

What insights can we gain from analysis of cause-of-death mortality data?

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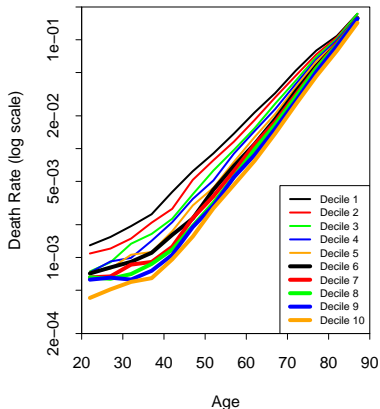
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Outline

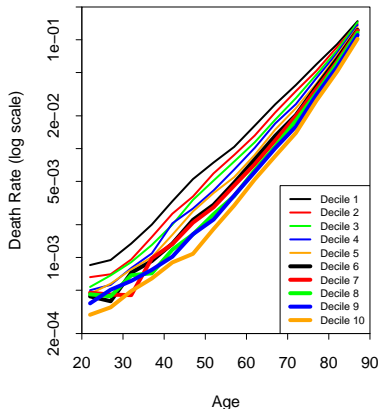
- Motivation: trends and inequalities in all-cause mortality
- Data for England
- Empirical analysis
- Discussion and Covid-19 postscript

Motivation: all-cause mortality

English Males Death Rates 2001
By Income Deprivation Decile



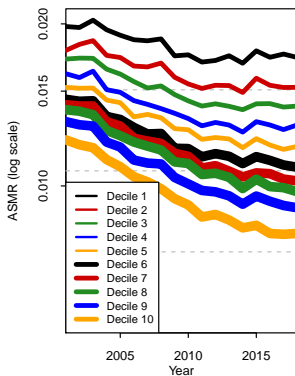
English Males Death Rates 2018
By Income Deprivation Decile



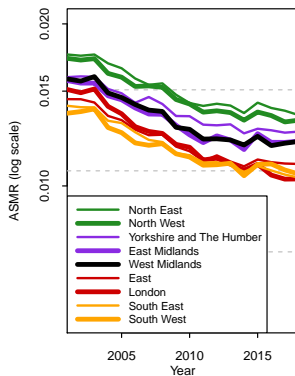
- Significant inequality between the most and least deprived
More than $4\times$ around age 50; narrowing at high ages
- 2001→2018: improving mortality; but also slight widening at middle and higher ages

Age Standardised Mortality Rates (ASMR; ages 40-89)

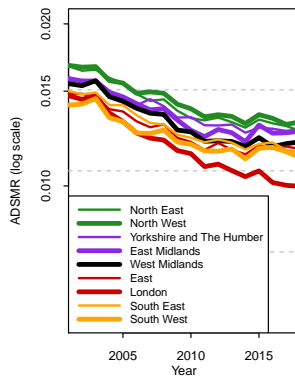
Females: ASMR by Income
All Cause Mortality



Females: ASMR by Region
All Cause Mortality



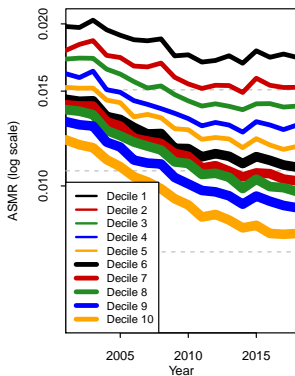
Females: ADSMR by Region
All Cause Mortality



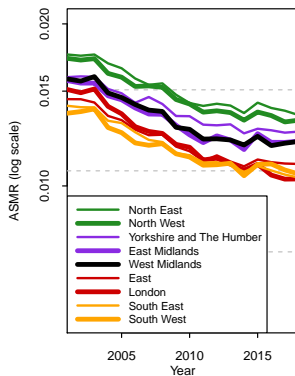
- ASMR= average mortality (40-89) weighted using a standard pop.
- Impact of income deprivation much bigger than region
- ADSMR: Age **and Deprivation** Standardised Mortality Rate
ADSMR adjusts regional mortality for differences in deprivation mix

Age Standardised Mortality Rates (ASMR; ages 40-89)

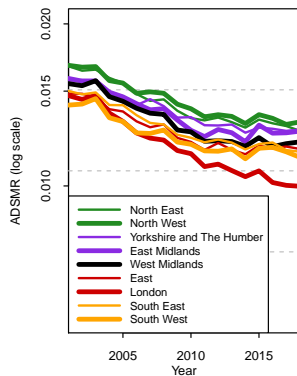
Females: ASMR by Income
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Females: ASMR by Region
All Cause Mortality



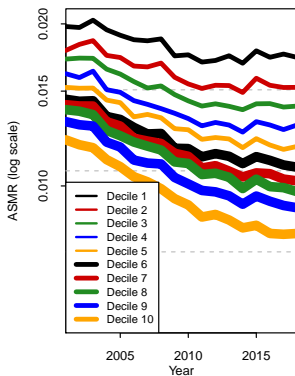
Females: ADSMR by Region
All Cause Mortality



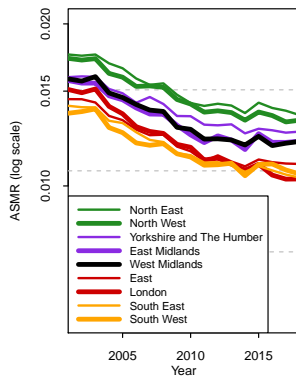
- Widening gap between the most and least deprived
- Mortality improvements: slowdown after 2010 in all deciles

Age Standardised Mortality Rates (ASMR; ages 40-89)

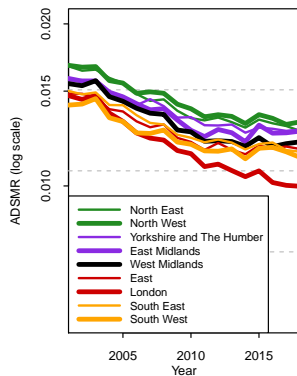
Females: ASMR by Income
All Cause Mortality



Females: ASMR by Region
All Cause Mortality



Females: ADSMR by Region
All Cause Mortality



- Significant differences between regions is partly explained by differences in the deprivation mix
- North-South split is not so big after deprivation adjustment
- London is a bit of an outlier

Purpose of looking at cause of death data

- What are the key drivers of all-cause mortality?
- How are the key drivers changing over time?
- Which causes of death have high levels of inequality?
- Can we point to specific causes of death as responsible for *growing inequality*?
- **Leading to:** insight into mortality underpinning life insurance and pensions

- Medical advances
- Public health initiatives
- Health spending by age
- Individual risk factors:
 - **Controllable**
e.g. smoking, diet, exercise, alcohol, sun, drugs, hygiene, risky sex, stress, environment...
 - Preventable (but not controllable)
e.g. infections such as HPV (→ cervical cancer)
 - Not (easily) controllable
e.g. genetic, character/personality traits, education, affluence,
...
- “Intermediate” risk factors: e.g. obesity, diabetes, high blood pressure, high cholesterol, chronic disease or prior health event (e.g. heart attack)

The Association with Socio-Economic Covariates

- Potential measures of socio-economic status:
 - Deprivation: low income; poor housing; unemployed; low qualifications;
 - Education (US data; Denmark)
 - Affluence (Denmark)

- **More deprived**; low educated; low affluence
 - ⇒ more likely to: smoke; have a poor diet; exercise less; drink too much alcohol
 - ⇒ higher mortality

Cause of Death Groupings

1	Infectious diseases	3	Cancer: oesophageal	6	Cancer: rectum, anus
2	Cancer: mouth, gullet	5	Cancer: colon	9	Cancer: other digestive system
4	Cancer: stomach	8	Cancer: pancreas	12	Cancer: skin
7	Cancer: liver	11	Cancer: lung, bronchus, trachea	15	Cancer: uterus
10	Cancer: larynx	14	Cancer: cervix	18	Cancer: prostate
13	Cancer: breast	17	Cancer: other female genital	21	Cancer: urinary organs
16	Cancer: ovary	20	Cancer: bladder	24	Cancer: other locations
19	Cancer: other male genital	23	Benign tumours		
22	Cancer: lymphatic etc.	26	Diabetes		
25	Blood diseases	28	Other mental illness	29	Parkinson's disease
27	Vascular dementia	31	Other diseases of nervous system		
30	Alzheimer's	33	Ischaemic heart diseases	34	Non-rheumatic valve disorders
32	Blood pressure + rheumatic fever	36	Cerebrovascular diseases	37	Circulatory diseases
35	Other heart diseases	39	Pneumonia	40	Other acute respiratory infections
38	Influenza	42	Other respiratory diseases		
41	Chronic Obstructive Pulmonary Disease	44	Other liver diseases	45	Other digestive diseases
43	Liver cirrhosis	47	Diseases: urine, kidney,...		
46	Diseases: skin, bone, tissue	49	Road/other accidents	50	Accidental Poisonings
48	Suicide				
51	Other causes				

Colours \Rightarrow broad CoD groups (e.g. **cancers**)

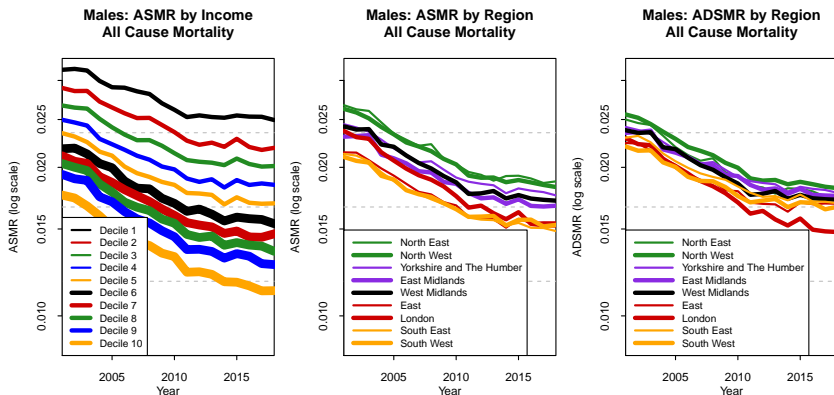
Detail \Rightarrow able to separate causes with and without significant risk factors or inequality

English Cause of Death Data

- 51 CoD groups
- Age groups 20-24, 25-29, ..., 85-89
- Single years 2001-2018

- by small area *income deprivation*: 10 deciles
- by region: 9 areas

Age Standardised Mortality Rates (ASMR; ages 40-89)



Income deprivation deciles: widening gap

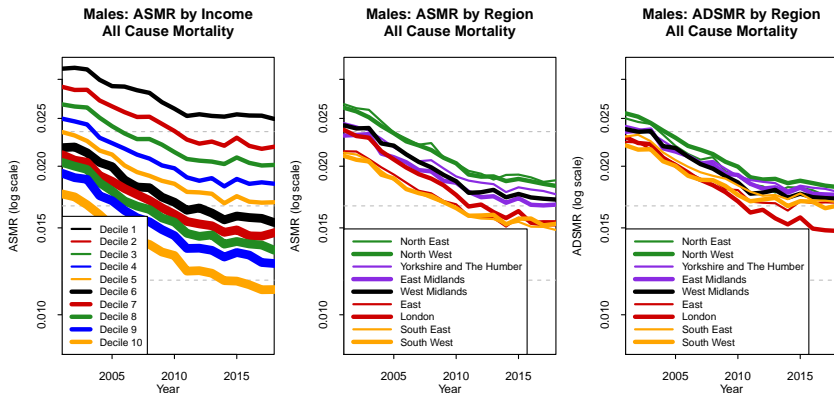
Clear "London Effect".

Greater improvements in healthcare??

Greater improvements in GDP??

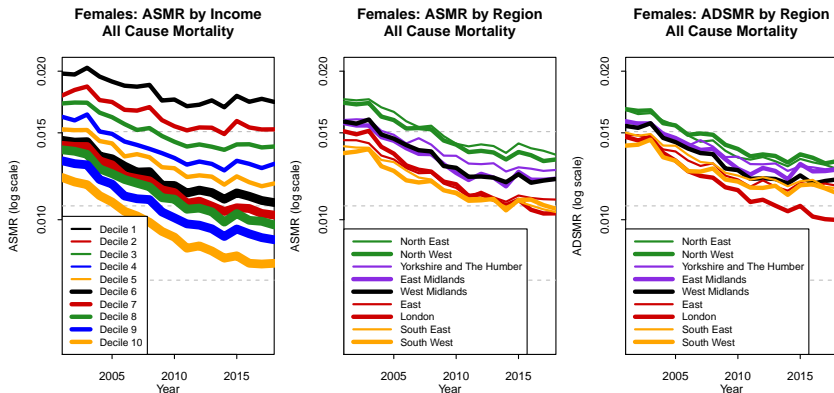
Educational attainment rising faster?? (immigration??)

England: Males (40-89) ASMR and ADSMR Inequality



- Differing trends between groups and before/after 2011
- Hence (??): mortality projections
 - different short-term mortality improvement rates
 - converging to the same long-term improvement rate

England: Females (40-89) ASMR and ADSMR Inequality

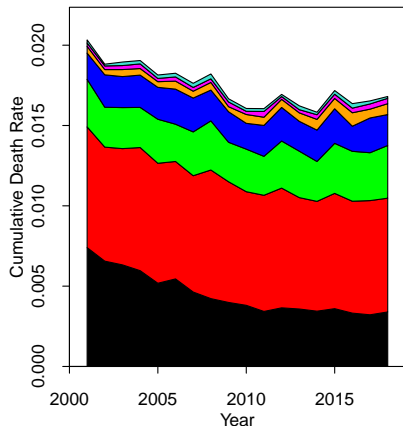


Males and females: significant regional effects remain after accounting for income deprivation

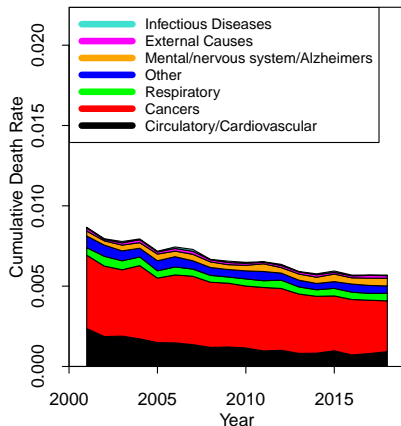
(All cause data: other non-regional covariates being investigated)

Seven CoD Groups: Females 65-69; Deciles 1 vs 10

**Decomposition of Death Rates for
Females Aged 65-69
Income Deprivation Decile 1**

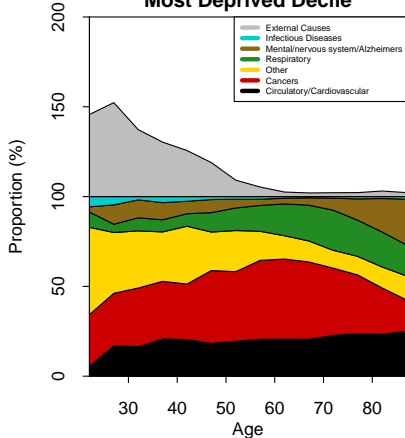


**Decomposition of Death Rates for
Females Aged 65-69
Income Deprivation Decile 10**

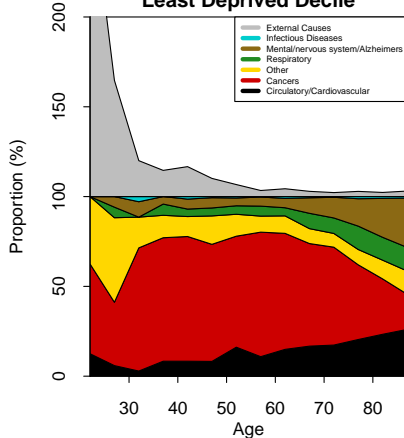


Seven CoD Groups: Females 2018; Deciles 1 vs 10; Proportions

Breakdown of All-Cause Mortality Females in 2018 Most Deprived Decile

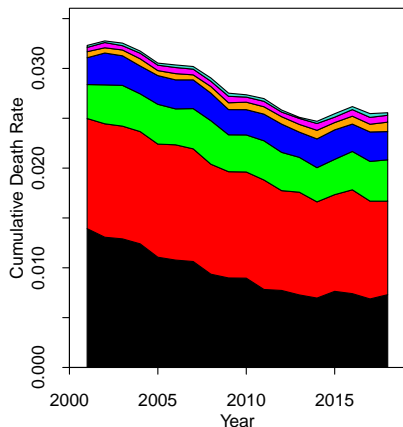


Breakdown of All-Cause Mortality Females in 2018 Least Deprived Decile

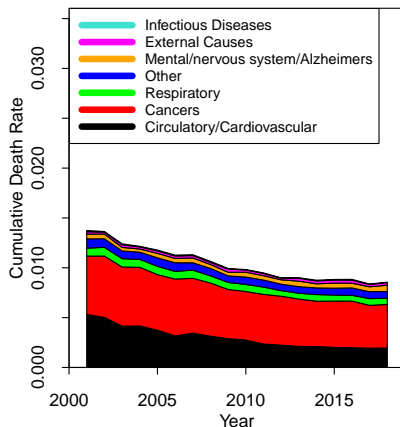


Seven CoD Groups: Males 65-69; Deciles 1 vs 10

**Decomposition of Death Rates for
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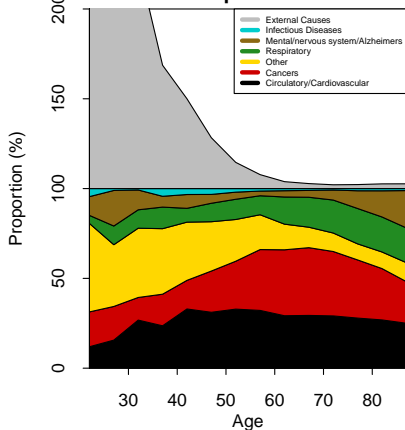


**Decomposition of Death Rates for
Males Aged 65-69
Income Deprivation Decile 10**

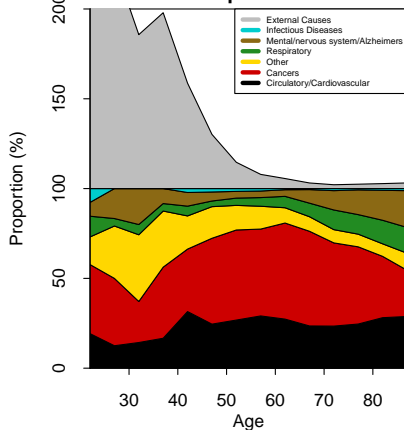


Seven CoD Groups: Males 2018; Deciles 1 vs 10; Proportions

Breakdown of All-Cause Mortality Males in 2018 Most Deprived Decile



Breakdown of All-Cause Mortality Males in 2018 Least Deprived Decile



Higher-Level CoD Summary

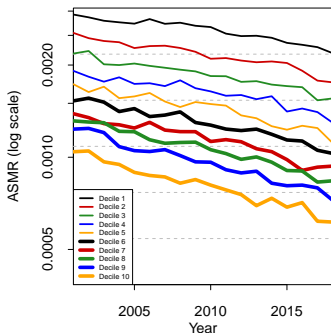
- Cardiovascular: big declines; less room to contribute to future all-cause mortality improvements
- Cancers: now the biggest killer, especially for females; limited past improvements; strongest potential for future all-cause improvements
- Respiratory: biggest inequalities
- Dementias: on the rise

Cause Of Death Data: More Detailed Analysis

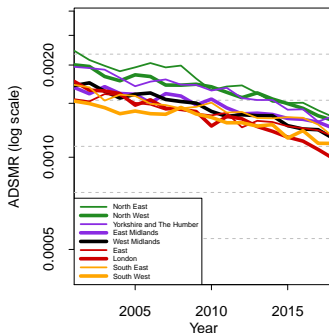
Highlights of the 51 causes of death....

Lung Cancer: Males

Males: ASMR by Income
Cancer: lungs, bronchus or trachea



Males: ADSMR by Region
Cancer: lungs, bronchus or trachea



Horizontal dotted lines: $\times\sqrt{2}$ apart

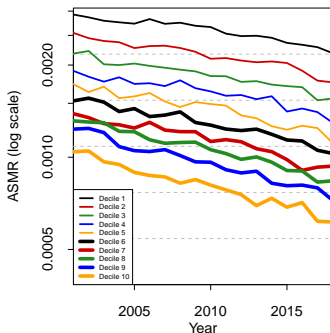
Each plot: bottom to top: $\times 8$

Left: 10 income deprivation deciles, $ASMR_l(t)$

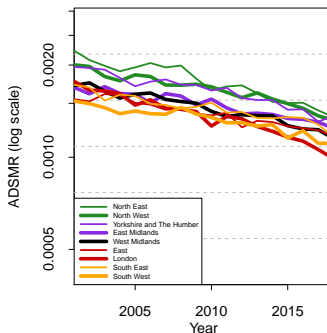
Right: 9 regions, $ADSMR(t)$

Lung Cancer: Males

Males: ASMR by Income
Cancer: lungs, bronchus or trachea



Males: ADSMR by Region
Cancer: lungs, bronchus or trachea



Significant variation between income deciles (\Leftarrow smoking habits)

smoking habits \Rightarrow smoking prevalence and intensity

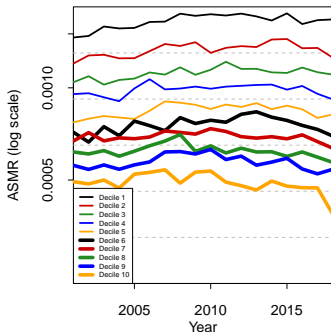
Significant variation between regions (after standardisation)

$\times 3$ by income decile; $\times 1.5$ variation by region

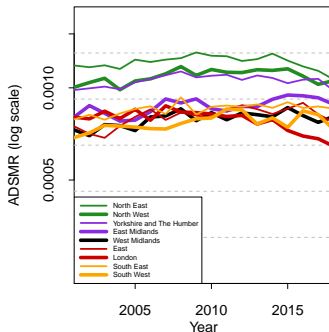
London effect (improving faster); Northern regions very poor

Lung Cancer: Females

Females: ASMR by Income
Cancer: lungs, bronchus or trachea



Females: ADSMR by Region
Cancer: lungs, bronchus or trachea



Different pattern from males

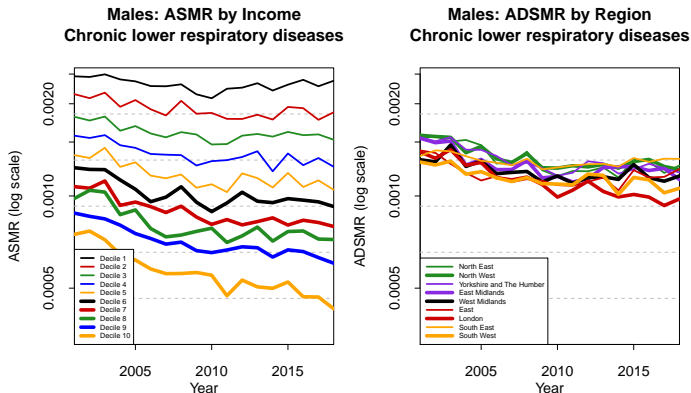
Slight worsening \Rightarrow ?? smoking prevalence/intensity rising

Some northern regions do badly

Wider regional spread

London effect

Chronic Lower Respiratory Diseases: Males

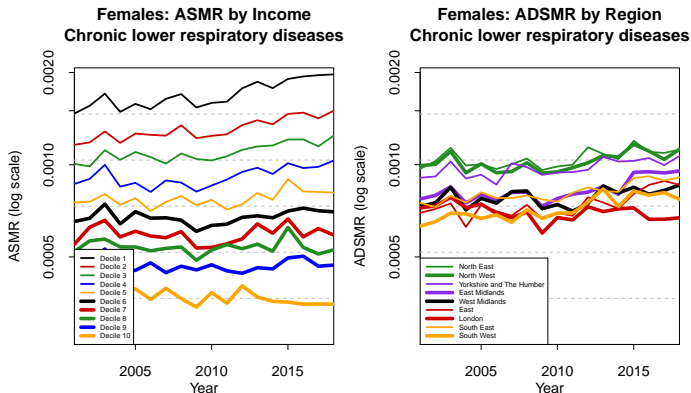


Similar pattern to lung cancer males

COPD: Chronic Obstructive Pulmonary Disease = major cause

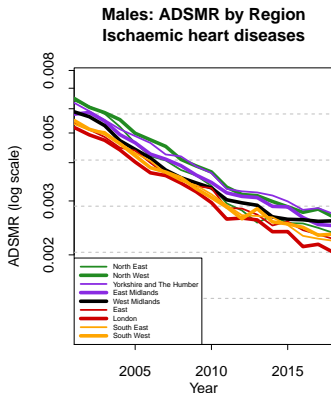
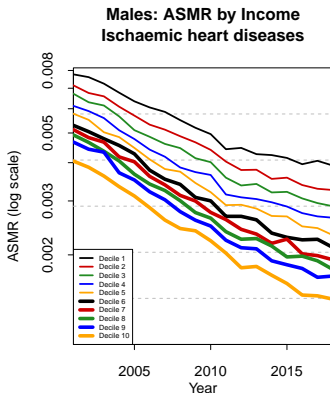
Smoking is the major controllable risk factor

Chronic Lower Respiratory Diseases: Females



Similar pattern to lung cancer females
Weaker improvements than males linked to smoking prevalence,
especially high deprivation

Ischaemic Heart Disease: Males



Significant inequality linked to **multiple controllable risk factors**

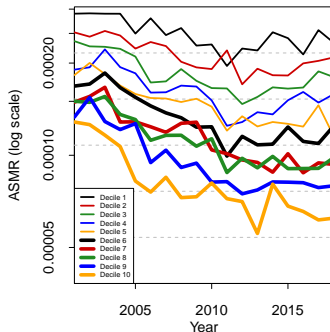
Success story: major improvements

Less good: widening gap and regional inequality; **slowdown differences**

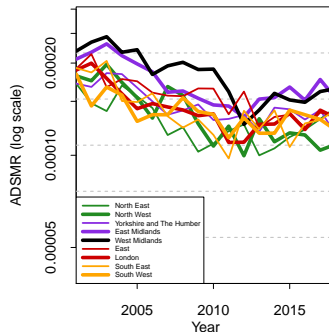
Females: similar picture

Diabetes: Females

Females: ASMR by Income
Diabetes



Females: ADSMR by Region
Diabetes



Widening gap and regional inequality
Males: similar picture

Impact of Controllable Risk Factors

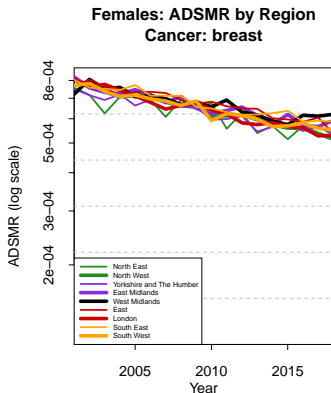
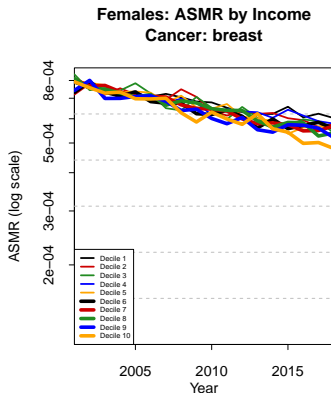
- By definition:
Risk factors (controllable and not controllable) \Rightarrow
Impact on cause of death rates
- Some **controllable risk factors** \Rightarrow big impact on some causes
e.g. smoking \rightarrow lung cancer
e.g. several risk factors \rightarrow ischaemic heart disease
 \Rightarrow **significant mortality inequality**
- Other causes of death:
no known (significant) controllable risk factors
e.g. prostate cancer, breast cancer

A Broad Observation

As the impact of a *controllable* risk factor on a particular CoD increases we observe:

- Greater inequality in the corresponding CoD death rates
 - by income deprivation
 - by region
 - by region **even after adjusting for differing levels of income deprivation**
- Possible sources of the region effect:
 - Other socio-economic variables?
E.g. education levels within each income deprivation decile; urban/rural
 - Greater deprivation on average across the region leads to generally poorer health behaviour?
 - Random variation across regions in health risk behaviours?

Breast Cancer: An Equality “Success Story” (?)

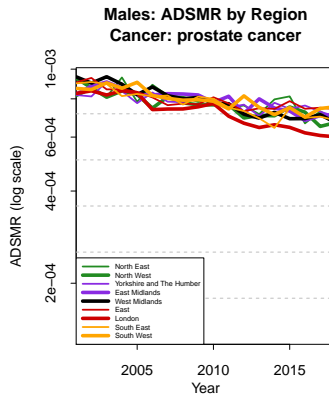
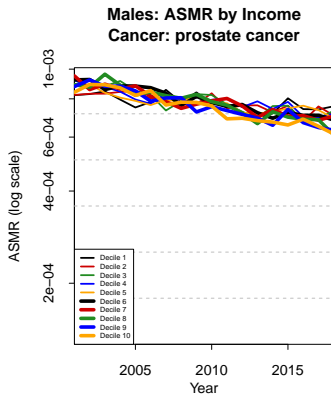


Limited controllable risk factors

“Success story”: relatively low income or regional inequality

Slight widening (?) in recent years

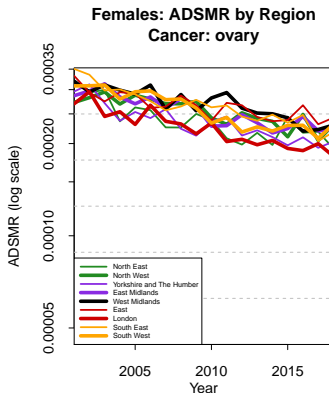
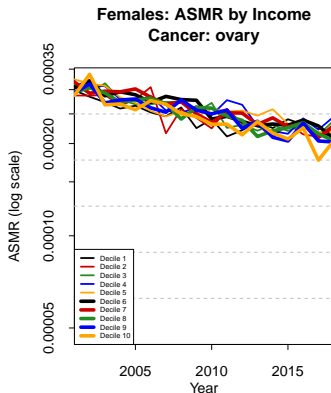
Prostate Cancer: A Small London Effect?



No significant income inequality

Small but significant differences between regions

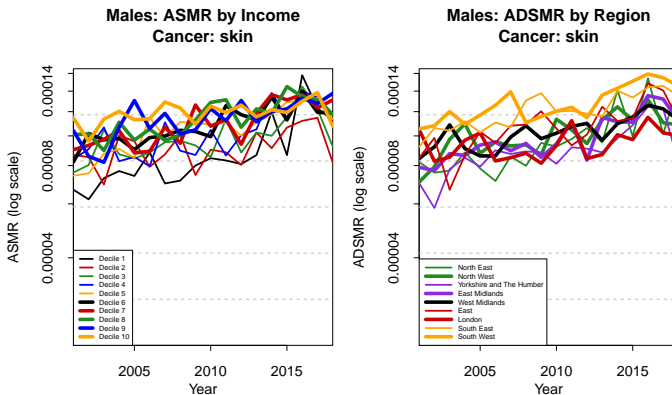
Ovarian Cancer: A Regional Lottery?



Limited controllable risk factors
Limited income effect

Small but significant regional effect

Which Causes of Death \Rightarrow Reverse Inequality?



Skin cancer: Males, Females

Least deprived have 20% to 30% *higher* skin cancer mortality

No other significant causes of death have reverse inequality

Which Causes of Death \Rightarrow Growing Inequality?

Where has the inequality gap widened from 2001 to 2018?

- Ischaemic heart disease
- Cerebrovascular
- Circulatory
- Lung cancer
- COPD
- Pneumonia
- Breast cancer and prostate cancer (modest widening)

In many cases the gap has increased by 20% to 50%.

Observations are *consistent with a widening gap in the prevalence of controllable risk factors*:
smoking, diet, exercise, alcohol etc.

Which Causes of Death \Rightarrow Decreasing Inequality?

Where has the inequality gap narrowed significantly from 2001 to 2018?

\Rightarrow consistent with the hypothesis that there are no **controllable risk factors** that have a narrowing gap

Contributors to the slowdown since 2011

General

- Data are quite noisy
- 2011 is not a precise slowdown date

Main contributors (ages 65-89) seem to be

- Heart diseases
(but less so for the least deprived groups)
- Dementias and Alzheimer's
- Pneumonia
- COPD
- Diabetes
- Road and other accidents

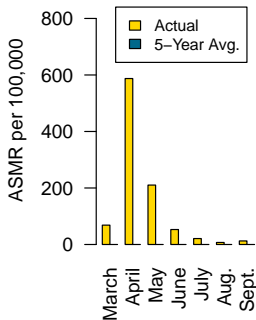
Many Questions Remain

- Can we improve upon *income deprivation* as a predictor?
 - All cause mortality
 - Cause of death mortality
- Is it possible to decompose improvements into medical advances and changes in risk “taking”?
- E.g. can we establish a clear link between
 - changes in smoking behaviour
 - changes in lung cancer and COPD mortality?
- What are the causes of the London Effect?

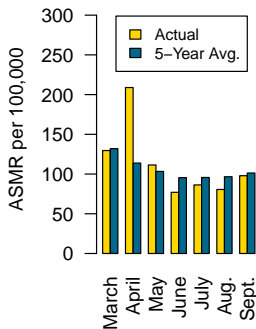


Postscript: What to do with 2020 data?

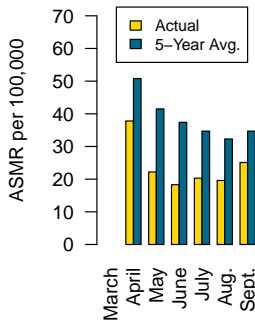
Covid



Dementia/Alzheimer's



Flu & Pneumonia



- One entirely new cause of death
- General disruption to other causes; knock on in 2021/22
- Misreporting: significant Covid deaths in April recorded as dementia
- Pneumonia: August actual = 60% of 5-year average \Rightarrow misreporting and/or a genuine consequence of lockdown?

Postscript: What to do with 2020 data? (cont.)

Pneumonia (+influenza)

- Misreporting?
40% shortfall is much larger than the August Covid-19 deaths
- Could the 40% have died earlier in 2020 from Covid?
Some, perhaps, but up to August only 6% of the population had been infected with Covid-19.
We would need 40% of the August 2020 pneumonia deaths to have been infected and die from Covid.
- Conclusion: a significant of the shortfall might be due to people staying at home with less exposure to the various pneumonia pathogens.

Summary

- Causes of death with associated **controllable risk factors**
⇒ mortality inequality
- Significant levels of inequality for most of the big CoD's
- Regional differences remain even after adjusting for deprivation
- Causes of death with **no controllable risk factors**
⇒ little or no inequality
- Mortality inequalities have widened since 2001
Link to multiple controllable risk factors
- Slowdown since 2011 + ischaemic heart disease
NO slowdown in the least deprived group



Thank You!

Questions?

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Actuarial
Research Centre

Institute and Faculty
of Actuaries

Bonus slides

Age Standardised Mortality Rates

- Basic definition

$$ASMR = \frac{\sum_x m(x)ES(x)}{\sum_x ES(x)}$$

- $m(x)$ = population or sub-population death rate all cause, or by cause of death
- $ES(x)$ = standard population exposures
- Four variations:
 - $ASMR$: national
 - $ASMR_i(i)$, for $i = 1, \dots, 10$ deprivation deciles
 - $ASMR_R(r)$, for $r = 1, \dots, 9$ regions
 - **Age and Deprivation Standardised Mortality Rate**
 $ADSMR_R(r)$, for $r = 1, \dots, 9$ regions

More deprived regions will naturally have a higher $ASMR_R(r)$

Region By Region Deprivation Profiles

Region	Income Deprivation Decile										Row Sum
	1	2	3	4	5	6	7	8	9	10	
1	20	15	12	10	7	7	7	7	8	7	100%
2	18	11	10	9	8	8	9	9	9	9	100%
3	15	11	10	8	9	9	10	9	9	9	100%
4	8	10	10	10	10	10	12	11	11	9	100%
5	16	12	10	9	9	9	10	10	9	7	100%
6	4	6	9	10	12	11	13	11	12	11	100%
7	9	16	15	14	11	9	7	6	6	6	100%
8	3	5	7	9	10	11	12	11	14	19	100%
9	4	6	8	10	12	13	14	13	11	9	100%

E.g. Row 1: percentage of LSOAs in each of deciles 1 to 10
 Everything else being equal: North-East (1) will have heavier mortality than the South-East (8)

ASMR Variants

- Suppress gender, g , year t and cause of death, c
- $m(x)$ = national death rate at age (group) x
- $m_I(i, x)$ = income-deprivation decile i death rate,
- $m_R(r, x)$ = region r death rate,
- $m_{RI}(r, i, x)$ = death rate at age x in region r , deprivation decile i .

ASMR Variants (cont.)

Each of these has corresponding ASMRs:

$$\begin{aligned}ASMR \equiv ASMR(t) &= \frac{\sum_{x=x_0}^{x_1} m(x)ES(x)}{\sum_{x=x_0}^{x_1} ES(x)} \\ASMR_I(i) &= \frac{\sum_{x=x_0}^{x_1} m_I(i, x)ES(x)}{\sum_{x=x_0}^{x_1} ES(x)} \\ASMR_R(r) &= \frac{\sum_{x=x_0}^{x_1} m_R(r, x)ES(x)}{\sum_{x=x_0}^{x_1} ES(x)} \\ASMR_{RI}(r, i) &= \frac{\sum_{x=x_0}^{x_1} m_{RI}(r, i, x)ES(x)}{\sum_{x=x_0}^{x_1} ES(x)}\end{aligned}$$

The Age and Deprivation Standardised Mortality Rate

$$ASMR_R(r) \equiv \frac{\sum_{x=x_0}^{x_1} ES(x) \sum_{i=1}^{10} m_{RI}(r, i, x) w_{RI}(r, i, x)}{\sum_{x=x_0}^{x_1} ES(x)}$$

$w_{RI}(r, i, x) = E_{RI}(r, i, x) / \sum_i E_{RI}(r, i, x)$ decile i weight amongst deciles 1 to 10, region r , age x

The ADSMR replaces weights $w_{RI}(r, i, x)$ by $\tilde{w}_{RI}(r, i, x) = 0.1$. Hence

$$\begin{aligned} ADSMR(r) &= \frac{\sum_{x=x_0}^{x_1} \sum_{i=1}^{10} m_{RI}(r, i, x) \tilde{w}_{RI}(r, i, x) ES(x)}{\sum_{x=x_0}^{x_1} ES(x)} \\ &= \frac{1}{10} \sum_{i=1}^{10} ASMR_{RI}(r, i). \end{aligned}$$