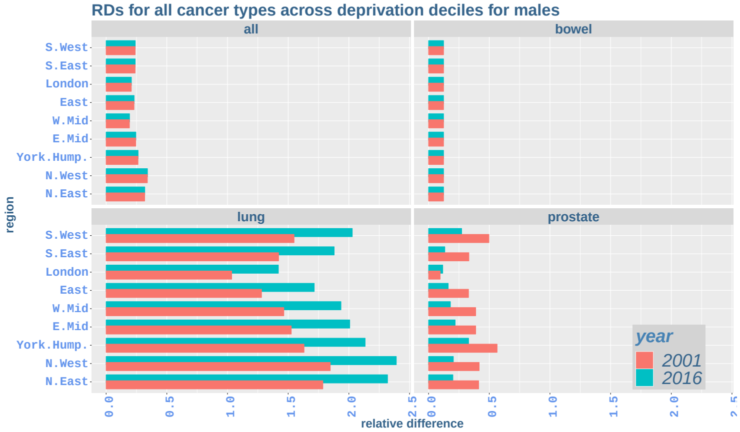
Variation in the IMD: males



$$AD_{t,r} = HR_{t,r} - LR_{t,r}$$

$$RD_{t,r} = \frac{HR_{t,r} - LR_{t,r}}{LR_{t,r}}, \quad t = 2001, 2016$$

where $HR_{t,r}$ is the highest rate and $LR_{t,r}$ is the lowest rate in year t for each region r.

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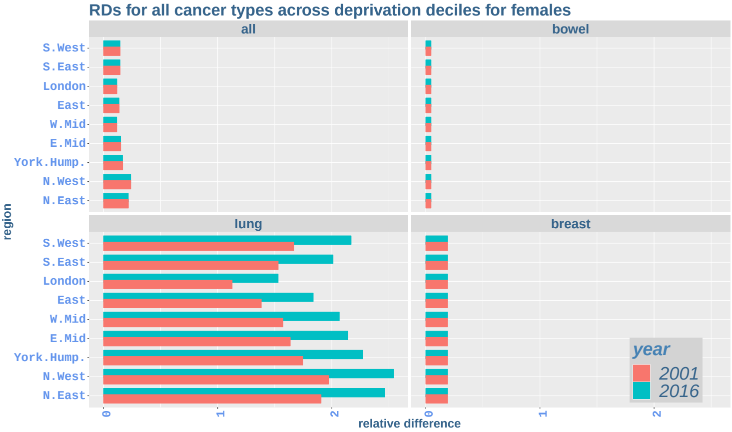
Variation in the IMD: females



- The change in RD is the highest in lung cancer for both genders
- RD in prostate cancer has declined for all regions apart from London
- RD in other cancer types mostly remained unchanged

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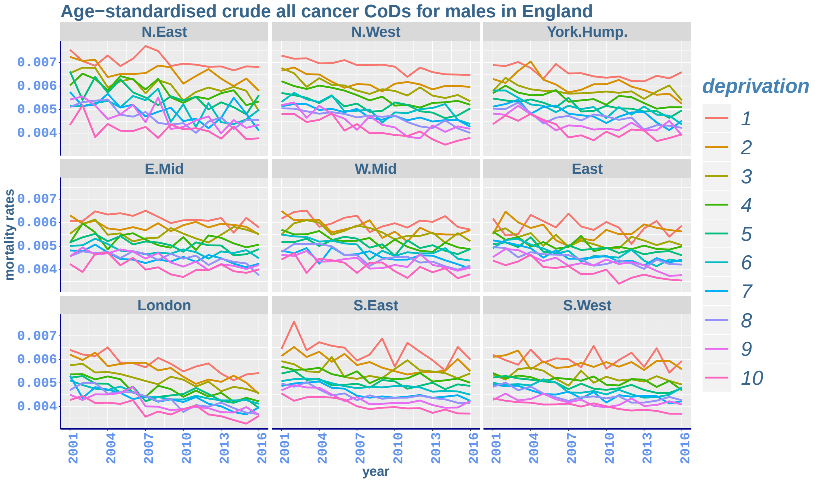
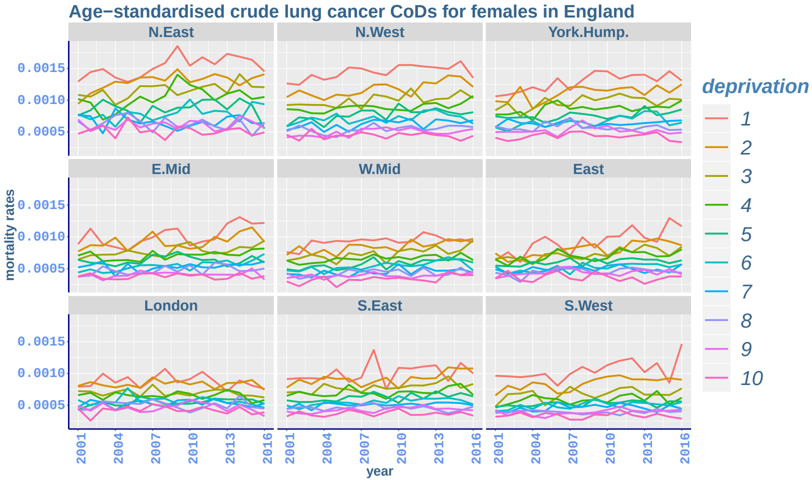
Crude all cancer mortality rates: males



- Pronounced differences between deprivation deciles
- A decreasing trend in all regions

Crude lung cancer mortality rates: females



- Remarkable differences between deprivation deciles depending on region
- Flattened rates for more affluent groups yet an increasing trend for more deprived groups

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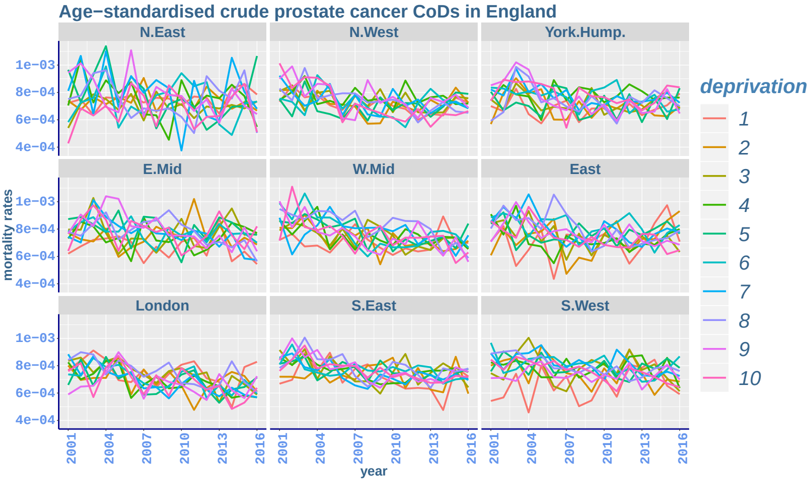
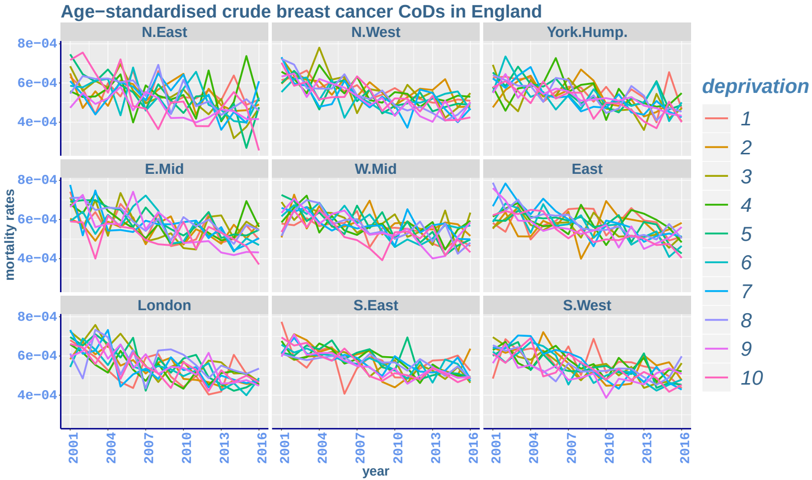
Crude prostate cancer mortality rates



- A slightly decreasing trend with the flattened rates in the most recent years
- Less deprivation or regional inequality

Crude breast cancer mortality rates



- A decreasing trend in all regions
- Less deprivation or regional inequality

Summary

- Deprivation and regional inequalities for all cancer morbidity are widening
- Remarkable deprivation and regional differences in lung cancer rates for both genders
- Deprivation inequality for bowel cancer morbidity rates remained unchanged
- Deprivation inequality for prostate cancer morbidity rates declined apart from London
- Deprivation inequality for breast cancer morbidity rates remained unchanged
- Crude CoD rates suggest inequalities for all cancer and lung cancer but not for prostate and breast cancers

Forthcoming research: Correlating morbidity and mortality datasets

Sources

1. Arık, A., Dodd, E., Streftaris, G.. Cancer Morbidity Trends and Inequalities in England - a Bayesian Analysis. Working paper.
2. Office for National Statistics. Cancer registration statistics, England, 2008, 2009, 2011, 2013 and 2016.

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Thank You!

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