Mortality Data By Socio-Economic Group, Region and Cause of Death: What Do the Patterns Tell Us?

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Outline

- Motivation and long term goals
- Data
- England: empirical analysis
- Discussion

Note: Sessional Research Meeting, Staple Inn, 6 January 2020

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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

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Digression: The Human Cause-of-Death Database

- `www.causesofdeath.org`
- 16 countries
- National data only, not socio-economic subgroups
- Data $\Rightarrow$
  - what are the most significant causes of death?
  - analysis of trends over time
- Here: socio-economic sub-populations $\Rightarrow$
  - Health inequalities
  - Differential trends

Drivers

- Medical advances
- Public health initiatives
- Health spending by age
- Individual risk factors:
    - Controllable (Cancer UK: *preventable*)
      e.g. smoking, diet, exercise, alcohol, sun, drugs,
      hygiene, risky sex, stress, environment...
    - Not (easily) controllable
      e.g. genetic, affluence, education,
      character/personality traits, ...
      ?? prior health events (e.g. heart attack)

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

Cause of Death Groupings

1	Infectious diseases	2	Cancer: oesophagus, stomach
3	Cancer: bowel, gut	4	Cancer: larynx
5	Cancer: trachea	6	Cancer: lung, bronchus
7	Cancer: breast	8	Cancer: uterus, cervix
9	Cancer: ovary	10	Cancer: other female genital
11	Cancer: prostate, testicular	12	Cancer: other male genital
13	Cancer: skin, bones and certain organs	14	Cancer: lymphatic
15	Benign tumours	16	Diseases: blood
17	Diabetes	18	Mental illness (+)
19	Diseases of nervous system excl. Alzh.	20	Alzheimers
21	Blood pressure + rheumatic fever	22	Ischaemic heart diseases
23	Other heart diseases	24	Cerebrovascular diseases
25	Circulatory diseases	26	Lungs, breathing diseases
27	Digestive diseases (excl. alcohol)	28	Alcohol-related liver disease
29	Diseases: skin, bone, tissue	30	Urine, kidney and related diseases
31	Road/other accidents	32	Other causes of death
33	Suicide	34	Accidental poisonings

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

- 34 CoD groups
- Age groups 20-24, 25-29, ..., 85-89
- Single years 2001-2016

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

England – Deprivation – Top 10 Causes of Death

Males; Ages 70-74; Year 2016

Rank	Most Deprived	Least Deprived
1	Respiratory (*)	Skin & organ cancer
2	Ischaemic heart disease	Ischaemic heart disease
3	Lung cancer (*)	Respiratory
4	Skin & organ cancer	Lung cancer
5	Cerebrovascular	Prostate cancer
6	Oesoph., stom. cancer	Cancer: lymphatic, myeloma, etc.
7	Bowel, gut cancer	Nervous system excl. Alzh.
8	Other heart disease	Cerebrovascular
9	Digestive diseases	Oesoph., stom. cancer
10	Prostate cancer	Bowel, gut cancer

No controllable risk factors: e.g. Prostate – almost no inequality.

Significant controllable risk factors feature much more heavily amongst the most deprived.

(*) Strongest relative risk $\Rightarrow$ even higher up table in most deprived

Females; Ages 70-74; Year 2016

Rank	Most Deprived	Least Deprived
1	Respiratory (*)	Skin & organ cancer
2	Lung cancer (*)	Lung cancer
3	Skin & organ cancer	Respiratory
4	Ischaemic heart	Ischaemic heart
5	Cerebrovascular	Breast cancer
6	Digestive diseases	Cerebrovascular
7	Other heart dis.	Cancer: lymphatic, myeloma, etc.
8	Breast cancer	Nervous system excl. Alzh.
9	Bowel, gut cancer	Bowel, gut cancer
10	Mental illnesses	Ovarian cancer

No controllable risk factors: e.g. Breast and other cancers

M/F: All significant CoD's: Group 1 mortality > Group 10 mortality

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 $i = 1, \ldots, 10$ deprivation deciles
  - $ASMR_R(r)$, for $r = 1, \ldots, 9$ regions
  - Age and Deprivation Standardised Mortality Rate $ADSMR_R(r)$, for $r = 1, \ldots, 9$ regions

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

Region By Region Deprivation Profiles

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

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:

$$ASMR \equiv ASMR(t) = \frac{\sum_{x=x_0}^{x_1} m(x) ES(x)}{\sum_{x=x_0}^{x_1} ES(x)}$$

$$ASMR_I(i) = \frac{\sum_{x=x_0}^{x_1} m_I(i,x) ES(x)}{\sum_{x=x_0}^{x_1} ES(x)}$$

$$ASMR_R(r) = \frac{\sum_{x=x_0}^{x_1} m_R(r,x) ES(x)}{\sum_{x=x_0}^{x_1} ES(x)}$$

$$ASMR_{RI}(r,i) = \frac{\sum_{x=x_0}^{x_1} m_{RI}(r,i,x) ES(x)}{\sum_{x=x_0}^{x_1} ES(x)}$$

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

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

$$= \frac{1}{10}\sum_{i=1}^{10} ASMR_{RI}(r,i).$$

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

Age Standardised Mortality Rates Males By Income for All Causes — ASMR for age range 40–89
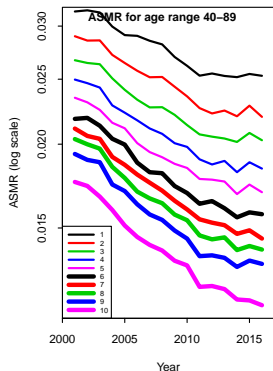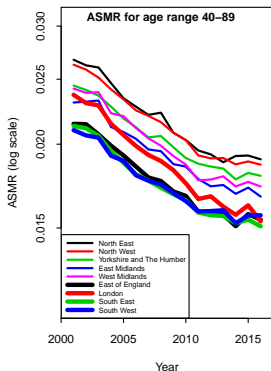
Age Standardised Mortality Rates Males By Region for All Causes — ASMR for age range 40–89

Age & Deprivation Standardised Mortality Rates Males By Region for All Causes — ADSMR for age range 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
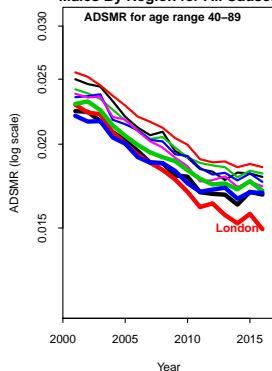
- Differing trends since 2011
- Hence (??): mortality projections
  - different short-term mortality improvement rates
  - converging to the same long-term improvement rate

England: Females (40-89) ASMR and ADSMR Inequality
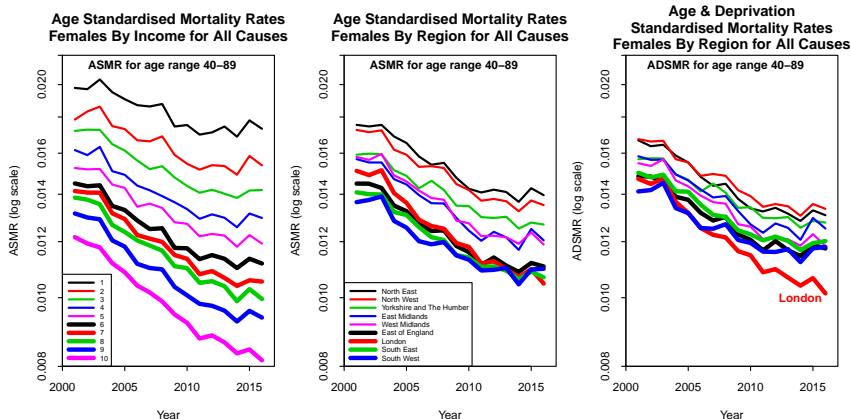
Males and females: significant regional effects remain after accounting for income deprivation
(All cause data: other non-regional covariates being investigated)

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

Decomposition of Death Rates for Females Aged 65–69 Income Deprivation Decile 1
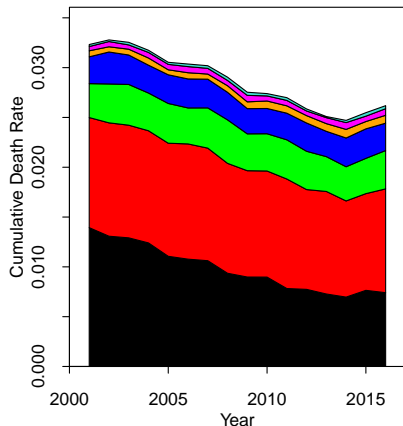
Decomposition of Death Rates for Females Aged 65–69 Income Deprivation Decile 10

Legend:
- Infectious Diseases
- External Causes
- Mental/nervous system/Alzheimers
- Other
- Respiratory
- Cancers
- Circulatory/Cardiovascular

Decomposition of Death Rates for Males Aged 65–69 Income Deprivation Decile 1

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

Legend:
- Infectious Diseases
- External Causes
- Mental/nervous system/Alzheimers
- Other
- Respiratory
- Cancers
- Circulatory/Cardiovascular
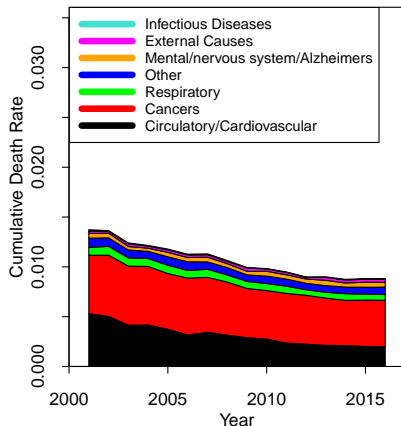
Higher-Level CoD Summary

- 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

Lung Cancer: Males

England Males ASMR By Income
Cancer: lungs

England Males ADSMR By Region
Cancer: lungs
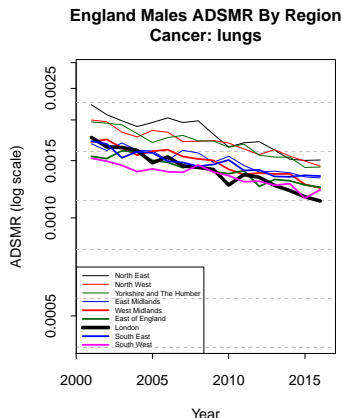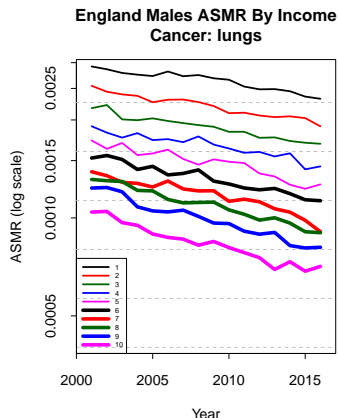
Horizontal dotted lines: $\times\sqrt{2}$ apart
Each plot: bottom to top: $\times 8$
Left: 10 income deprivation deciles, $ASMR_I(t)$
Right: 9 regions, $ADSMR(t)$

Lung Cancer: Males

England Males ASMR By Income Cancer: lungs

England Males ADSMR By Region Cancer: lungs
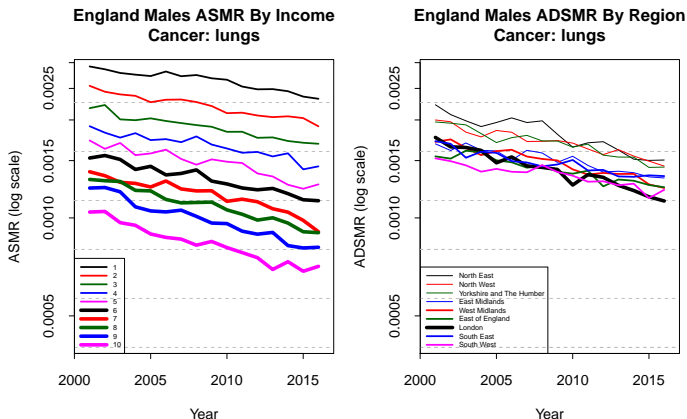
Significant variation between income deciles ($\Leftarrow$ smoking prevalence)

Significant variation between regions (after standardisation)

$\times 1.5$ variation by region; $\times 2.5$ by income decile

London effect; Northern regions very poor

Lung Cancer: Females

England Females ASMR By Income Cancer: lungs

England Females ADSMR By Region Cancer: lungs
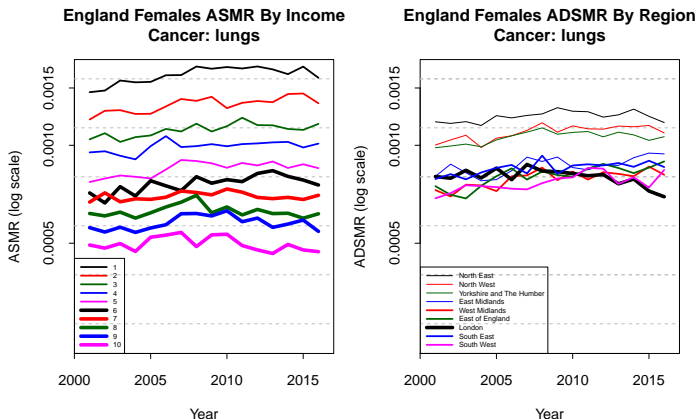
Different pattern from males

Slight worsening $\Rightarrow$?? smoking prevalence rising

Same northern regions do badly

Wider regional spread

London effect

England Males ASMR By Income
Respiratory diseases

England Males ADSMR By Region
Respiratory diseases
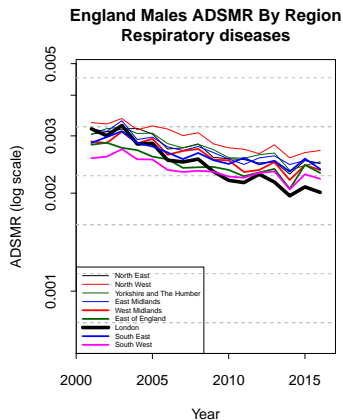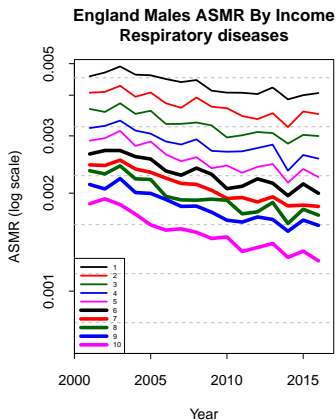
Similar pattern to lung cancer males
Chronic Obstructive Pulmonary Disease = major cause, with smoking as
the major controllable risk factor

Respiratory Diseases: Females

England Females ASMR By Income Respiratory diseases

England Females ADSMR By Region Respiratory diseases
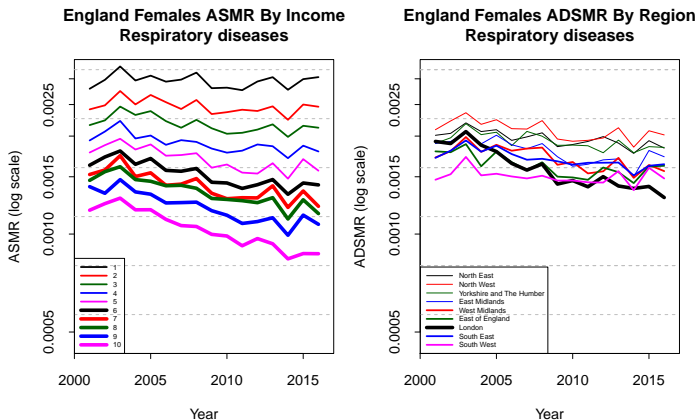
Similar pattern to lung cancer females

Weaker improvements than males linked to smoking prevalence, especially high deprivation

Ischaemic Heart Disease: Males

England Males ASMR By Income Ischaemic heart diseases

England Males ADSMR By Region Ischaemic heart diseases
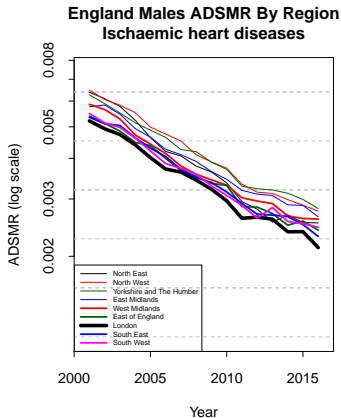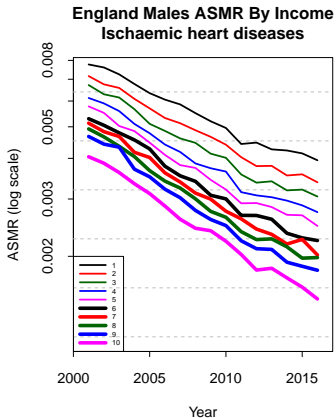
Significant inequality linked to multiple controllable risk factors

Success story: major improvements

Less good: widening gap and regional inequality; slowdown differences

Females: similar picture

Diabetes: Females

England Females ASMR By Income Diabetes
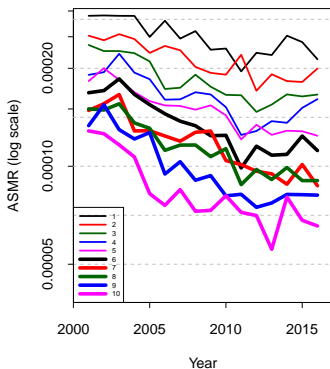
England Females ADSMR By Region Diabetes
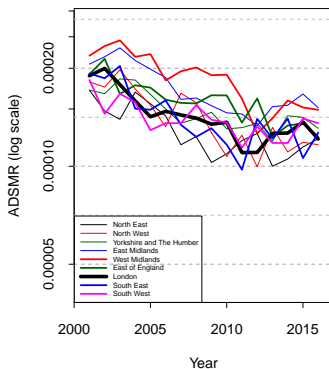
Widening gap and regional inequality
Males: similar picture

Impact of Controllable Risk Factors

- 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 $\longrightarrow$ lung cancer
  e.g. several risk factors $\longrightarrow$ 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
  - 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"

England Females ASMR By Income
Cancer: breast

England Females ADSMR By Region
Cancer: breast
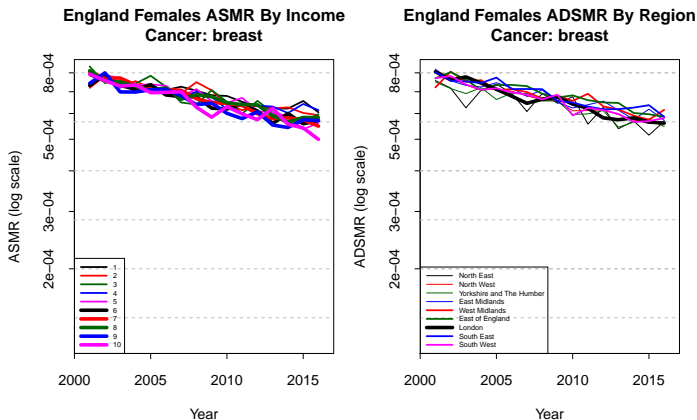
Limited controllable risk factors

"Success story": no significant income or regional inequality
(including ?? diagnosis)

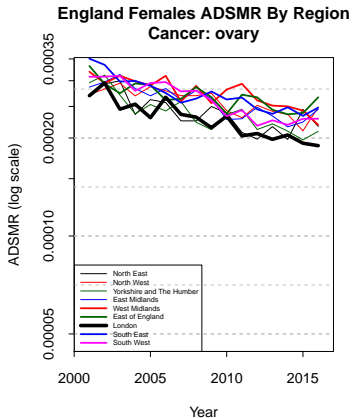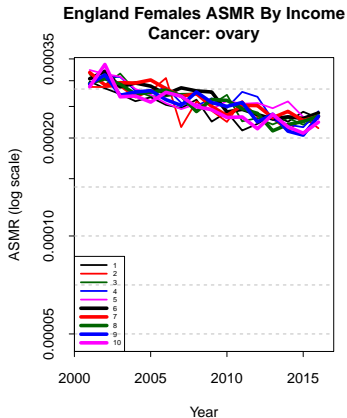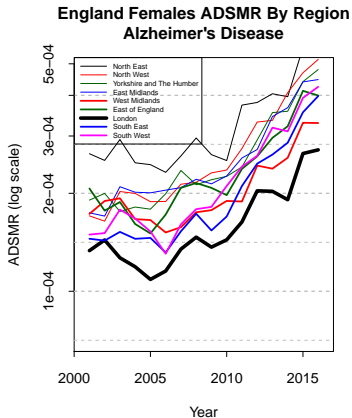# Prostate Cancer: A Small London Effect?

England Males ASMR By Income
Cancer: prostate

England Males ADSMR By Region
Cancer: prostate
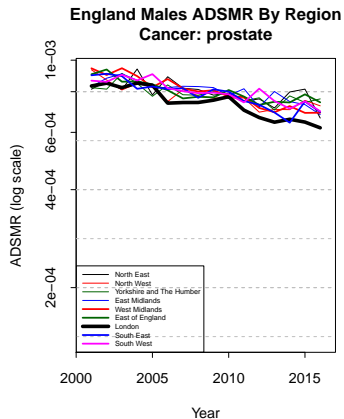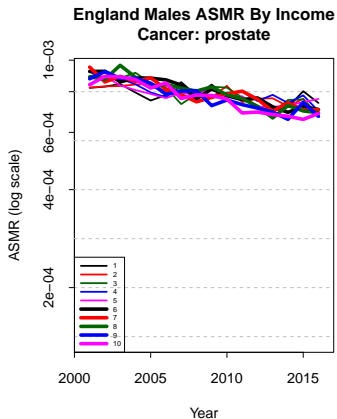
No significant income inequality
Small but significant differences between regions

Ovarian Cancer: A Regional Lottery?

Limited controllable risk factors
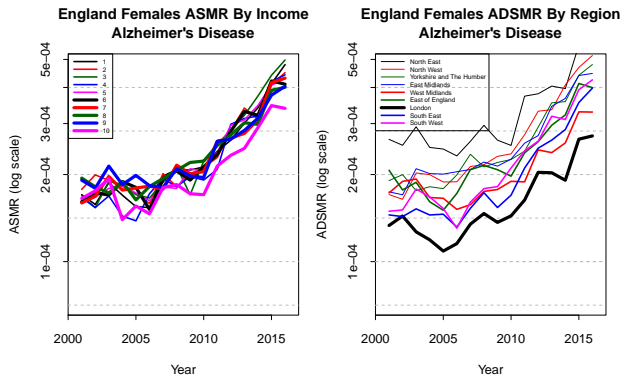Limited income effect
Significant regional effect

Alzheimers: Females (no clear controllable risk factors)

England Females ASMR By Income Alzheimer's Disease

England Females ADSMR By Region Alzheimer's Disease
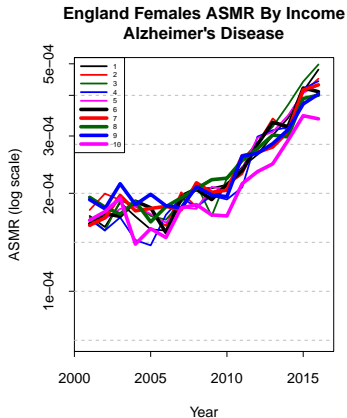
Modest income effect

Strong regional effect $\Rightarrow$?? health migration

Alzheimers: Females (no clear controllable risk factors)

England Females ASMR By Income Alzheimer's Disease

England Females ADSMR By Region Alzheimer's Disease

Deterioration $(2\times) \Rightarrow$??

- evidence for non-independence of causes of death improvements elsewhere
  $\Rightarrow$?? more frail survivors in old age
- gradual shift in *reported* cause of death

England Females ASMR By Income Mental illnesses, dementia

**England Females ADSMR By Region Mental illnesses, dementia**
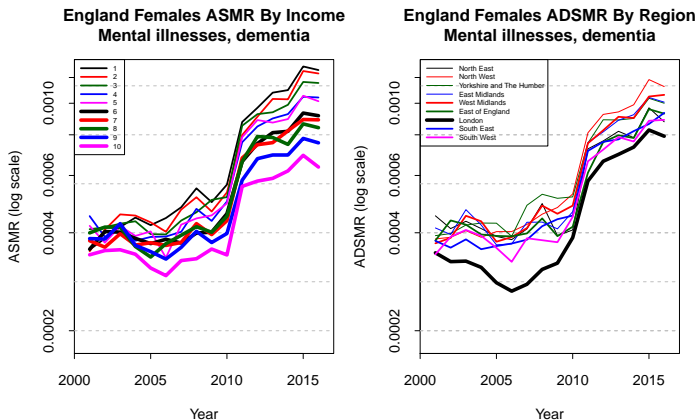
Inequality: similar risk factors to cardiovascular diseases

Deteriorating mortality

Jump in 2011: change in reporting $\leftrightarrow$ cerebrovascular

Alcohol-related liver disease
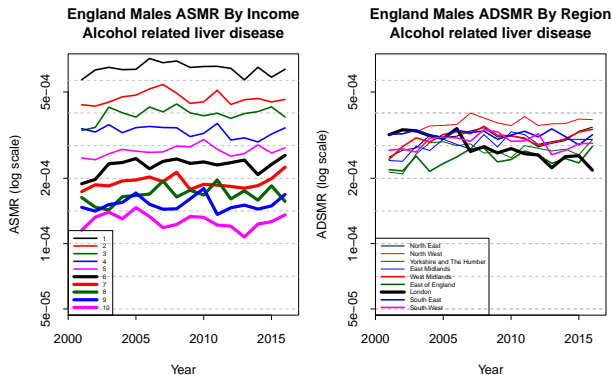
Case and Deaton (2015): "Deaths of despair"

Accidental poisoning

England Males ASMR By Income — Accidental poisonings

England Males ADSMR By Region — Accidental poisonings
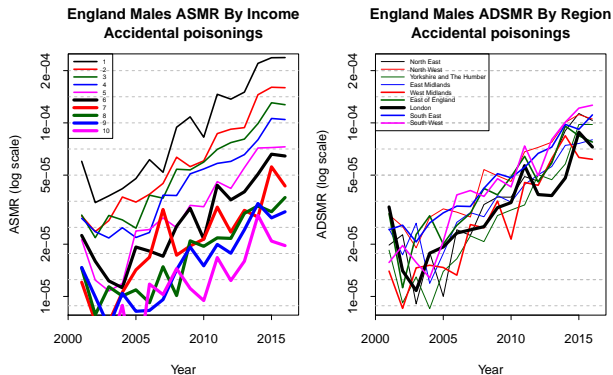
Case and Deaton (2015): "Deaths of despair"

Which Causes of Death ⇒ Growing Inequality?

- Ischaemic heart disease
- Diabetes
- Cerebrovascular
- Circulatory
- Respiratory diseases
- Mental illnesses (females)
- Lung cancer

⇒ a widening gap in the prevalence of controllable risk factors: smoking, diet, exercise, alcohol etc.

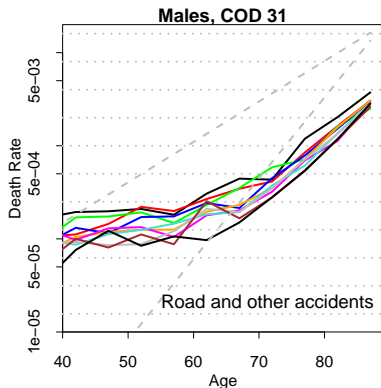no significant causes of death with narrowing inequality gap
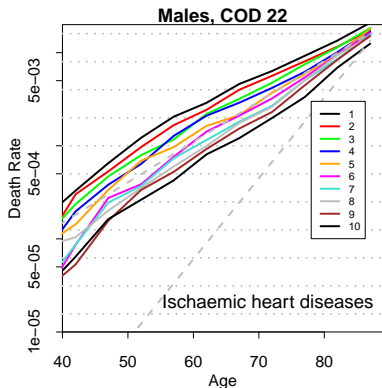
Contributors to the slowdown since 2011

Main contributors seem to be

- Heart diseases
  (but less so for the least deprived)
- Dementias and Alzheimer's
- Possibly respiratory diseases
- Possibly diabetes

Males, COD 22 — Ischaemic heart diseases

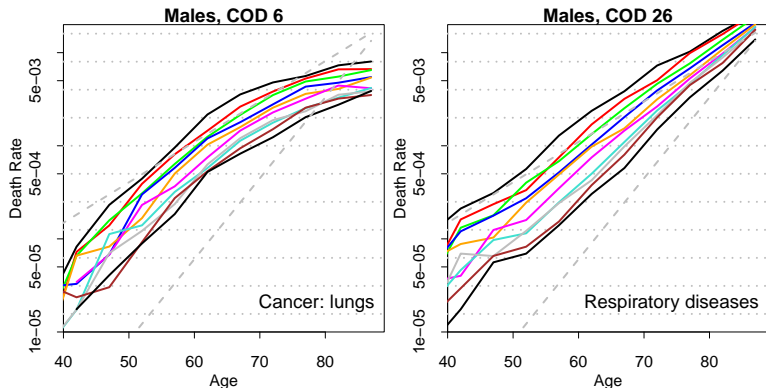**Males, COD 31** — Road and other accidents

Group 1 $\Rightarrow$ Gompertz type with rate ~ 0.1 (flatter grey dashed line)
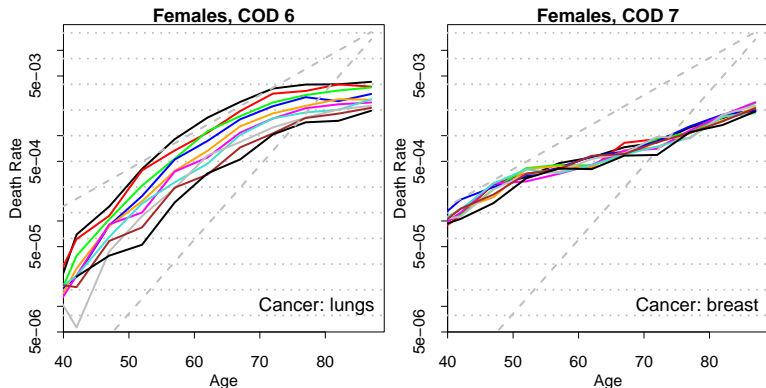$\Rightarrow$??? common underlying ageing/disease mechanism
Narrowing inequality with age
Accidents, high ages: goes hand in hand with Group 1 underlying
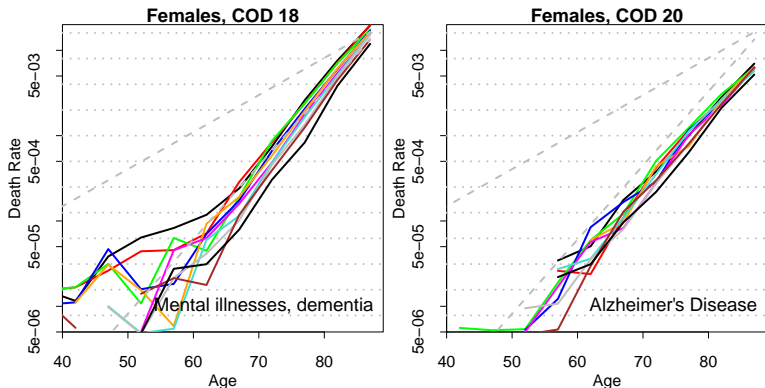ageing???

Death rates by age in 2016: smoking

Different shapes ⇒
??? changing relative risk with age
??? strong frailty effect with lung cancer

Death rates by age in 2016: Group 2

Group 2 ⇒ rising mortality but flatter shape than Gompertz(0.1)
Mostly cancers ⇒ is the disease mechanism different from Group 1???

Death rates by age in 2016: Group 3

Females, COD 18 — Mental illnesses, dementia

Females, COD 20 — Alzheimer's Disease

Group 3: Gompertz with rate ~ 0.2 (steeper grey dashed line)

All Group 3: causes of death related to deterioration/disease of brain

$\Rightarrow$??? a different disease mechanism from Group 1 ageing

Death rates by age in 2016: Group 4
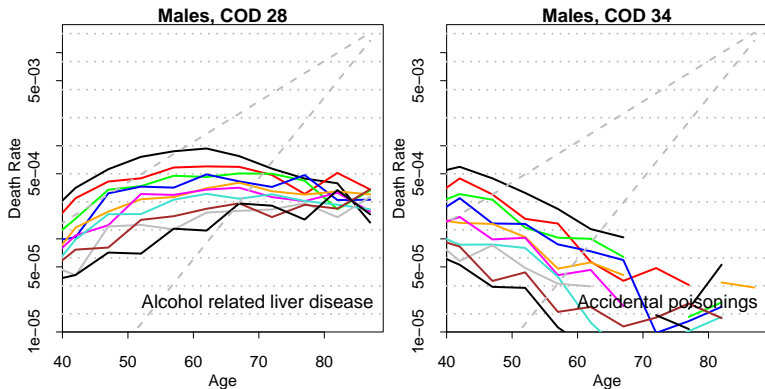
Group 4: flat or decreasing with age

Summary

- Causes of death with associated controllable risk factors
  $\Rightarrow$ 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
  $\Rightarrow$ 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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W: `www.macs.hw.ac.uk/~andrewc/ARCresources`