Modelling cancer risk – uneven outcomes

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SCOR Foundation Webinar:
Cancer, COVID-19 and Inequalities
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Estimating the impact of the COVID-19 pandemic on breast cancer

Dr A Arik, Prof G Streftaris

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Network

Research funding from:

- Society of Actuaries (US)

  HWU Centers of Actuarial Excellence

  Predictive Modelling for Medical Morbidity Risk Related to Insurance

CAE Center of Actuarial Excellence
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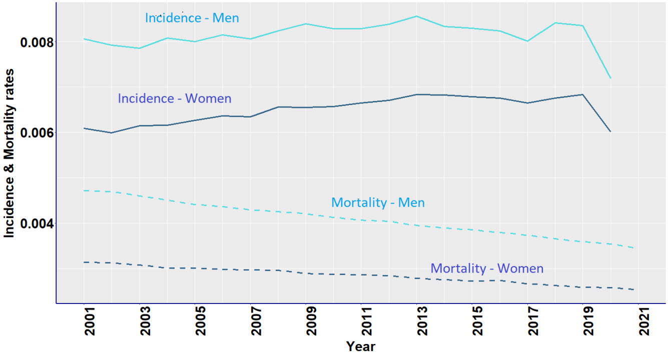
Collaborators:

- Dr A Arik (HWU)
- Prof A Cairns (HWU)
- Prof E Dodd (Southampton)

Trend over time: 2001-2021

All-cancer incidence & mortality (no modelling)
Age standardised rates



Increasing (flattening) trends for incidence

Decreasing mortality trends

Higher rates for men

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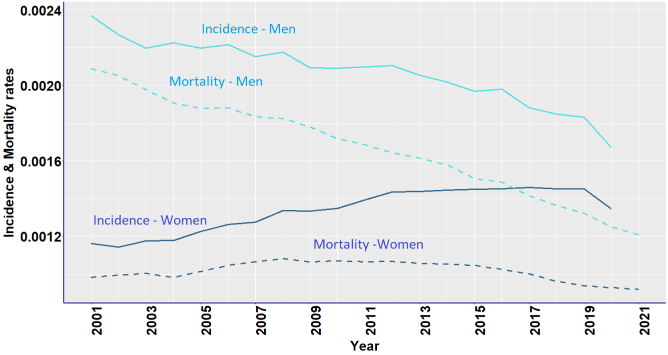
Notable exception in trend:

Lung cancer, 2001-2021 (no modelling)

Age standardised rates



Decreasing incidence, mortality for men

Increasing incidence for women

Regional and socioeconomic differences in cancer rates?

- How big is the gap?
- Is it getting better? Worse?
- What is the future outlook?

We need modelling - to account for uncertainty and noise.

Cancer data

Cancer incidence and deaths data
England: Office for National Statistics (ONS)

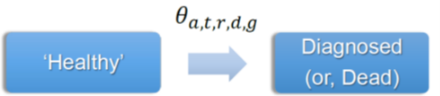
- Age groups: <1, 1-4, 5-9, ..., 95+

  Age-standardised results, based on the European Standard Population (ESP) 2013
- Gender
- Years: 2001 - 2017 (*some* up to 2021)
- Income Deprivation (ID) decile (or quintile)

  1: most deprived; 10: least deprived
- Regions of England:
  North East, North West, Yorkshire and the Humber, East Midlands, West Midlands, East, London, South East, South West

Stochastic modelling

- Bayesian (GLM-type) Poisson model for cancer rates



- Transition characterised by underlying rate $\theta_{a,t,r,d,g}$
- $\theta_{a,t,r,d,g}$: incidence (or mortality) rate depending on:

  age, **t**ime, **r**egion, **d**eprivation, **g**ender

$$E[\log(\theta_{a,t,r,d,g})] = \beta_0 + \beta_1\, age + \beta_2\, time + \beta_{3,reg} + \beta_{4,depr} + \beta_{5,gend}$$

  (later, also age-at-diagnosis, smoking)

- Quantify uncertainty (probability intervals)

Initial findings and main trends (Arik et al, 2020, 2021)

Important factors:

- All-cancer and *life-style* cancers, e.g. lung and bowel cancer: all main variables (age, time, deprivation, gender, region) are **important**
- Breast and prostate cancer mortality: deprivation is **not** important

How do various factors affect rates? (in general ...)

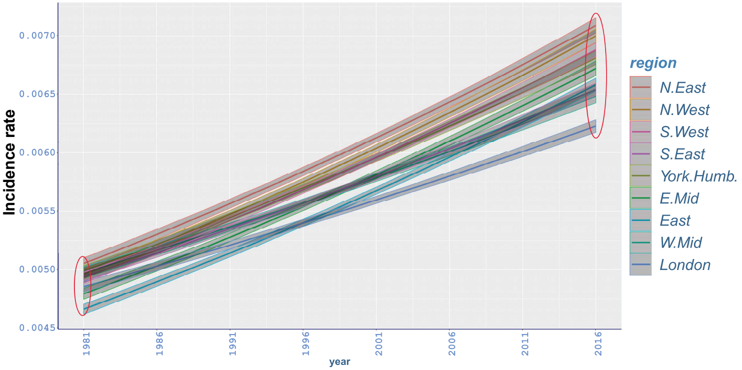
- Age: higher rates at older ages
- Time:
  - higher incidence in more recent years
  - lower mortality
- Gender: higher rates for men
- Region? Deprivation?

Regional & socio-economic variation in cancer rates?

- Is there a geographical pattern?
- Are rates different for those more deprived?
- Does variation change over time?
- Is variation the same for different types of cancer?

Regional variation

All cancer incidence – Females, 1981-2016



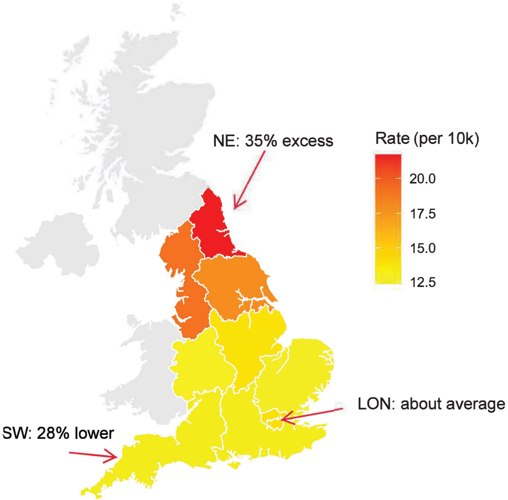
Increasing trend in all regions

Higher incidence in north

Gap widening with time

Regional effect

Lung cancer incidence – Females, 2017

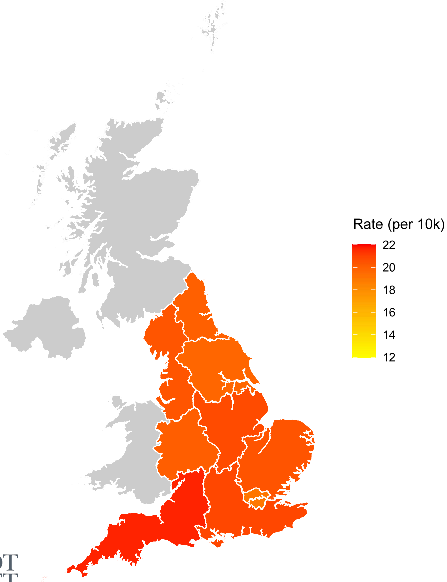


Regional effect compared to average

North v. south?

Regional effect

Breast cancer incidence – 2017



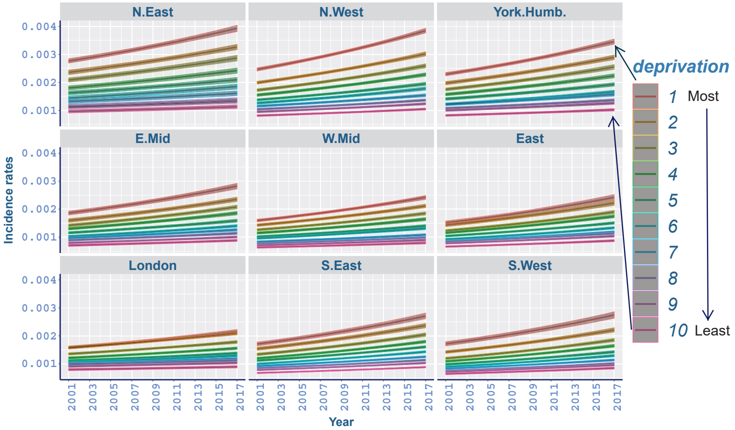
Not a 'life-style' cancer

Regional variation much lower

Deprivation inequality in cancer rates

Lung cancer incidence – Females, 2001-2017

Income deprivation: (1) most deprived ... (10) least deprived



Higher rates for most deprived (1)

Differences by ID getting wider through time

Inequalities more evident in northern regions

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Mortality in future: Bayesian forecasting

Main (GLM-type) Poisson model for mortality rates:

...

$$E[\log(\theta_{a,t,d,r})] = \beta_0 + \beta_{1,a} + \beta_{2,t} + \beta_{3,r} + \beta_{4,d} + \beta_5 \mathrm{AAD}_{r,d} + \beta_6 \mathrm{NS}_{a,t-20}$$

- $\mathrm{AAD}_{r,d}$: age-at-diagnosis
  – estimated with incidence model
- $\mathrm{NS}_{a,t-20}$: non-smoking prevalence
  – fitted model, 20-year lag

Add 'random walk' (time series model) for year effect:

$$\beta_{2,t} = \mathrm{drift} + \beta_{2,t-1} + error_t$$
$$\text{for } t = 2002, \ldots, 2036.$$

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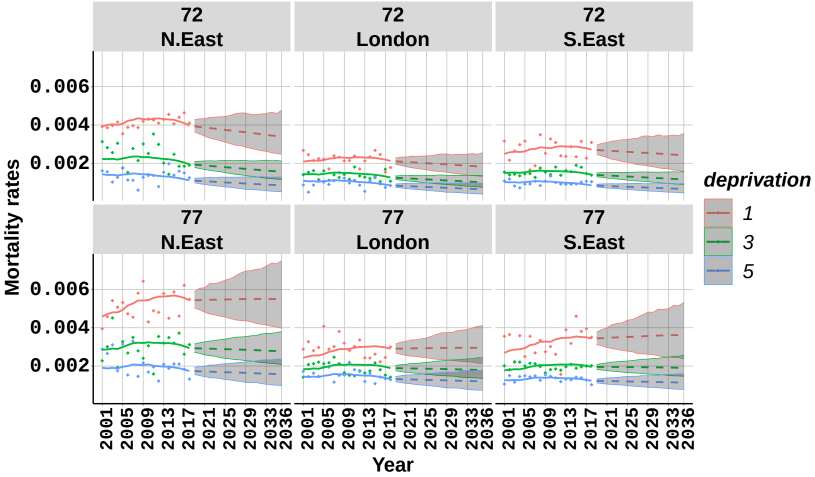
Projected mortality – Lung cancer, 2001 - 2036

Women 72, 77 yo, deprivation *quintiles*

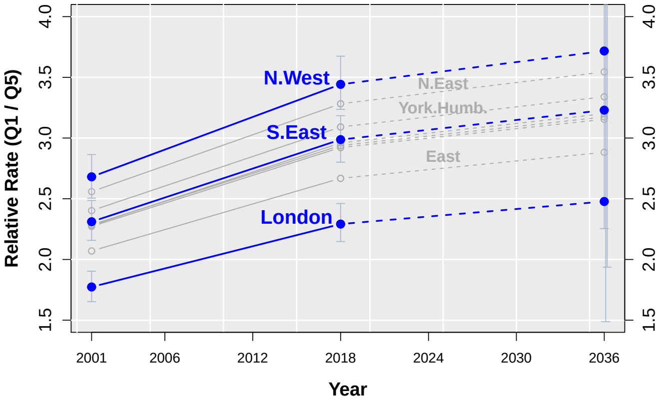


- Projected rates for most and least deprived NOT overlapping

Mortality gap: most v least deprived over time

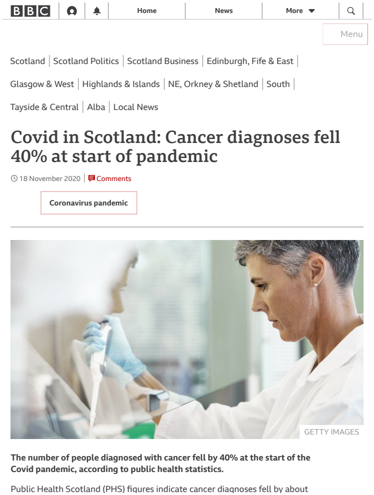
Lung cancer, **Women**, 2001 - 2036

Relative rate: $\dfrac{\text{Mortality for } \textbf{most} \text{ deprived}(Q_1)}{\text{Mortality for } \textbf{least} \text{ deprived}(Q_5)}$



N.West, 2001:	$RRate_{\textbf{most/least}\ depr}$	$= \times\mathbf{2.6}$
2018:		$= \times\mathbf{3.4}$
2036:		$= \times\mathbf{3.7}$

Impact of diagnosis delays on mortality



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Covid in Scotland: Cancer diagnoses fell 40% at start of pandemic

18 November 2020 | Comments

Coronavirus pandemic

GETTY IMAGES

The number of people diagnosed with cancer fell by 40% at the start of the Covid pandemic, according to public health statistics.

Public Health Scotland (PHS) figures indicate cancer diagnoses fell by about

- Estimate average age-at-diagnosis (AAD) with incidence data, model
- Include AAD as risk factor in mortality model
  e.g.
  $$E[\log(\theta_{a,t,d,r})] = \beta_0 + \beta_{1,a} + \beta_{2,t} + \beta_{3,r} + \beta_{4,d} + \beta_5 \mathrm{AAD}_{r,d} + \beta_6 \mathrm{NS}_{a,t-20}$$
- Estimate impact on mortality

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Projected mortality – Lung cancer, 2001 - 2036

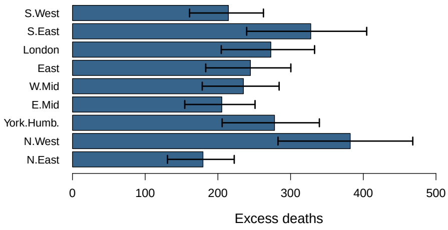
Quantify Covid-19 impact on future mortality

- Assume increase in AAD: e.g. 1, 3, 6 months
  - Use ONS region future population estimates
  - Assume future deprivation structure unchanged
- Fit Bayesian forecasting model:
  - under no change in AAD (baseline scenario)
  - under 1-month (etc) AAD increase (Covid scenario)
  - estimate excess deaths

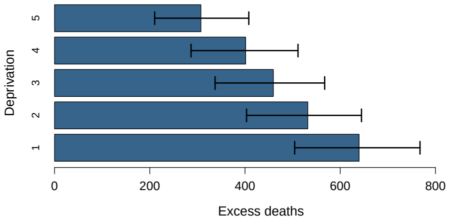
Projected mortality – Lung cancer, women, 2001 - 2036

Excess mortality due to 1-month increase in AAD

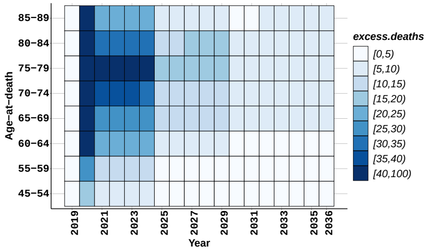
By region:



By deprivation:



By age & year:



Total excess deaths: 2,340
(95% CI: 1,743 - 2,869)

With 6-month AAD increase:
10,180 (7,944 - 12,340)

Summary

1. Regional and socioeconomic gap for cancer rates is widening in England

   ... but not for all cancer types

2. Projection for lung cancer mortality shows persistent deprivation gap

3. ... and significant excess deaths associated with Covid-like disruptions
   (that also vary across regions and deprivation)

4. *Can public health interventions at regional and deprivation level contribute to lower cancer incidence and deaths?*

More details in:

- Arık, A., Cairns, A., Dodd, E., Macdonald, A.S., Streftaris, G. (2023) The effect of the COVID-19 health disruptions on breast cancer mortality for older women: A semi-Markov modelling approach, *arXiv:2303.16573*.
- Yiu, M.T.L., Kleinow, T., Streftaris, G. (2023) Cause-of-death contributions to declining life expectancies using cause-specific mortality reversion scenarios, *to appear, North American Actuarial Journal*.
- Jose, A., MacDonald, A. S., Tzougas, G., & Streftaris, G. (2022). A Combined Neural Network Approach for the Prediction of Admission Rates Related to Respiratory Diseases. *Risks*.
- Arık, A., Dodd, E., Cairns, A., Streftaris, G. (2021) Socioeconomic disparities in cancer incidence and mortality in England and the impact of age-at-diagnosis on cancer mortality, *PLOS ONE*.
- Arık, A., Dodd, E., Streftaris, G. (2020) Cancer morbidity trends and regional differences in England - a Bayesian Analysis, *PLOS ONE*.

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