

Bayesian projections of breast and lung cancer mortality: disparities and impact of diagnosis delays

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Estimating The Impact Of The COVID-19 Pandemic On Breast Cancer Deaths - An
Application On Breast Cancer Life Insurance – SCOR Foundation for Science

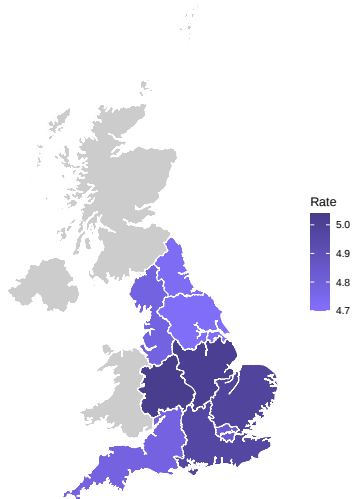
- 1 Trends in cancer rates over time
 - mainly lung cancer (LC) and breast cancer (BC)
- 2 Stochastic modelling for cancer rates
- 3 Variation by region and deprivation
- 4 Mortality projection into the future
- 5 Change in cancer rates during COVID years
- 6 Impact of diagnosis delays on cancer mortality

Cancer data

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

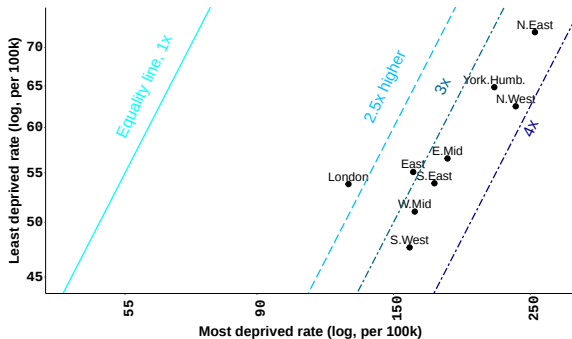
- Age groups: 0, 1-4, 5-9, ..., 95+
Age-standardised results, based on the European Standard Population (ESP) 2013
- Gender
- Years: 2001–2018 (*some* up to 2022)
- Income Deprivation deciles or quintiles
1: most deprived; 10: least deprived
1: most deprived; 5: least deprived
- Regions of England: North East, North West, Yorkshire and the Humber, East Midlands, West Midlands, East, London, South East and South West

Regional variation: BC mortality, 2018



✓ Rate is per 10K
✓ Deprivation is not significant

Most v. least deprived by region: LC mortality, women, 2017



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

- A life-style cancer
- Rates for **most deprived** much higher
- Regional variation

What insights we gain: (Arik et al., 2020, 2021)



Study points to big surge in under-50 cancer cases

6 September · Comments



The number of cancer cases among the under-50s around the world appears to have risen sharply in the past 30 years, a study suggests.

- **Age:** higher rates at older ages?
 - changing?
 - lifestyle factors?
- **Time:**
 - higher incidence in more recent years
 - lower mortality
- **Gender:** higher rates for men
- **Regional inequality** exists
- **Socio-economic differences** are more relevant to life-style cancers

Bayesian forecasting for cancer mortality

$$C_{a,t,d,g,r} \sim \text{Poisson}(\theta_{a,t,d,g,r} E_{a,t,d,g,r})$$

$$\theta_{a,t,d,g,r} \sim \text{Lognormal}(\mu_{a,t,d,g,r}, \sigma^2)$$

$$\mu_{a,t,d,g,r} = \beta_0 + \beta_{1,a} + \beta_{2,t} + \beta_{3,r} + \beta_{4,d} + \beta_5 \text{AAD}_{r,d} + \beta_6 \text{NS}_{a,t-20} + \text{interaction terms}$$

$$\beta' \sim \text{Normal}(0, 10^4) \quad [\text{vague priors for risk factor effects}]$$

$$\sigma^2 \sim \text{Inv.Gamma}(1, 0.1)$$

Add random walk with drift for 'period' effect:

$$\beta_{2,t} = \text{drift} + \beta_{2,t-1} + \epsilon_t$$

$$\text{drift} \sim \text{Normal}(0, \sigma_{\text{drift}}^2)$$

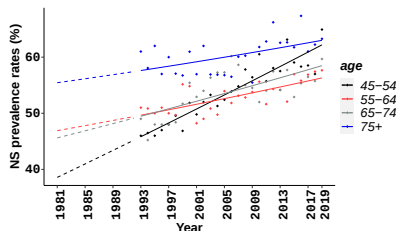
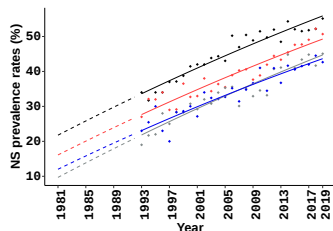
$$\epsilon_t \sim \text{Normal}(0, \sigma_{\beta_2}^2)$$

$$\sigma_{\beta_2}^2 \sim \text{Inv.Gamma}(1, 0.001)$$

for $t = 2002, \dots, 2036$, where $\hat{\sigma}_{\text{drift}}^2 = \frac{\hat{\sigma}_{\beta_2}^2}{2018-2001}$

Non-smoker prevalence rates: England, 1993–2019

Non-smoker (NS) prevalence observed (**dots**) and fitted (**solid line**) rates for men (**left**) and women (**right**)



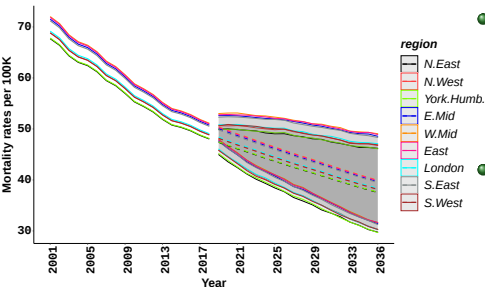
Increasing trend for NS prevalence

... more evident in men

Reconstruct NS prevalence (**dashed**) backwards to 1981:

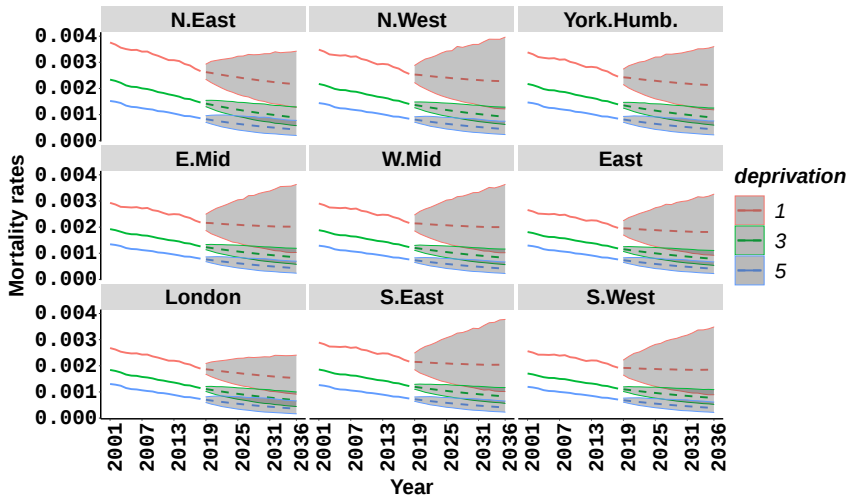
$$NS_{a,t} = \beta_0 + \beta_{1,a} + \beta_2 t + \beta_3 t^2 + \beta_{4,a} t$$

Regional gap: BC, women, 2001–2036



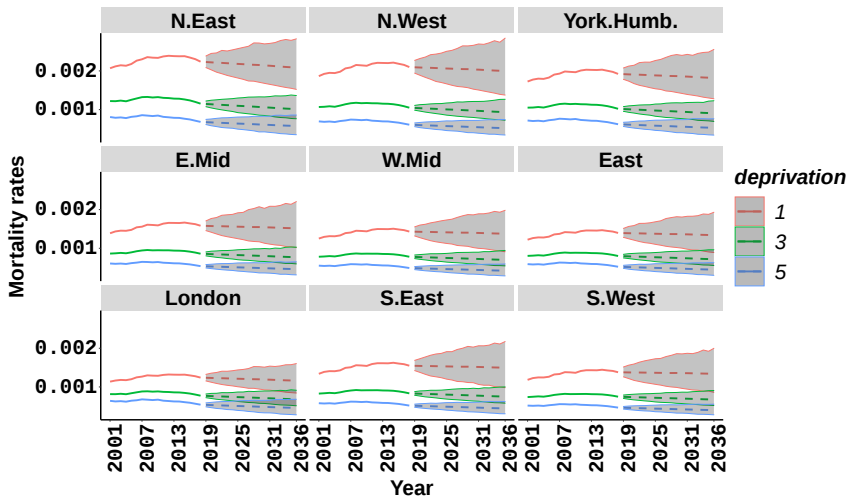
- Significant improvement in mortality from 2001 to 2018
 - ... and persists in the future years
- Region is significant
 - ... yet ONLY marginal differences in mortality across regions

Projected mortality: LC, men, 2001–2036



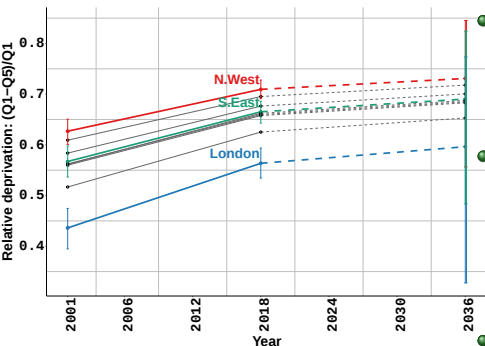
- Age-standardised mortality rates in (1) most deprived ... (5) least deprived
- Projected rates for most & least deprived *NOT* overlapping

Projected mortality: LC, women, 2001–2036



- Age-standardised mortality rates
- Mortality for women *NOT* always decreasing

Deprivation gap: LC, women, 2001–2036



- Increasing deprivation gap from 2001 to 2018

... persists in the future years

- Relative deprivation gap

$$\frac{\hat{\theta}_{t,\text{quintile } 1,r} - \hat{\theta}_{t,\text{quintile } 5,r}}{\hat{\theta}_{t,\text{quintile } 1,r}}$$

- $\hat{\theta}_{t,d,r}$: age-standardised fitted mortality rates

- Comparable findings in men

Change in cancer deaths between 2020 and 2022

Registered deaths v. Expected deaths

- 2% marginal **decline** in LC deaths for women in England
 - ... 3–6% marginal **increase** in East and West Midlands, and South West
 - ... 2–7% marginal **increase** at ages 70 to 89
- 4% marginal **decline** in LC deaths for men in England
 - ... 3% marginal **increase** at ages 80 to 84
- 1% marginal **decline** in BC deaths in England
 - ... 1–5% marginal **increase** in North East, Yorkshire and the Humber, East Midlands
 - ... 10–13% **increase** at ages 80 to 89

Impact of diagnosis delays on mortality



Scottish cancer cases rise by 15% after pandemic drop

28 March



GETTY IMAGES

Breast cancer screening was paused in 2020 due to the Covid-19 pandemic

Cases of cancer in Scotland increased by almost 15% in a year after dropping in the first 12 months of the pandemic.

- Estimate average age-at-diagnosis (AAD) with incidence rates

$$AAD_{t,d,g,r} = \frac{\sum_a a \hat{\lambda}_{a,t,d,g,r} E_a^{std}}{\sum_a \hat{\lambda}_{a,t,d,g,r} E_a^{std}}$$

$$AAD_{d,g,r} = \frac{\sum_t AAD_{t,d,g,r} E_{t,d,g,r}}{\sum_t E_{t,d,g,r}}$$

- $\hat{\lambda}_{a,t,d,g,r}$: fitted incidence rates
- Include AAD as risk factor in mortality model

e.g.

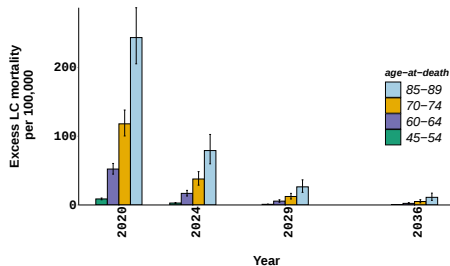
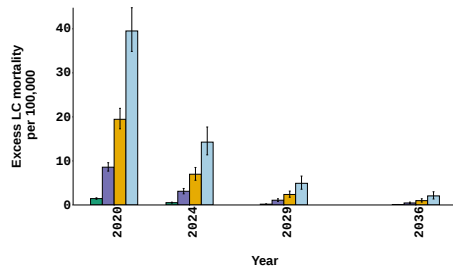
$$\mu_{a,t,d,r} = \beta_0 + \beta_{1,a} + \beta_{2,t} + \beta_{3,r} + \beta_{4,d} + \beta_5 AAD_{d,r} + \beta_6 NS_{a,t-20}$$

- Estimate impact on mortality

Quantify the impact of delays on future mortality

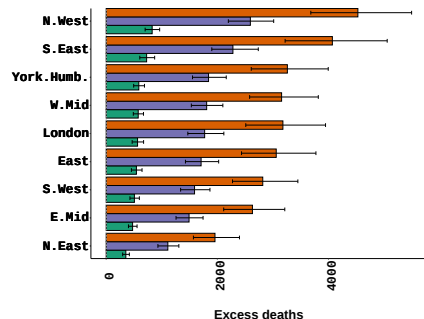
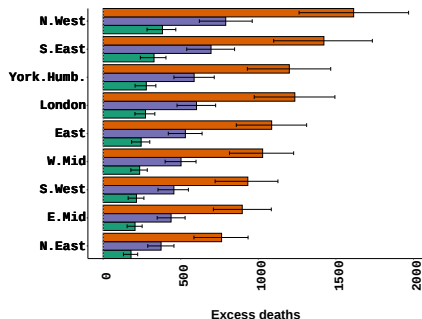
- Assume increase in AAD from 2020
 - Use ONS region-based future population estimates
 - Assume future deprivation structure unchanged
 - The impact of an increase in AAD distributed over future years
- Fit Bayesian forecasting model:
 - under no change in AAD (baseline scenario)
 - under 1- to 6-month AAD increase (scenario 1 to 3)
 - estimate **excess deaths**:
expected death in a given scenario -
expected death in the baseline scenario

Excess mortality by age: LC, men, 2020–2036



- Annual excess mortality due to 1-month (**left**) and 6-month (**right**) diagnosis delays
- LC is the leading cause of death for ages 65 to 79 (ONS, 2023)

Total excess deaths by region: LC, 2020–2036

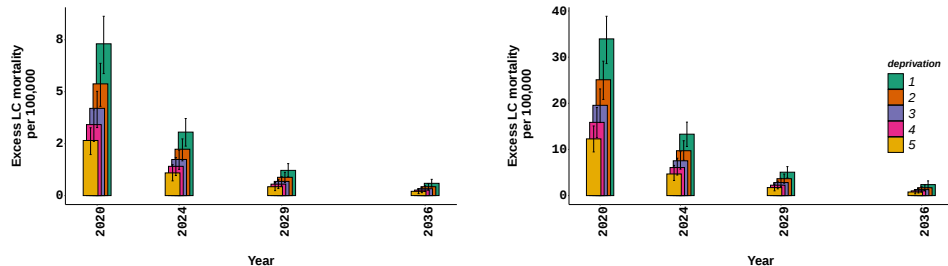


Excess deaths due to 6-month diagnosis delay:

10,180 [7,944 to 12,340] (women) v.
28,660 [23,040 to 35,090] (men)

- Excess deaths in women (left) and men (right) due to 1-month, 3-month, and 6-month delays
- Excess mortality differs by region

Excess mortality by deprivation: LC, women, 2020–2036



- Annual excess mortality due to 1-month **(left)** and 6-month **(right)** diagnosis delays
- Higher excess mortality in the most deprived quintile

Summary

- ① Regional and socioeconomic gap for cancer rates is widening in England
... but not for all cancer types
- ② Smoking is significant to explain both BC and LC mortality
- ③ COVID-related disruptions lead to significant increase in cancer deaths
– age and region dependent
- ④ Projection for LC mortality shows persistent deprivation gap
– and significant excess deaths by age, region, and deprivation as a result of 1- to 6-month delays in diagnoses

Implications of this study

- New medical technologies and early cancer diagnoses improve cancer survival
- Flexible and more detailed models are relevant to medical underwriting of related insurance contracts
- Quantifying disparities can help insurers understand how insured portfolios differ from general population
- Time trends and changes important in long-term pricing and reserving
- Upcoming pandemics?
- Cancer surge among under 50s: insured ages?

More details in:

- 1 Arık, A., Cairns, A., Streftaris, G. Cancer mortality projection: disparities, COVID-19, and late diagnosis impact, <https://arxiv.org/abs/2405.05643>.
- 2 Arık, A., Cairns, A., Dodd, E., Macdonald, A.S., Streftaris, G. The effect of the COVID-19 health disruptions on breast cancer mortality for older women: A semi-Markov modelling approach, *Scandinavian Actuarial Journal*, 2024.
- 3 Arık, A., Cairns, A., Dodd, E., Macdonald, A.S., Streftaris, G. Estimating the impact of the COVID-19 pandemic on breast cancer deaths among older women, *Living to 100 Research Symposium*, 16 February 2023, conference monograph.
- 4 Arık, A., Dodd, E., Cairns, A., Streftaris, G. Socioeconomic disparities in cancer incidence and mortality in England and the impact of age-at-diagnosis on cancer mortality, *PLOS ONE*, 2021.
- 5 Arık, A., Dodd, E., Streftaris, G. Cancer morbidity trends and regional differences in England - a Bayesian Analysis, *PLOS ONE*, 2020.

Thank You!

Questions?

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