

Socioeconomic Disparities in Cancer Risk in England

Ayşe Arık and George Streftaris

Heriot-Watt University, Edinburgh

joint work with Erençül Dodd, and Andrew Cairns

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- 1 Purpose of our research
- 2 Data
- 3 Modelling framework
- 4 Regional and socioeconomic disparities
- 5 Summary and future directions

Purpose of our research

- 1 Focus on all-cancer, lung, bowel, prostate, and breast cancer rates
- 2 Analyse and model incidence/mortality rates to identify
 - temporal trends
 - variation by region and deprivation
- 3 Quantify the impact of age-at-diagnosis on mortality
- 4 Project cancer rates in future years

Cancer registration data and cancer deaths data for 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 - 2017
- 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

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

Bayesian models for incidence and mortality rates

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

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

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

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

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

- $C_{a,t,d,g,r}$: number of cancer registrations/deaths of a given malignant neoplasm at age a in year t for gender g in deprivation level d and region r
- $E_{a,t,d,g,r}$: mid-year population estimates
- $\theta_{a,t,d,g,r}$: incidence/mortality rates of a given malignant neoplasm
- \mathbf{X} : vector of covariates: age, year, deprivation, gender, region, average age-at-diagnosis + appropriate interaction(s)
- β : vector of coefficients

Model selection

- 1 Bayesian variable selection methodology used
- 2 Chooses the **best** model for

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

according to model fitting criteria

(here marginal likelihood & deviance information criterion)

- 3 Results suggest that all main variables (age, time, deprivation, gender, region) are important for all-cancer and **life-style** cancers, i.e. lung and bowel cancer
 - deprivation is not important for breast and prostate cancer mortality

Change points

- Allow change point(s) in time trends (and age)
- Change point analysis, based on BIC, is considered for detection of changes

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

may become

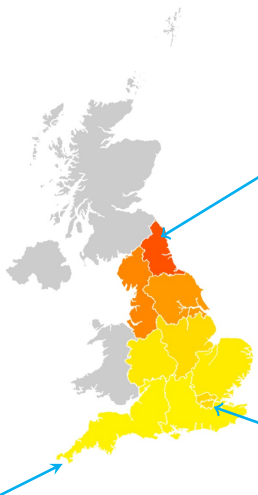
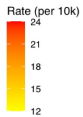
$$\mu_{a,t,d,g,r} = \beta_0 + \beta_{1,1} \text{ year}_{<2006} + \beta_{1,2} \text{ year}_{\geq 2007} + \dots$$

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

Regional variation in lung cancer incidence - Females, 2017

N.East:40% excess

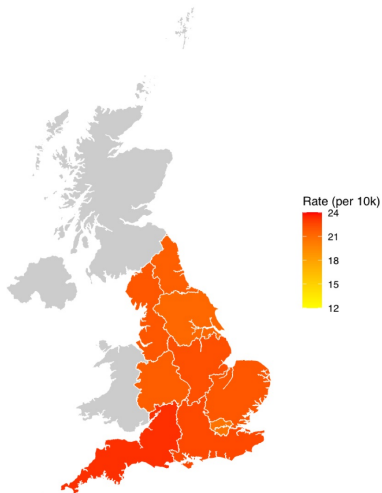
Regional effect compared to average North v. south?



S.West:18% lower

London:about average

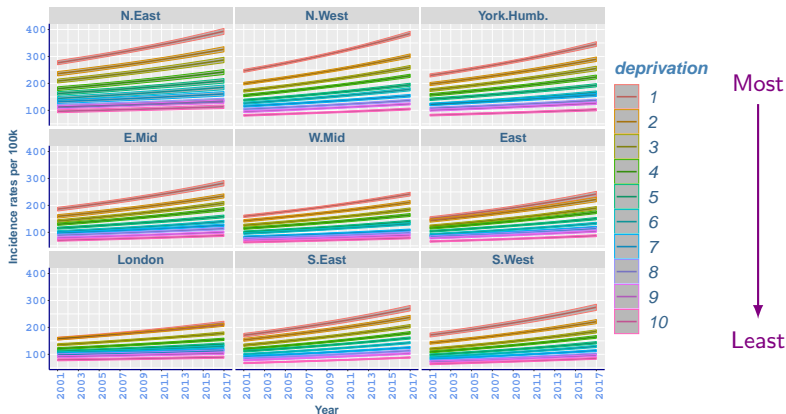
Regional variation in breast cancer incidence - 2017



- ✓ Not a life-style cancer
- ✓ Regional variation much lower

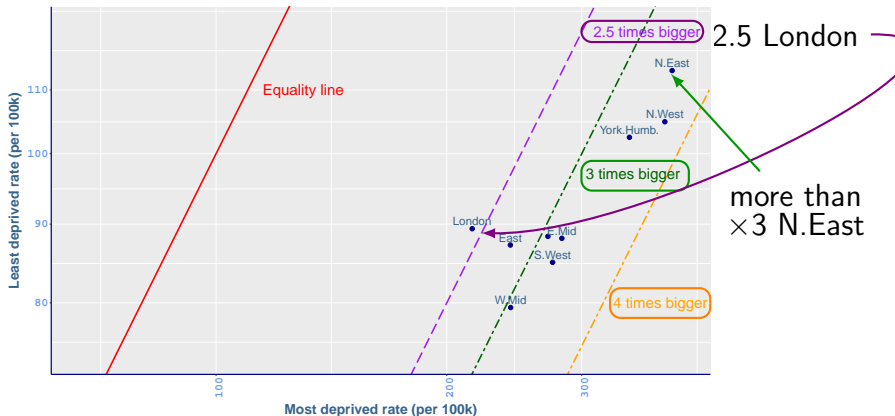
Deprivation inequality in cancer rates

Lung cancer incidence - Females, 2001-2017



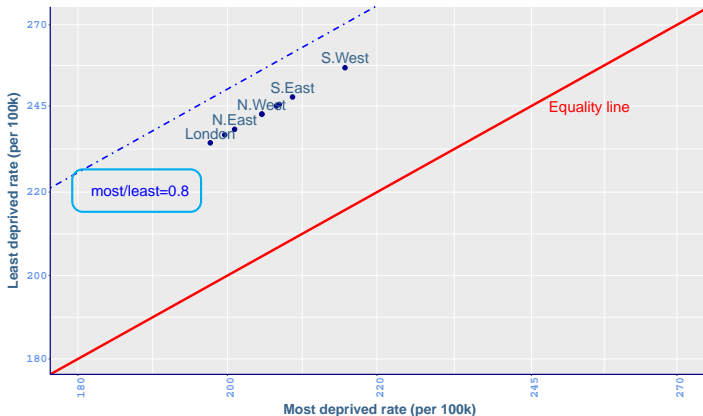
- Higher rates for most deprived (1)
- Variation by IMD getting higher
- Inequalities more evident in northern regions

Most v. least deprived by region Lung cancer incidence - Females, 2017



- Rates for **most deprived** much higher
- Regional variation

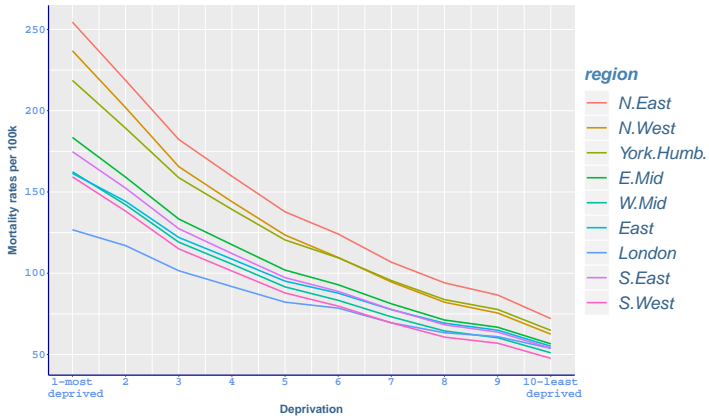
Most v. least deprived by region Breast cancer incidence - 2017



- Rates for **least deprived** higher
- No regional variation

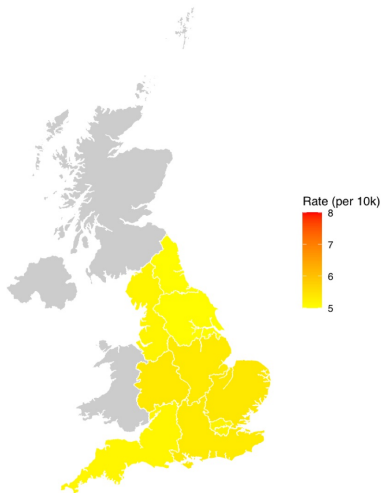
Deprivation inequality in cancer rates

Lung cancer mortality - Females, 2017



- Higher rates for most deprived (1)
- Inequalities more evident in more deprived groups

Regional variation in breast cancer mortality - 2017



✓ Deprivation is not-significant

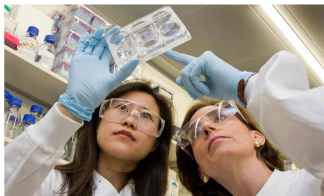
Impact of diagnosis on mortality

Early cancer diagnoses plummeted in England during Covid pandemic

Official figures spark fears that patients may miss out on treatment until it is too late

Denis Campbell

Wed 5 May 2021 19:45
BST



▲ The number of people in England diagnosed with stage one cancer was down 33% in March-June 2020 compared with a year earlier. Photograph: Alamy Stock Photo

The number of people being diagnosed with cancer early in England has plummeted during the Covid pandemic, sparking fears that many will only be treated when it is too late to save them.

✓ Estimate average age-at-diagnosis, AAD, with incidence data

✓ Include AAD as a factor in mortality model

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

E_a^{std} : exposures at age a in the ESP 2013

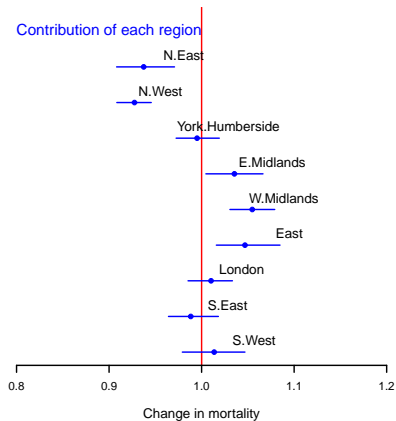
$$AAD_{d,g,r} = \frac{\sum_t E_{t,d,g,r} AAD_{t,d,g,r}}{\sum_t E_{t,d,g,r}}$$

$E_{t,d,g,r}$: original exposure aggregated over age

Impact of diagnosis on mortality by region

All cancers - Males

- Impact of age-at-diagnosis compared to the mean level across regions (set to 1)
- N.West: significantly lower effect
- East: significantly higher effect
- London: not significantly different from the average



Impact of diagnosis delay on mortality

Lung cancer - Females

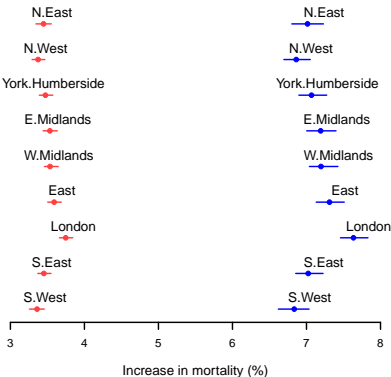
Estimate impact of delay in AAD:

- 6-month delay:
 - 3.5% increase in mortality
- 1-year delay:
 - 7% increase in mortality
- Highest impact in London

6-month delay



12-month delay



A projection model

Lung cancer mortality - Males, 2001-2018

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

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

$$\mu_{a,t,d,r} = \beta_0 + \beta_{1,a} + \beta_{2,t} + \beta_{3,r} + \beta_{4,d} + \beta_5 \text{AAD}_{r,d}$$

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

$$\beta_0, \beta_1, \beta_3, \beta_4 \text{ and } \beta_5 \sim \text{Normal}(0, 10^4),$$

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

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

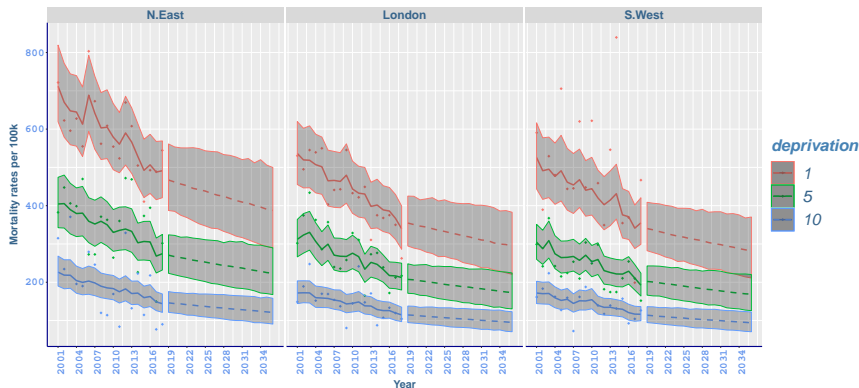
$$\epsilon_t \sim \text{Normal}(0, \sigma_{\beta_2}^2)$$

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

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

Projected cancer rates

Lung cancer mortality - Males, age 72, 2001-2035



- Decreasing trend over years
- Projected rates for most and least deprived NOT overlapping

Summary and future directions

- 1 Regional and socioeconomic gap for cancer rates is widening
 - but not for all cancer types
- 2 Delay in diagnosis can lead to significant increase in type-specific cancer deaths
- 3 Can public health interventions at regional and deprivation level contribute to prevention of cancer incidence and deaths?
- 4 What are the implications for related insurance products?
- 5 What is the impact of Covid-19 on cancer incidence and mortality?

More details in:

- 1 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.
- 2 Arık, A., Dodd, E., Streftaris, G.. Cancer morbidity trends and regional differences in England - a Bayesian Analysis, PLOS ONE, 2020.

Thank You!



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