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

Andrew J.G. Cairns

Heriot-Watt University, Edinburgh

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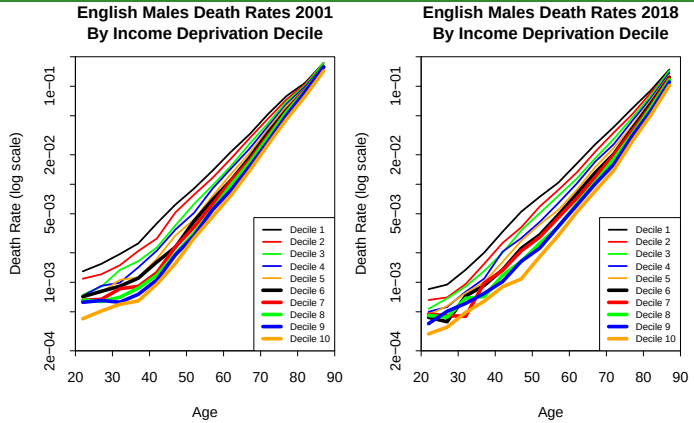
Outline

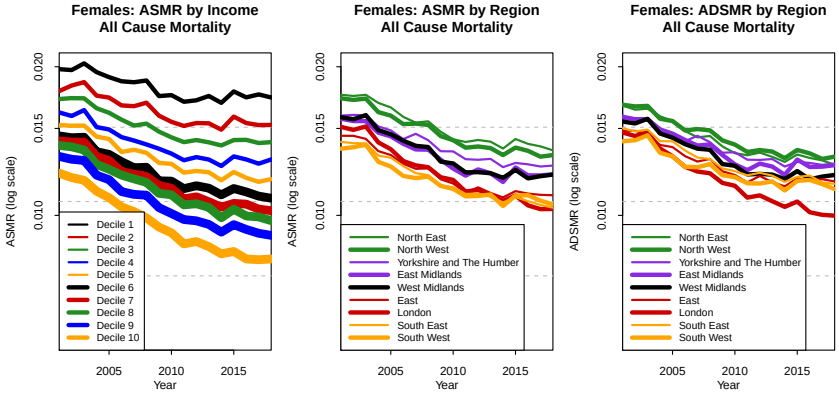
- Motivation: trends and inequalities in all-cause mortality
- Cause-of-death data for England
- Empirical analysis
- Discussion and Covid-19 postscript

Motivation: all-cause mortality – the age profile of inequality – 2001 vs 2018



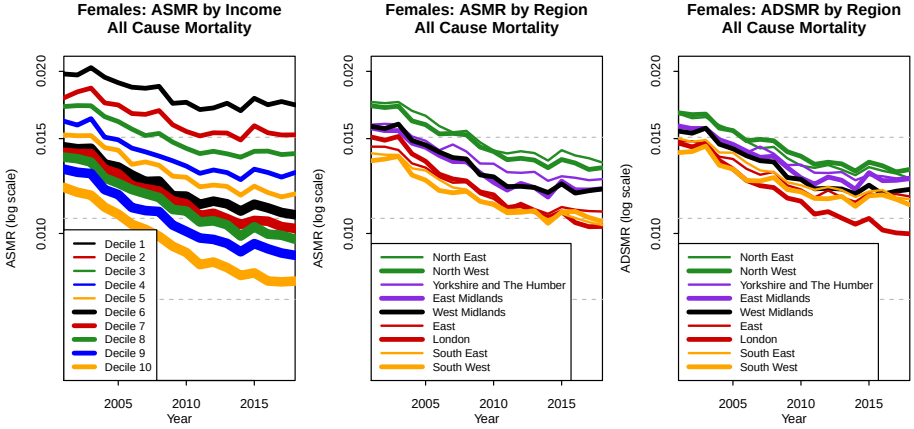
- Income deprivation = part of the Index of Multiple Deprivation (IMD)
- Significant inequality between the most and least deprived
  More than 4× around age 50; narrowing at high ages
- 2001→2018: improving mortality; but also slight widening at middle and higher ages

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



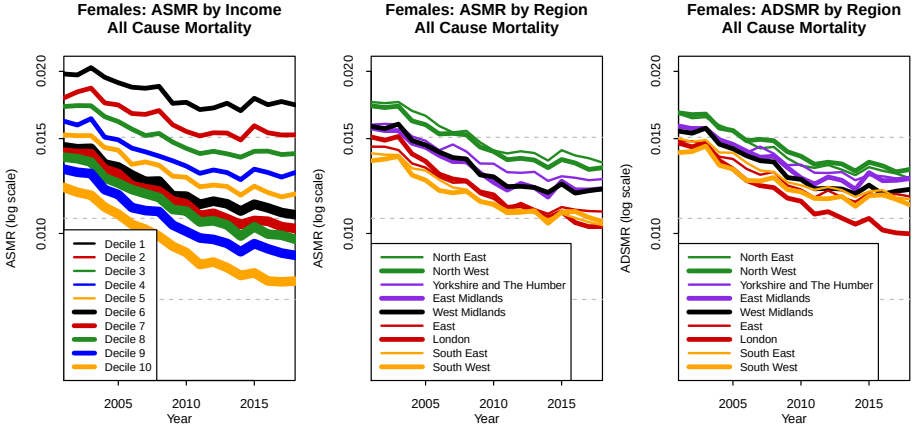
- ASMR= average mortality (40-89) weighted using a standard population
- **Left:** Impact of income deprivation much bigger than region
- **Right:** ADSMR: Age and Deprivation Standardised Mortality Rate
  ADSMR adjusts regional mortality for differences in deprivation mix

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



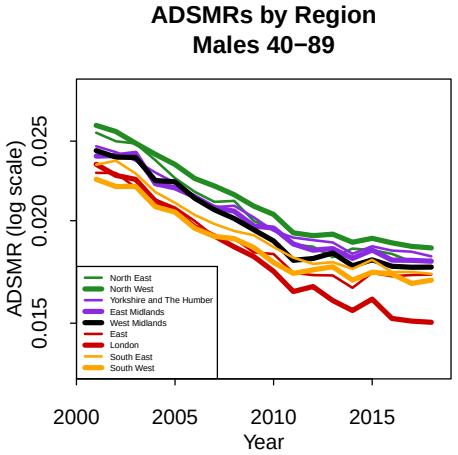
- Widening gap between the most and least deprived
- Mortality improvements: slowdown after 2010/2011 in all deciles

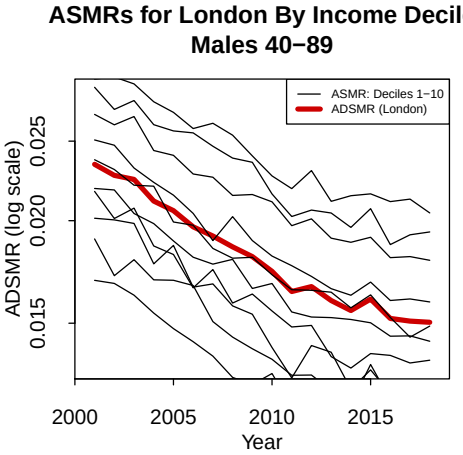
Age Standardised Mortality Rates (ASMR; ages 40-89)



- Significant differences between regions is partly explained by differences in the deprivation mix
- North-South split is not so big after deprivation adjustment
- London: significantly different trend from other regions

Digression: London – the effect of IMD migration





- London average IMD decile: 4.5 (2004, 2010) $\longrightarrow$ 5.0 (2019)
- ASMRs by decile $\Rightarrow$ IMD improvements only explain part of the London effect
- Trends by cause of death might shed more light on the London effect

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*?
- Can the *London effect* be linked to specific causes of death?
- Leading to insight into:
  - mortality underpinning life insurance and pensions;
  - and national, regional and sub-regional mortality

Drivers of mortality improvements and mortality inequality

- Medical advances + implementation
- Public health initiatives
- 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 ($\rightarrow$ cervical cancer)
  - Not (easily) controllable or preventable

    e.g. genetic, ethnic, 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
  $\Rightarrow$ more likely to: smoke; have a poor diet; exercise less; drink too much alcohol
  $\Rightarrow$ higher mortality

Why do mortality inequalities exist?

- Individuals and their behaviour $\Rightarrow$ variation from one area or group to the next
  - **prevalence of underlying controllable risk factors**
  - prevalence of preventable or non-controllable risk factors
  - average propensity to get an **early diagnosis**
  - average level of engagement with the **treatment process** following diagnosis
  - average level of engagement with **preventative measures**
  - health/ill-health migration
- Local health service
  - quality of local, cause-specific medical care
  - timeliness of emergency response
  - effectiveness of local screening programmes
  - effectiveness of local public-health campaigns
  - local variations in reporting of the underlying cause of death
  - *variation in quality of care by socio-economic group*
- Given variation in prevalence, relative risks drive inequalities

Why do mortality inequalities exist?

The degree of mortality inequality varies considerably between causes of death.

- Some causes: very little inequality
- Other causes: high levels of inequality

The biggest mortality inequalities will exist for specific causes of death, C, where

(a) there is significant variation by area or socio-economic group in the prevalence of specific controllable risk factors X, Y, ...

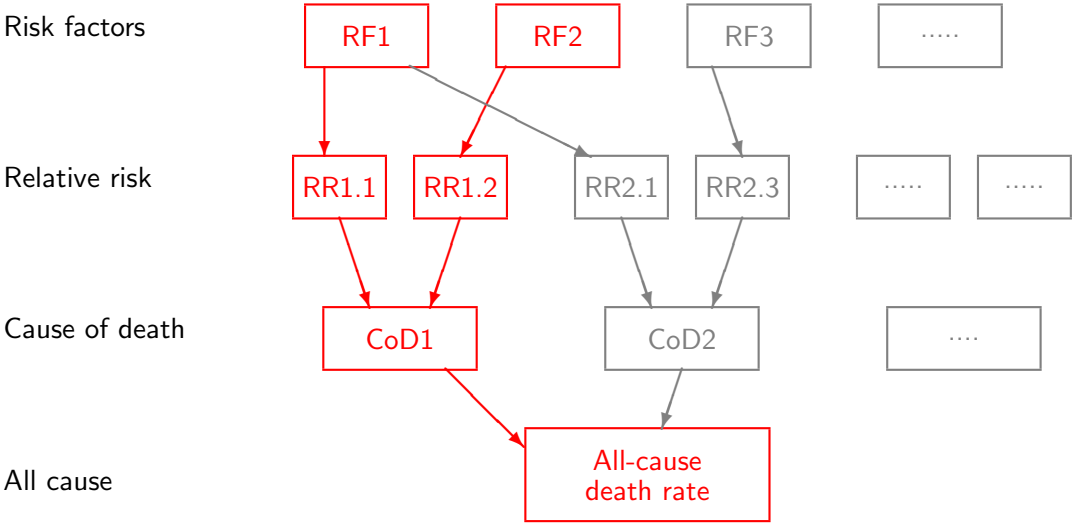
(b) some of these risk factors have a significant impact on the chances of dying from cause C (i.e. high relative risk).

(c) Impact on *all-cause mortality inequality* if C contributes a significant percentage to all-cause mortality.

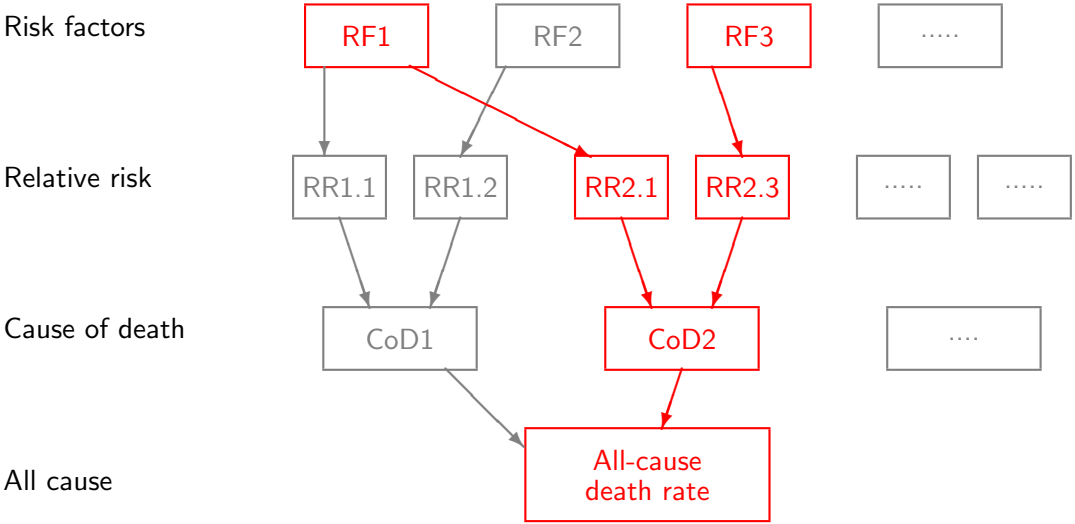
Examples:

- There is significant variation in smoking prevalence, diet, exercise, etc., but ...
- Breast cancer: relative risks for different risk factors are very low $\Rightarrow$ little inequality
- Lung cancer: relative risk for smoking is very high $\Rightarrow$ high levels of inequality

Why do mortality inequalities exist?



Why do mortality inequalities exist?



Cause of death groupings

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

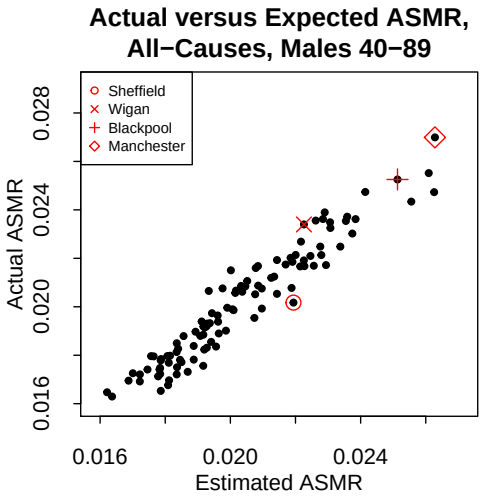
Dataset A:

- 51 CoD groups
- Age groups 20-24, 25-29, ..., 85-89
- Single years 2001-2018
- by *income deprivation*: 10 deciles
- by *region*: 9 areas

Dataset B:

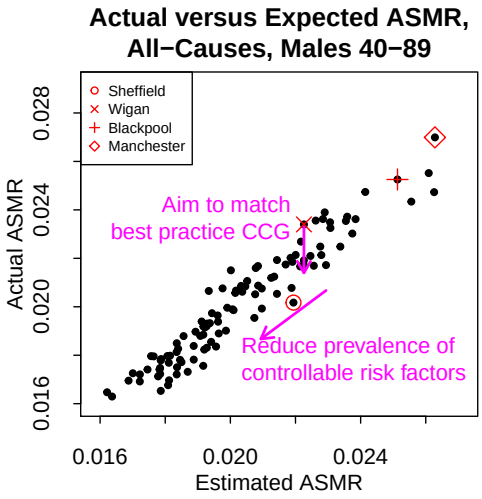
- 52 CoD groups (# 52 = Covid)
- Age groups 0, 1-4, 5-9, 10-14, ..., 85-89
- Single years 2001-2020
- by *Clinical Commissioning Group*: 106 CCGs across England

Clinical Commissioning Groups, Actual versus Expected (all-cause mortality)



- CCGs: death rates and ASMRs depend on socio-economic mix
- Expected ASMR is based on predicted mortality using the *LIFE* index
  takes account of e.g. income deprivation, urban/rural etc.
- Some variation between actual and expected

CCGs – "Levelling up" ⇒ ASMRs down!

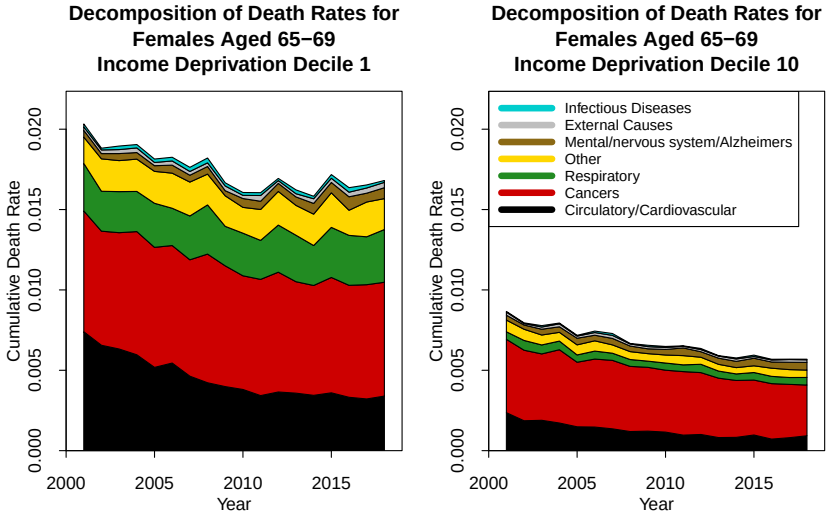


Two ways to reduce the ASMR:

- Learn from CCGs that do well on a *like-for-like basis* (Wigan → Sheffield)
- Identify key controllable risk factors and try to push down prevalences

Comparisons of CCGs by cause of death might help to customise local health policy

Seven CoD groups: females 65-69; deciles 1 vs 10; breakdown by year



Existing knowledge from analysis of higher-level cause of death groupings:

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

Cause of death data: more detailed analysis – 51 causes

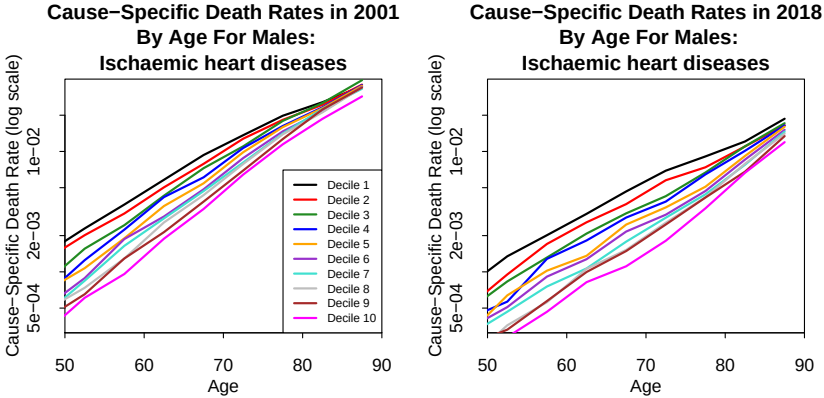
Visualising the data in different ways reveals more insights:

- Death rates by cause of death
  by sex, age, year, (region, deprivation decile) or CCG
  - potentially aggregated into larger groups
  - mean over deprivation deciles ⇒ deprivation standardised death rates
- Age Standardised Mortality Rates (ASMRs) by cause of death
  by sex, age range, year, (region, deprivation decile) or CCG
  - potentially aggregated into larger groups
  - average over deprivation deciles ⇒ Age and Deprivation Standardised Mortality Rates

Aggregation (including ASMR over ages): improves the signal-to-noise ratio in plots

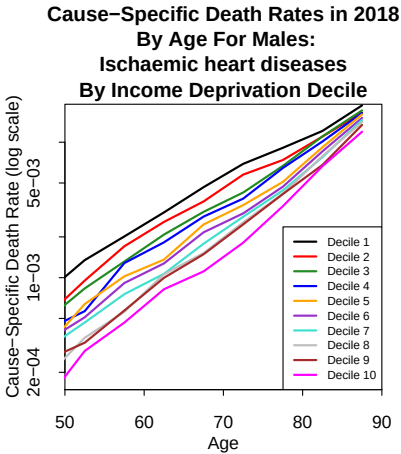
Use Ischaemic Heart Disease to illustrate data visualisation options,
(please contact me if you want to see other plots)

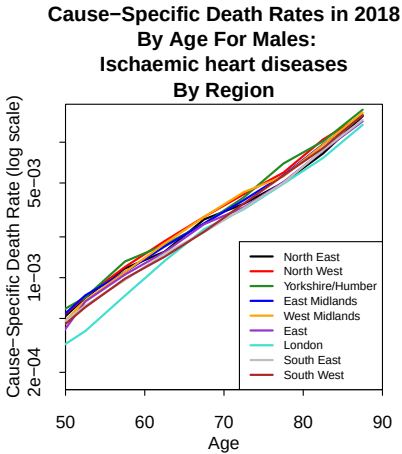
Ischaemic heart disease: death rates by age and income deprivation decile, 2001→2018



- Significant improvements between 2001-2018
- Significant inequality by deprivation at younger ages, narrowing at higher ages

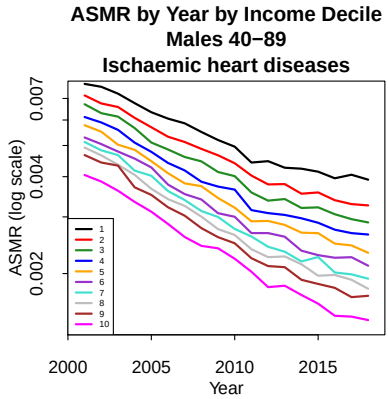
Ischaemic heart disease: death rates by age and income deprivation decile or region

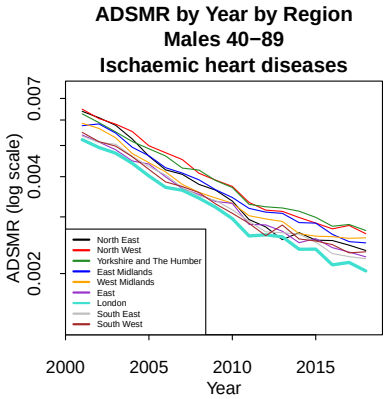




- Significant inequality by deprivation at younger ages, narrowing at higher ages
- Some inequality by region, but not narrowing with age – persistent 20-30% gap above age 65

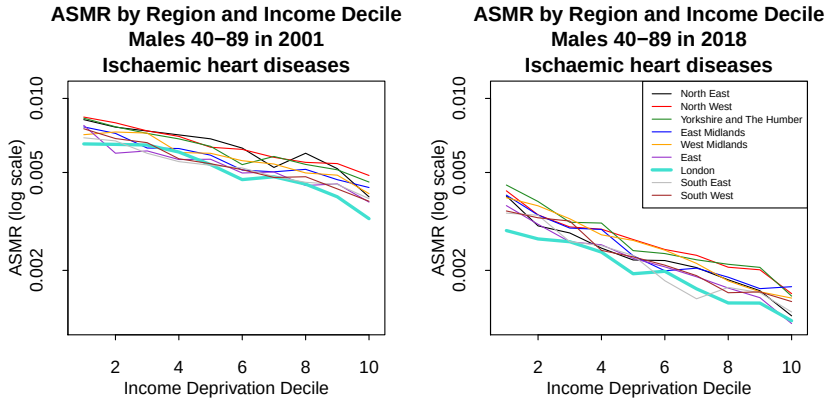
Ischaemic heart disease: ASMR/ADSMR by year





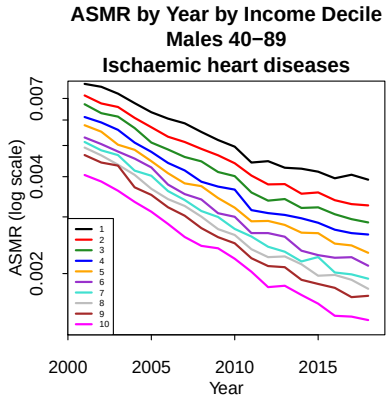
- Significant improvements over time; slowing after 2011
- Significant inequality by decile; increasing over time
- Some residual regional variation after deprivation standardisation
- London has persistently low ADSMR

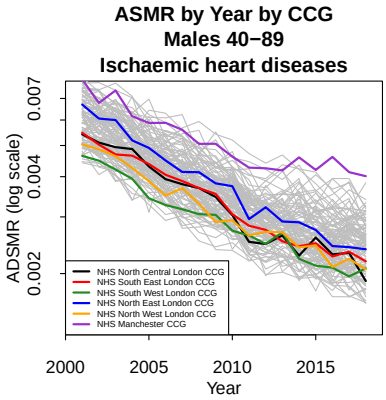
Ischaemic heart disease: ASMRs for individual (region, decile) combinations



- ADSMR averages over all deciles; London consistently lower
  How do individual deciles compare between regions?
- Both 2001 and 2018:
  London has consistently lower ischaemic heart disease ASMRs *in all income deprivation deciles*

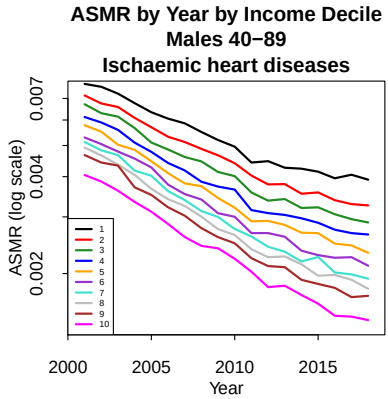
Ischaemic heart disease: ASMR by deprivation or Clinical Commissioning Group (CCG)

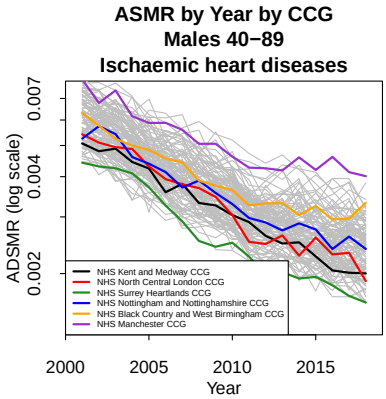




- 106 CCG's: more volatile (more noise) than 10 income deprivation deciles
- Considerable inequality by CCG, with a widening gap
- Five London CCGs: slightly narrowing gap
- Manchester CCG: ends up with the highest rates (matching all-cause mortality)

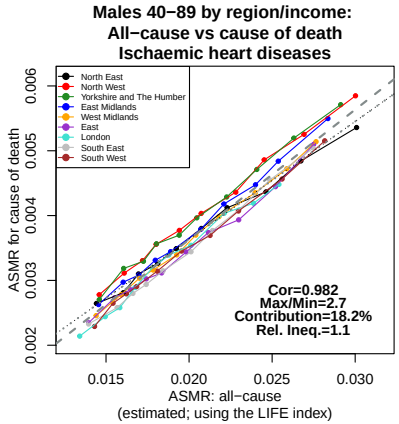
Ischaemic heart disease: ASMR by deprivation or Clinical Commissioning Group (CCG)

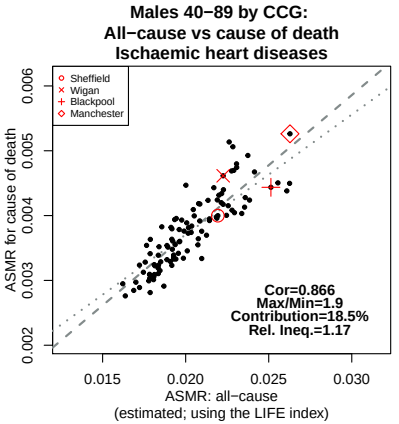




- Six of the larger CCGs (less volatile) across England
- Divergent paths

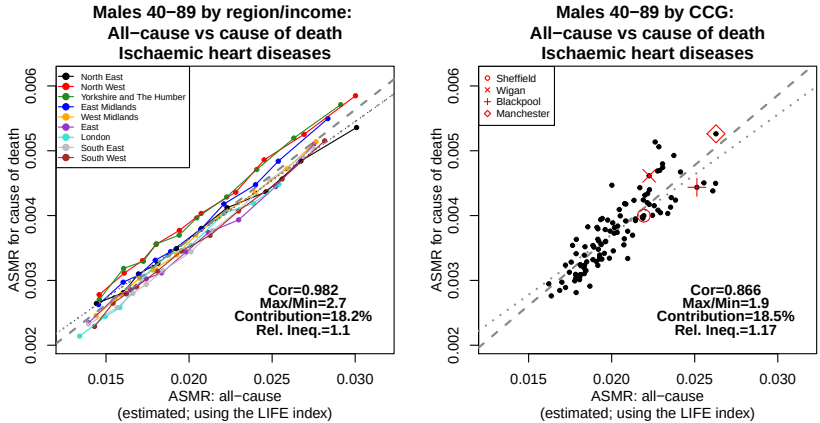
Ischaemic heart disease: cause-of-death ASMR versus all-cause ASMR





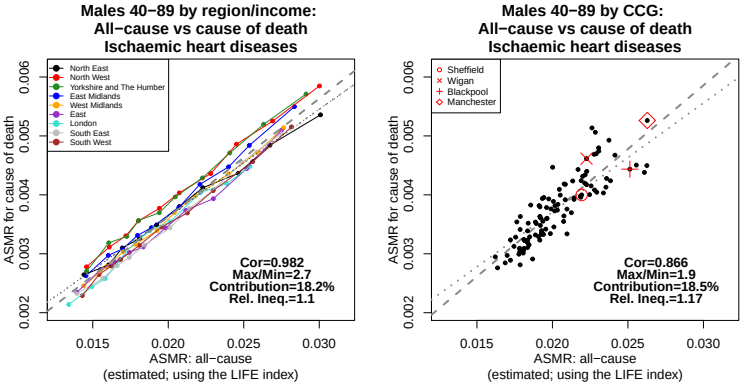
- ASMRs: mean over the years 2001-2018 (reduces single year noise; lose the trend)
- ASMR all cause: based on expected mortality using the *LIFE* index
- Left: 9×10 regions x deciles Right: 106 CCGs

Ischaemic heart disease: cause-of-death ASMR versus all-cause ASMR



- **Statistics: Correlation; max ASMR / min ASMR; Contribution=CoD as a % of all-cause**
- **Relative inequality, RI:** $RI = 1 \Rightarrow$ inequality in proportion to all-cause inequality (dotted line); $RI > 1 \Rightarrow$ higher levels of inequality (dashed line)
- RI is higher when there are significant controllable risk factors and higher relative risks

Ischaemic heart disease: cause-of-death ASMR versus all-cause ASMR



- Left: coloured lines are approximately parallel
  $\Rightarrow$ consistent but small inequality ($\sim \pm 10\%$) by region across all deciles
- Right: $\Rightarrow$ further variations within regions
- Specific CCGs (e.g. $\diamond$ Manchester): high or low relative to the fitted (dashed) line?
- E.g. what can Wigan learn from Sheffield?

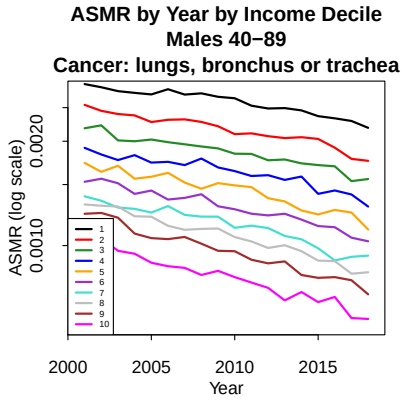
Other causes of death

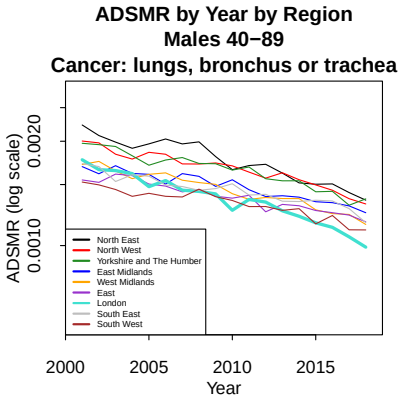
- Ischaemic heart disease $\Rightarrow$ multiple risk factors
  $\Rightarrow$ difficult to be precise about the reasons for inequality
- Lung cancer and COPD have smoking as the main risk factor
  + relative risk associated with smoking is very high
- Caution: the impact of smoking at the individual and group level depends on
  - smoking prevalence (group level)
  - smoking intensity (heavy or light smokers)
  - years since commencement
  - percentage and duration of quitters

  The word "prevalence" is used as a proxy for the combined impact of these factors
- Lung-cancer plots: different groups have significantly different trajectories over time

  What do we infer? Differences in how smoking "prevalence" changes through time

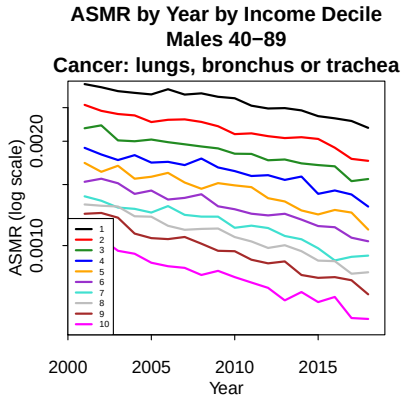
Lung Cancer: Males

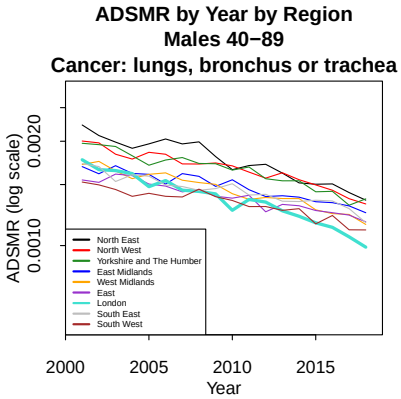




Left: 10 income deprivation deciles, $ASMR_l(t)$
Right: 9 regions, $ADSMR(t)$

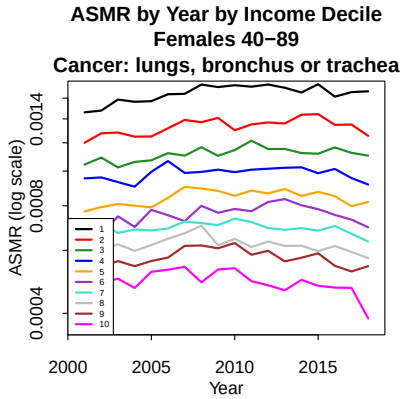
Lung Cancer: Males

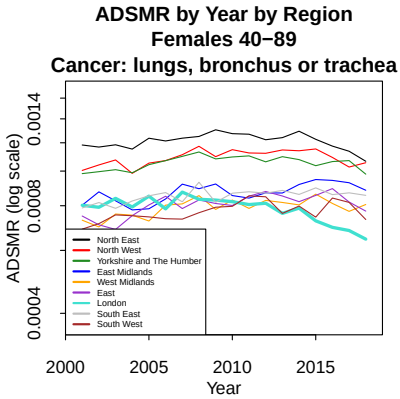




- Significant variation between income deciles ($\Leftarrow$ smoking "prevalence")
- Significant variation between regions (after deprivation standardisation)
- $\times 3$ by income decile; $\times 1.4$ variation by region
- London effect (improving faster); Northern regions very poor

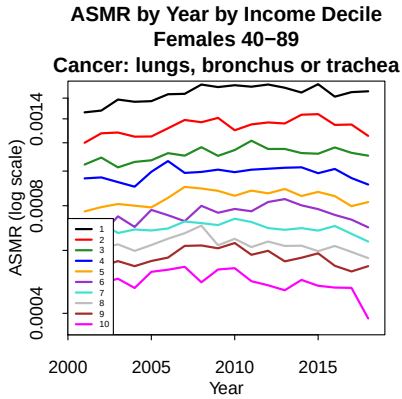
Lung Cancer: Females

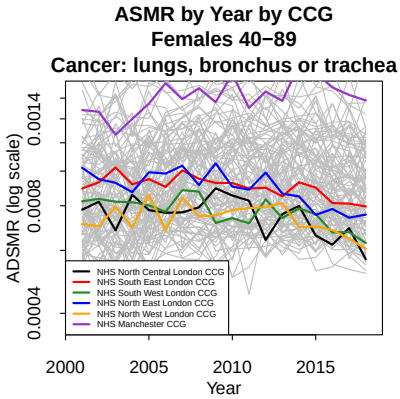




- Different pattern from males
- Slight worsening ⇒ ?? smoking "prevalence" rising
- Some northern regions do badly; wider regional spread
- London effect

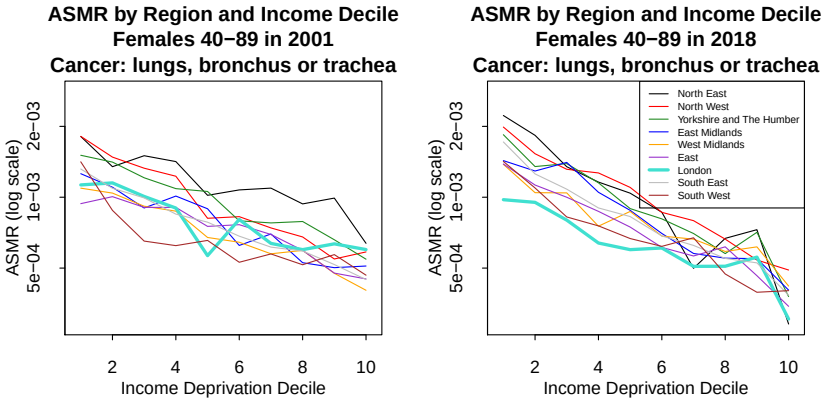
Lung Cancer: Females by Decile and CCG





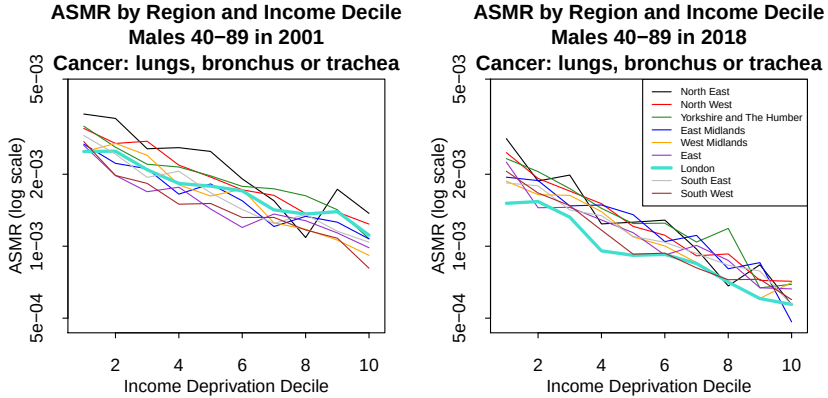
- Five London CCGs all improving (all faster than all-England decile 10)
- Manchester worsening

Lung cancer: ASMRs for individual (region, decile) combinations



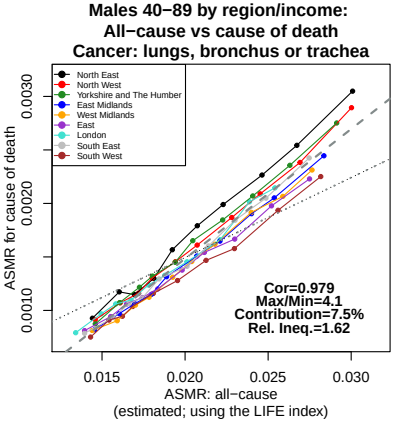
- Outside London: $ASMR(r, d)$ worsened in low deciles; $ASMR(r, d)$ improved in hgh deciles
- London: $ASMR(r, d)$ improving from 2001-2018 in all deciles
- Inference: smoking prevalence in the more deprived groups has fallen in London but is has risen elsewhere $\Rightarrow$ contribution to the "London effect"

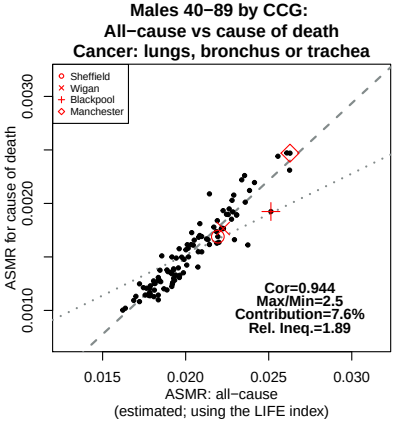
Lung cancer: ASMRs for individual (region, decile) combinations



- Inference 1: smoking prevalence has been falling in all regions and deciles
- Inference 2: smoking prevalence has been falling faster in London in all deciles

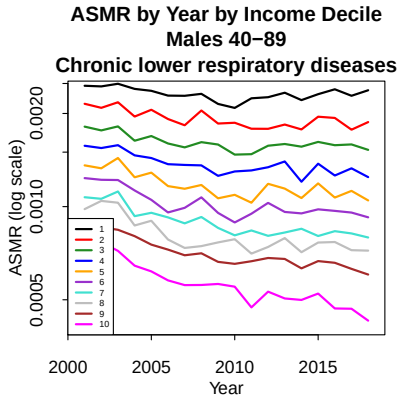
Lung cancer: cause-of-death ASMR versus all-cause ASMR

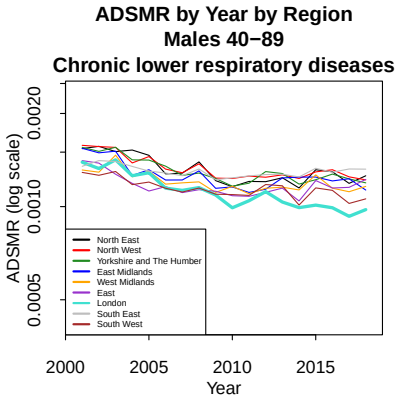




- Relatively strong and consistent regional effects across deciles
- Relative Inequality, Rel. Ineq., $>> 1 \leftrightarrow$ high relative risk for smokers
- Blackpool is well below the CCG regression line

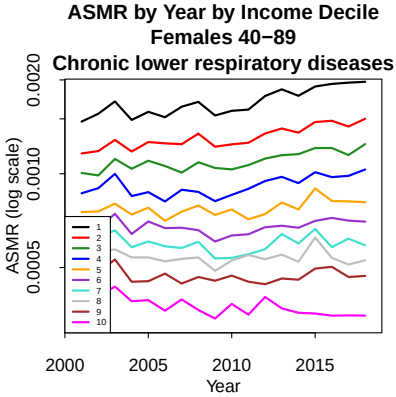
COPD (Chronic Obstructive Pulmonary Disease): Males

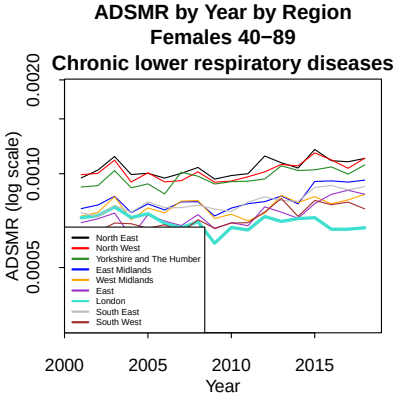




- Very similar patterns to lung cancer: both dependent on smoking "prevalence"
- But e.g. decile 1 for COPD is flatter than for lung cancer
- Inference: lung cancer treatments have improved faster than COPD treatments

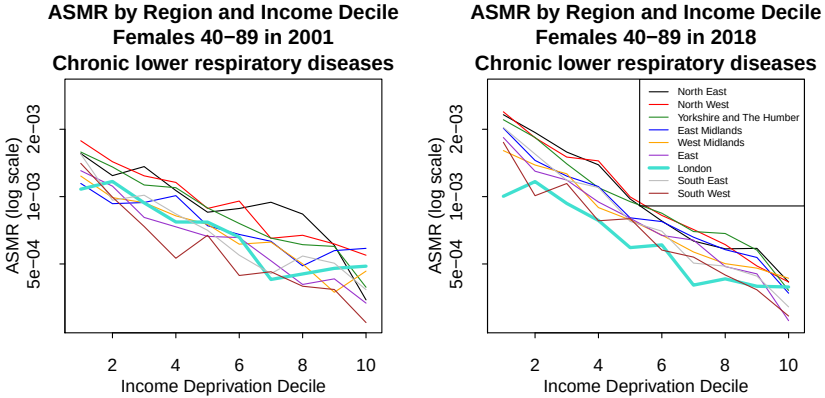
COPD: Females





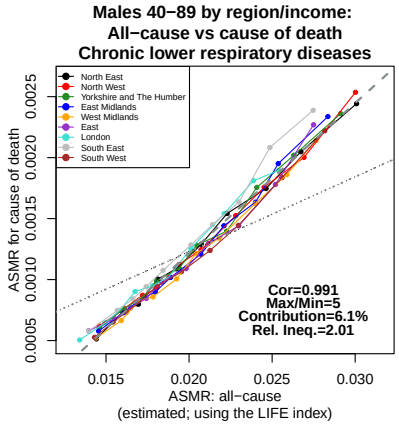
Different pattern from males
Slight worsening ⇒ ?? smoking prevalence/intensity rising
Some northern regions do badly
Wider regional spread
London effect

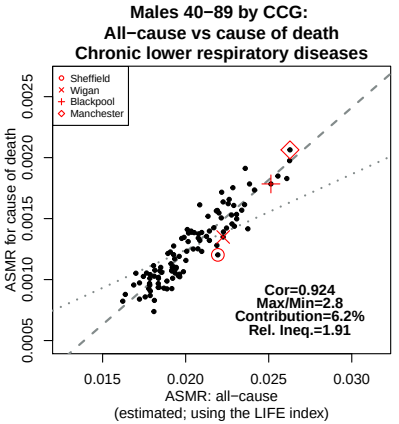
COPD: ASMRs for individual (region, decile) combinations



- Similar conclusion to lung cancer:
  London improving faster than other regions across all deciles

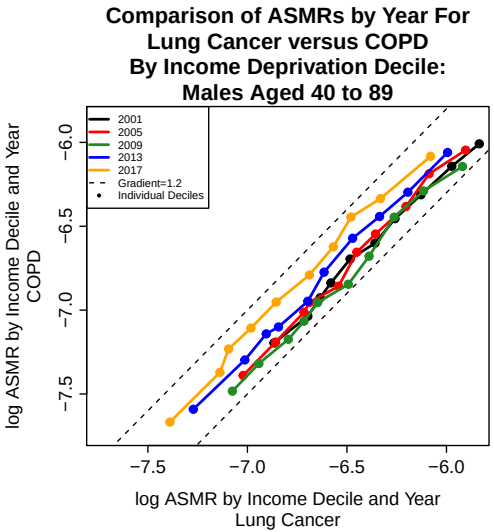
COPD: cause-of-death ASMR versus all-cause ASMR





- Weaker regional effects across deciles than lung cancer (females: stronger effect)
- Relative Inequality, Rel. Ineq., $>> 1 \leftrightarrow$ higher relative risk for smokers
- Blackpool closer to the regression line (than lung cancer): ???

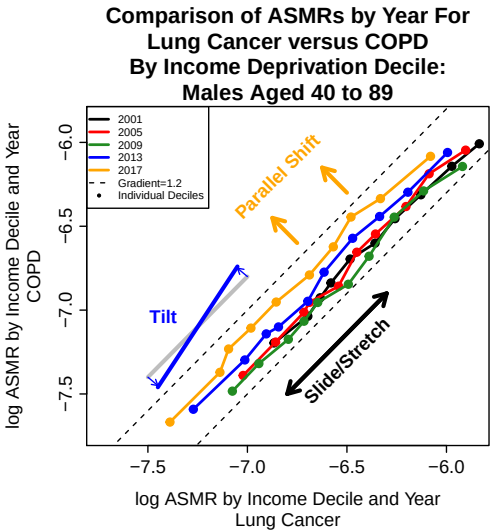
ASMRs: Lung cancer versus COPD by income deprivation decile for selected years



- In each year: strong linear relationship between lung cancer and COPD by decile
- Gradient of 1.2 consistent with a higher relative risk for COPD
- Some movement from year to year

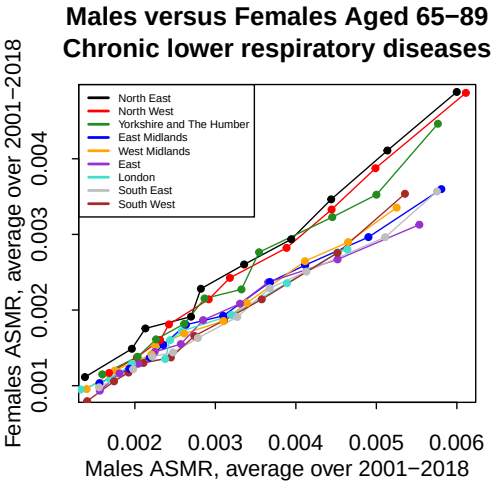
- Challenge:
  - published estimates of the individual lung-cancer and COPD relative risks vary quite considerably
  - but the gradient of 1.2 tells us about the relationship between the two

ASMRs: Lung cancer versus COPD by income deprivation decile



- **Slide/Stretch:** consistent with changes in the underlying "smoking prevalence" OR: similar improvements in treatment
- **Parallel shift:** consistent with *different levels of improvement* in the treatment of lung cancer and COPD
- **Tilt:** consistent with changes in the relative risk for lung cancer or COPD (??? relative risk mainly due to onset rather than treatment)

- Parallel shift (+ other plots) suggests that, *everything else being equal*, lung cancer mortality has been falling at 1-2% p.a. faster than COPD mortality



- Plot suggests high correlation between smoking "prevalence" in males and females
- Females 60-80% of males
- But **black**, **red**, **and** **green** lines lie above the rest
  $\Rightarrow$ in NE, NW and Y&H:
  females *even* more likely to be smokers than in other regions on a decile-by-decile basis
- Ages 40-64:
  - London: females 55% of males
  - Other regions: 80-90%

CCGs: What do the cause-of-death charts tell us?

- Focus on the more important causes $\Rightarrow$ narrower confidence intervals
- Is a specific CCG significantly above or below the regression line?
- Wigan (high compared to all-cause comparator Sheffield)
  - high mortality: **most cardiovascular/circulatory diseases**; vascular dementia; pneumonia
  - about right: lung cancer, COPD
- Sheffield
  - low mortality: some cardiovascular/circulatory diseases; most respiratory diseases
  - high mortality: Alzheimer's disease
  - about right: lung cancer
- Blackpool (all-cause in line with expected):
  - low mortality: lung cancer, ischaemic H.D.
  - high mortality: liver cancer, circulatory diseases, pneumonia, alcoholic liver and other digestive diseases, accidental poisoning
- Manchester (all-cause in line with expected):
  - But: ischaemic heart disease well above other CCGs in the worst five

- Age and Deprivation Standardised Mortality Rate (ADSMR) for London has fallen faster than other regions
  - Smoking-related diseases: lung cancer, COPD, (pneumonia), (blood pressure)
  - Alcohol-related diseases: liver diseases, liver cancer
  - Other: pneumonia, blood pressure (very high $\rightarrow$ high)
- Other causes of death have been consistently low:
  - Cancers: oesophageal, colon, ovary, urinary
  - Alzheimer's (??? health migration)
  - Cardio./Circ.: ischaemic HD, cerebrovascular, circulatory $\leftrightarrow$ other heart diseases (high)

Inference: differences are a mixture of

- Better improvements than other regions in the prevalence of some controllable risk factors, especially in the more deprived deciles
- Persistently better treatments for certain diseases

Poll

Which cause of death has a significant level of *negative* inequality?

- A: breast cancer
- B: Parkinson's disease
- C: skin cancer
- D: increased blood pressure and rheumatic fever

Other vignettes

- Skin cancer:
  - the only cause of death with a significant negative Relative Inequality
  - also significant regional inequalities:
    high: SE and SW England
- Parkinson's disease has a slight negative Relative Inequality
  (??? inversely related to smoking)
- Urban/rural:
  - Rural tend to have lower all-cause mortality
  - Rural CCGs relative to the regression line for each cause:
    - (slightly) low mortality: pneumonia; alcoholic liver disease
    - (slightly) high mortality: colon cancer; suicide

Which Causes of Death ⇒ 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%.

There are **no** *causes of death with a narrowing gap*

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

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

Covid-19 postscript

- Covid-19 has been very disruptive to all-cause mortality
- Similarly disruptive to cause-of-death mortality statistics
- 2001-2020 data by CCG is counts deaths by *underlying cause*
- With Covid-19 separated out: relatively few causes have a clear jump in 2020
- **Up on the recent trend**
  - **Parkinson's (+20%)** and Alzheimers (misreported Covid deaths???)
  - breast cancer
- **Down on the recent trend**
  - **pneumonia (-15%)** and some other respiratory diseases
- 2021 and beyond: continuing disruption; ??? temporary rise in cancer-related and some other causes of death
  - delayed diagnosis
  - short/long-term changes in behaviour

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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?
- Targeted survey data might be useful, guided by inferences from cause-of-death

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Summary and conclusions

- Causes of death with associated controllable risk factors
  $\Rightarrow$ mortality inequality
- Causes of death with no controllable risk factors
  $\Rightarrow$ little or no inequality
- Significant levels of inequality for most of the big CoD's
- Regional differences remain even after adjusting for deprivation
- Mortality inequalities have widened since 2001
  Link to multiple controllable risk factors
- Smoking remains as a major driver of mortality in more deprived groups, especially outside of London
- There is no "quick fix": changing health behaviour now will take many years to filter through to lower death rates

Thank You!

Questions?

E: A.J.G.Cairns@hw.ac.uk
W: www.macs.hw.ac.uk/~andrewc/ARCresources

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