

# US Mortality: Underlying Trends By Socioeconomic Group and Cause of Death

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# Outline

- Background and motivation
- Source data
- All-cause mortality
- Cause-of-death mortality
- Cohort effects

# Background and motivation

- Interested in mortality variation by socio-economic group
- Different levels of mortality
- Variable inequality gap through time
- Some differences due to controllable risk factors (e.g. smoking)
- We seek to understand the differences and dynamics

- Exposures
- Deaths
- Leading to death rates, subdivided by
  - gender
  - education level
  - cause of death

## Data: Deaths

- Source: Centers for Disease Control and Prevention (CDC)
- Individual death records 1989-2015
- Anonymised data from death certificates
- Calendar year
- Gender and age at death
- Educational attainment
- Cause of death
- .....

## Data: Deaths – issues

- Cause of death:
  - Classification: ICD-9 & ICD-10
  - Other changes in practice (e.g. UK 2011)
- Education:
  - Two classification systems
  - Missing data (years; states)



## Data: Exposures

- Multiple sources
  - Human Mortality Database (HMD)
  - Current Population Survey (CPS)
- HMD
  - total US population,  $E(t, x)$
  - adjusted for anomalies using Cairns et al. (2016)

## Data: Exposures (cont.)

- CPS
  - sample data;  $\sim 60,000$  records per year
  - ages up to 79
  - includes educational attainment
- Small sample  $\Rightarrow$  education proportions are noisy

## Data: Exposures (cont.)

- Redondo Loures & Cairns (2019):
  - smoothing through time by cohort
  - smoothing for consistency within calendar years

$$E(e, t + s, x + s) = E(t + s, x + s) \cdot R(e, t + s, x + s)$$

- $e$  = education level
- $R(e, t + s, x + s)$  = smoothed education proportions for cohort  $t - x$ .

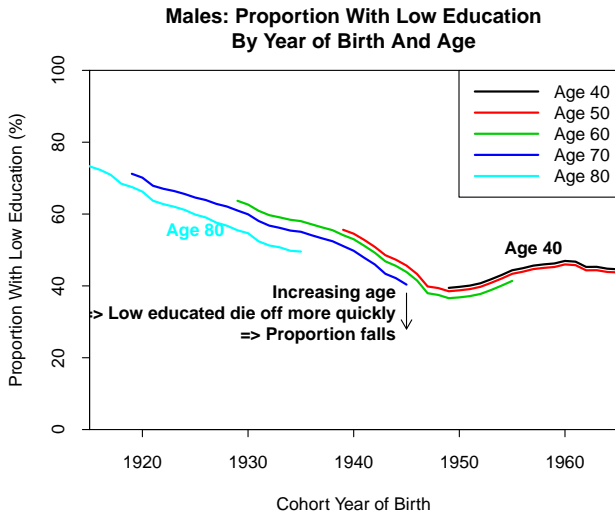
## Education level: two coding systems

- Coding system 1  $\rightarrow$  system 2  
(years  $\rightarrow$  level)
- Reasonable consistency for
  - Low:  $\leq$  high school graduate
  - Medium: some college/university  $<$  BSc
  - High:  $\geq$  BSc

## Education level: two coding systems (cont.)

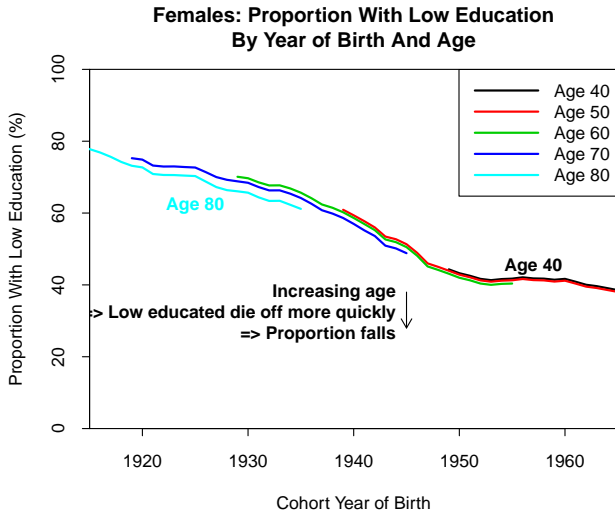
- Education level is self-reported (deaths and exposures)  
⇒ potential for unconscious bias  
E.g. true *medium* reported as *high* education on death certificate  
More obvious when we extrapolate above age 79 (CPS max)
- Final split:
  - **Low:**  $\leq$  high school graduate
  - **High:** some college/university plus BSc and higher

# Low education: males, proportions by cohort



Potential cohort effects: general decline; “peak education”: 1950 cohort

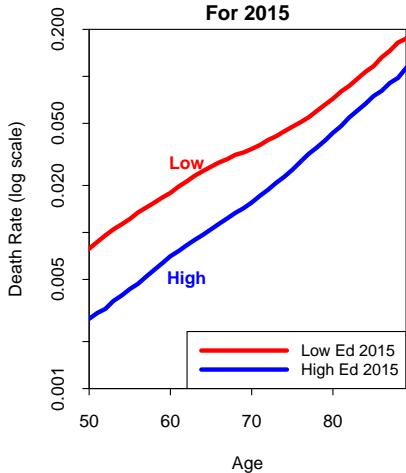
# Low education: females, proportions by cohort



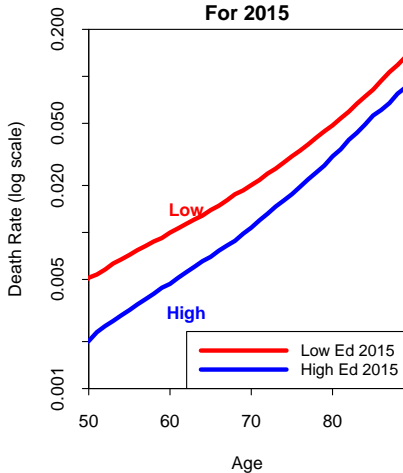
Similar pattern; higher levels of education than males since 1960 cohort

# All cause mortality: males, females, 2015

**Male All Cause Death Rates  
by Education Group  
For 2015**



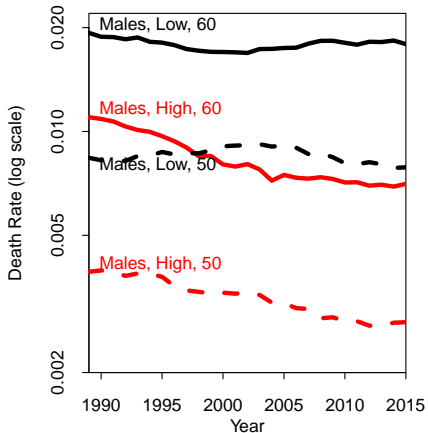
**Female All Cause Death Rates  
by Education Group  
For 2015**



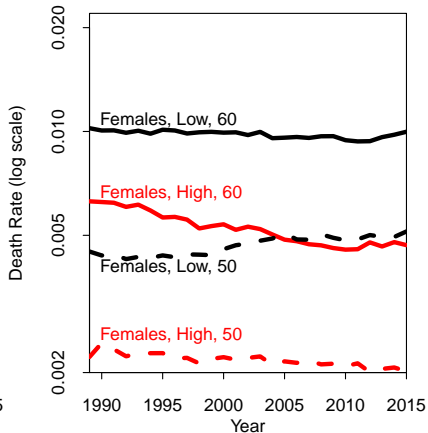


# All cause mortality: males, females aged 50, 60

## Male All Cause Mortality



## Female All Cause Mortality



Increasing inequality

Stagnation: low educated groups (Case and Deaton, 2015, 2017)

- Significant mortality inequality by education group
- Greater inequality at younger ages
- Some evidence for cohort effects (year of birth)
- Cause of death data can give us some insight into trends and inequalities

## 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*?



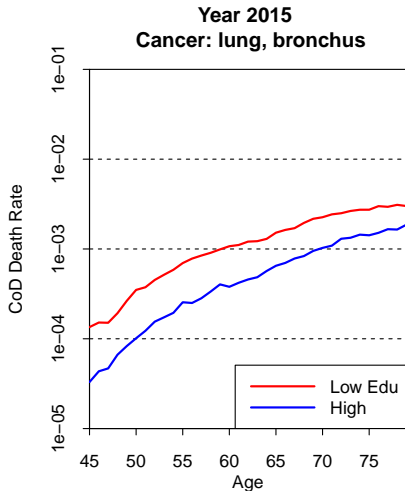
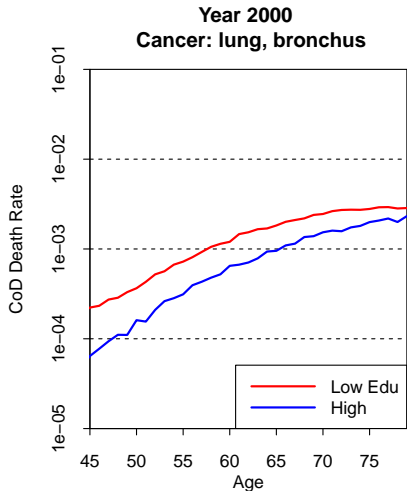
# Drivers of mortality improvements/differences

- Medical advances
- Health spending
- Public health initiatives
- Individual risk factors:
  - Controllable
    - e.g. smoking, diet, exercise, alcohol, sun, drugs, ...
    - leading to cohort effects and inequality
  - Not (easily) controllable
    - e.g. genetic, affluence, education, character/personality traits, unemployment, ...

# Cause of Death Groupings

1	Infectious diseases	2	Cancer: mouth, gullet
3	Cancer: stomach	4	Cancer: gut, rectum
5	Cancer: larynx	6	Cancer: trachea
7	Cancer: lung, bronchus	8	Cancer: breast
9	Cancer: uterus, cervix	10	Cancer: ovary
11	Cancer: other female genital	12	Cancer: prostate
13	Cancer: other male genital	14	Cancer: liver
15	Cancer: pancreas	16	Cancer: skin
17	Cancer: urinary organs	18	Cancer: bladder
19	Cancer: lymphatic	20	Benign tumours
21	Cancer: other locations		
22	Diseases: blood	23	Diabetes
24	Vascular dementia	25	Other mental illness
26	Diseases of nervous system excl. Alzh.	27	Alzheimers
28	Blood pressure + rheumatic fever	29	Ischaemic heart diseases
30	Other heart diseases	31	Diseases: cerebrovascular
32	Diseases: circulatory		
33	Chronic Obstructive Pulmonary Disease	34	Influenza, pneumonia
35	Other respiratory diseases		
36	Diseases: digestive (excl. alcohol (# 40))	38	Diseases: urine, kidney,...
39	Diseases: skin, bone, tissue		
40	Road/other accidents	41	Other causes
37	Alcohol → liver disease	42	Suicide
43	Accidental Poisonings		

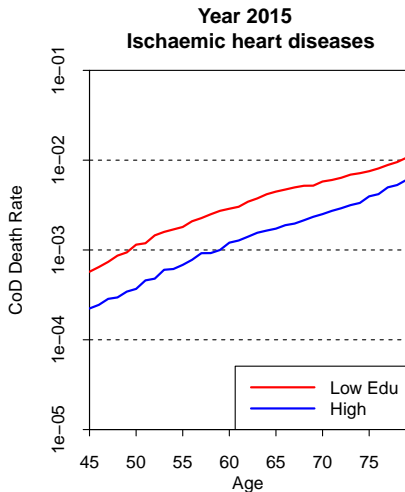
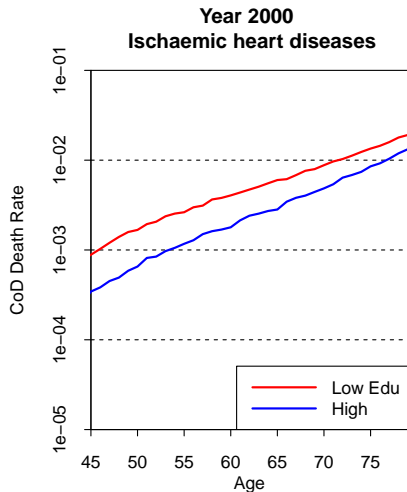
# Females: lung cancer



Wider gap; widening gap; stagnation

2017, age 45: 4× ⇒ approx 4× as many smokers

# Males: ischaemic heart disease



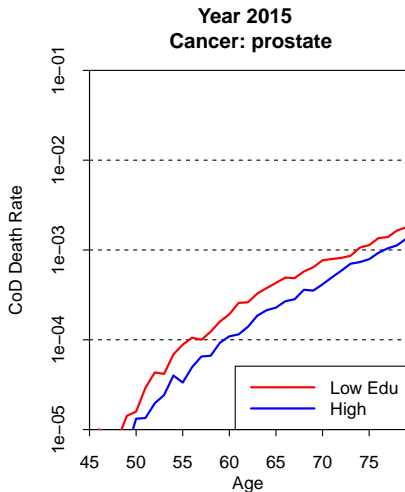
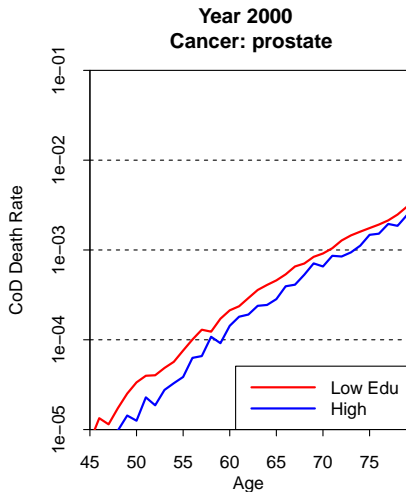
Wide gap; widening gap; improvements over time

# Impact of Controllable Risk Factors

- Risk factors (controllable and not controllable)  
⇒  
Impact on cause of death rates
- **Some risk factors ⇒ big impact on some causes**  
e.g. smoking → lung cancer  
e.g. several risk factors → ischaemic heart disease  
⇒ significant inequality gaps
- **Some causes of death:**  
*no known (significant) controllable risk factors*  
e.g. prostate cancer, breast cancer

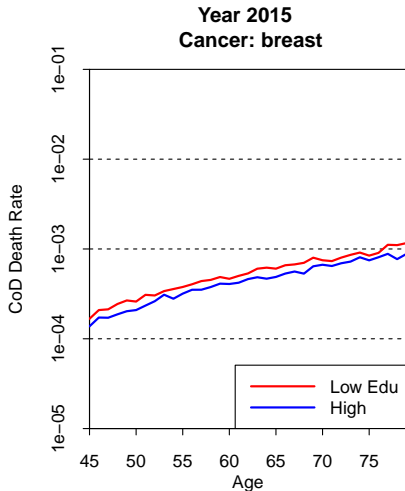
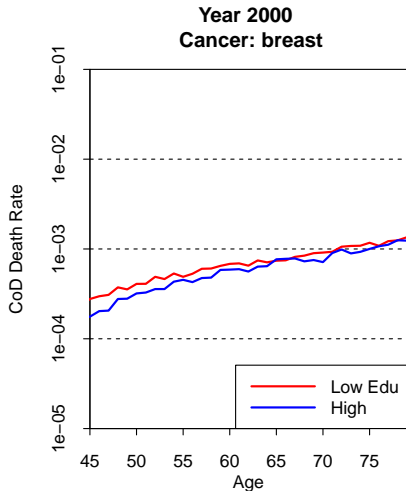


# Males: prostate cancer



Small gap: [healthcare](#); conscientiousness; genetic  
(but wider gap than e.g. England and Denmark)

# Females: breast cancer

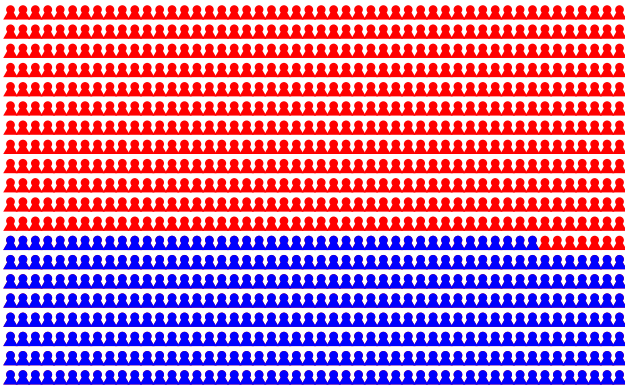


Small gap: [healthcare](#); conscientiousness; genetic  
(but wider gap than e.g. [England](#) and [Denmark](#))

# Differences between low and high education groups

## Low v High Educated Males Aged 60

For every 1000 deaths in the low education group:  
607 excess deaths in the low education group

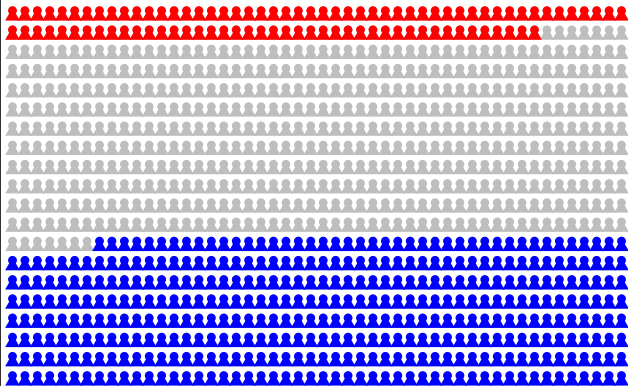


393 deaths in the high education group

# Differences between low and high education groups

## Low v High Educated Males Aged 60 Ischaemic Heart Disease: 93 excess deaths

For every 1000 deaths in the low education group:

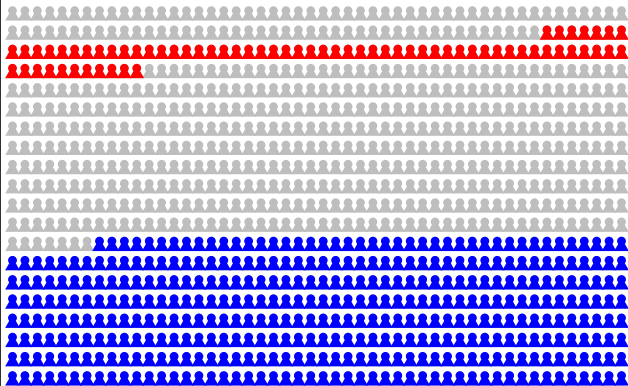


393 deaths in the high education group

# Differences between low and high education groups

## Low v High Educated Males Aged 60 Lung Cancer: 68 excess deaths

For every 1000 deaths in the low education group:

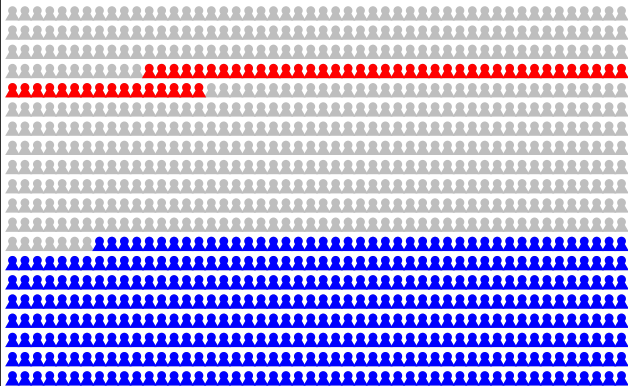


393 deaths in the high education group

# Differences between low and high education groups

## Low v High Educated Males Aged 60 Deaths of Despair: 55 excess deaths

For every 1000 deaths in the low education group:



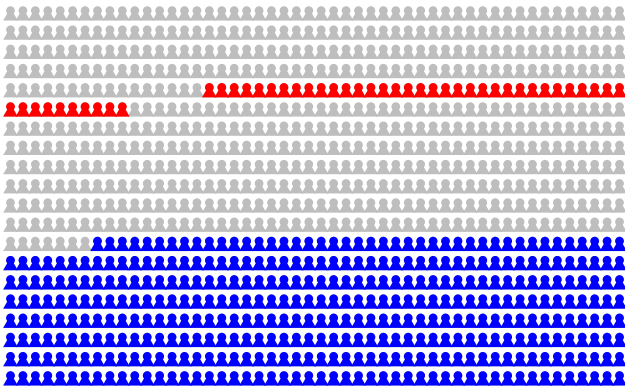
393 deaths in the high education group

# Differences between low and high education groups

## Low v High Educated Males Aged 60

Chronic Obstructive Pulmonary Disease: 44 excess deaths

For every 1000 deaths in the low education group:

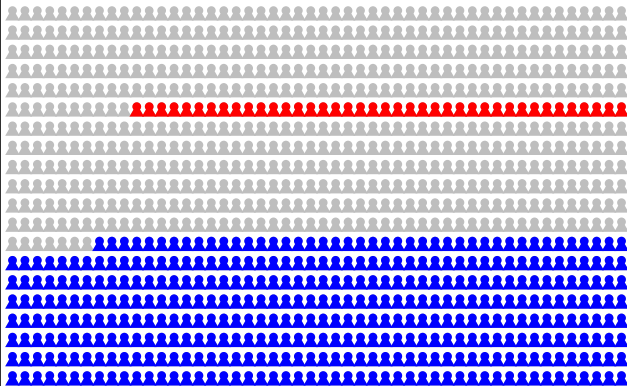


393 deaths in the high education group

# Differences between low and high education groups

## Low v High Educated Males Aged 60 Other Heart Diseases: 40 excess deaths

For every 1000 deaths in the low education group:



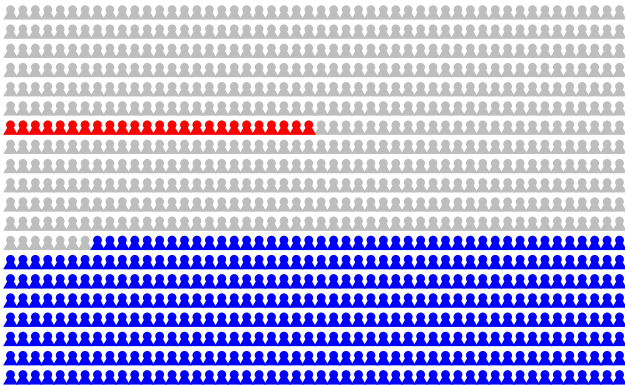
393 deaths in the high education group



# Differences between low and high education groups

## Low v High Educated Males Aged 60 Infectious Diseases: 25 excess deaths

For every 1000 deaths in the low education group:

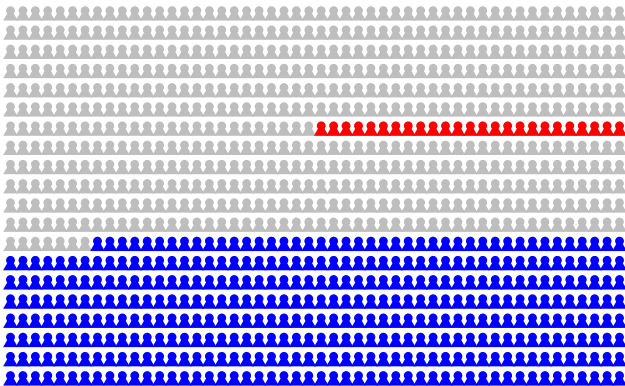


393 deaths in the high education group

# Differences between low and high education groups

## Low v High Educated Males Aged 60 Road & Other Accidents: 25 excess deaths

For every 1000 deaths in the low education group:

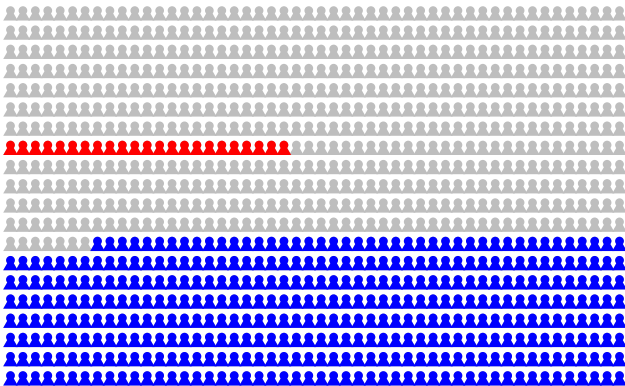


393 deaths in the high education group

# Differences between low and high education groups

## Low v High Educated Males Aged 60 Diabetes: 23 excess deaths

For every 1000 deaths in the low education group:



393 deaths in the high education group

## Drivers of Change 1991-2003, 2003-2013

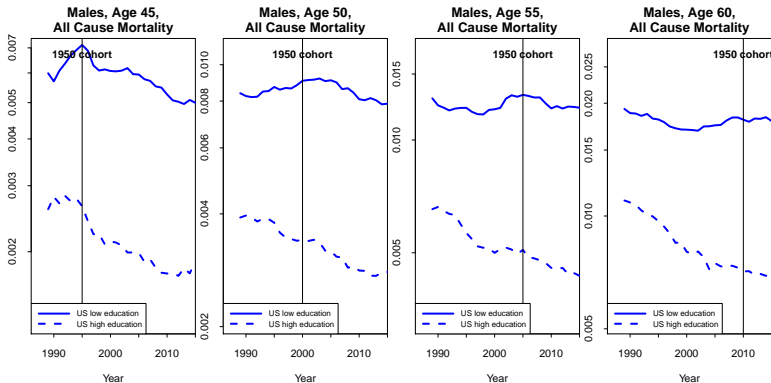
- Which causes of death have contributed to
  - Improvements in mortality (gains)
  - Increases in mortality (losses)
- Low educated males
- 1993-2003
- 2003-2013
- **Absolute change in mortality**  
(not % change in cause of death rate)







# US Males: A Possible Cohort Effect



**Cohort effect:** cohorts born around 1950 have poorer mortality than those born before or after.

**Suggests:** Weakens the hypothesis that the situation is generally bad for low educated males.



# What is a cohort effect?

- Statistically:  
*a component in a model that quantifies adjustments to mortality by year of birth*
- How do they arise?
- One reason is:
  - populations might not be homogeneous
  - heterogeneities within a population are often linked to year of birth
  - examples of such heterogeneities are
    - smokers and non-smokers
    - healthy diet or exercise regime
    - manual and non-manual workers (e.g. pension plan)

## Quantifying cohort effects

- Use stochastic mortality models.
- Here (suppress gender and education)

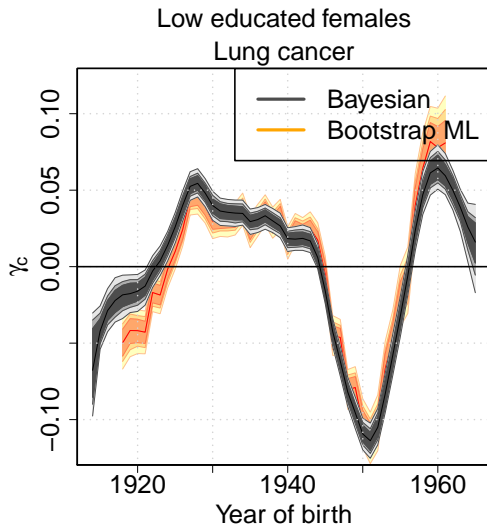
$$\log m(c, t, x) = \alpha(c, x) + \kappa_1(c, t) + \kappa_2(c, t)(x - \bar{x}) + \gamma(c, t - x)$$

- $c$  = cause of death (or all cause mortality)
- $t - x$  = year of birth
- $\alpha(c, x)$  = age effect; base table
- $\kappa_1(c, t), \kappa_2(c, t)$  = period effects
- $\gamma(c, t - x)$  = cohort effect
- Model fitted to cause-specific deaths+exposures data
- Full Bayesian implementation
  - Bivariate random walk for  $\kappa$
  - $AR(2)$  model for  $\gamma$
- Outputs here: focus on  $\gamma(c, t - x)$

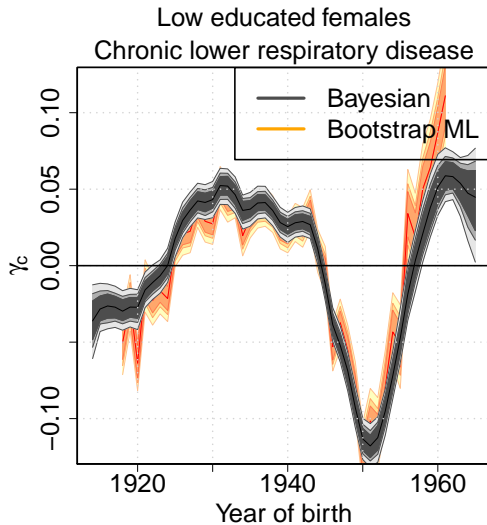
## Model fitted to

- US males & females
- High & low education
- 1989-2015
- Ages 50-75

# Females, low education: lung cancer

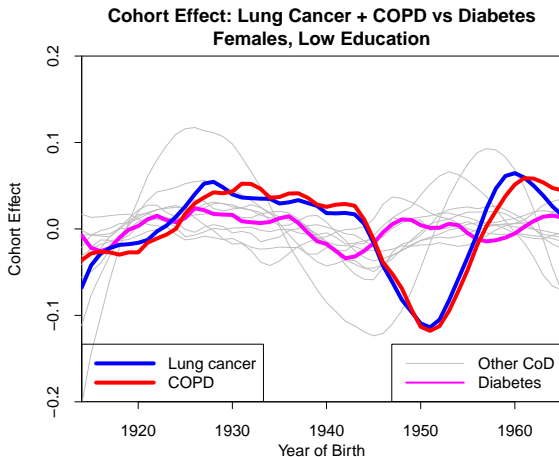


## Females, low education: COPD



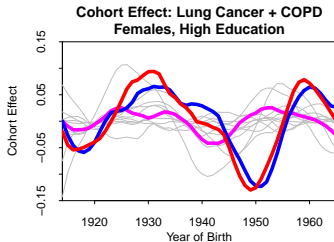
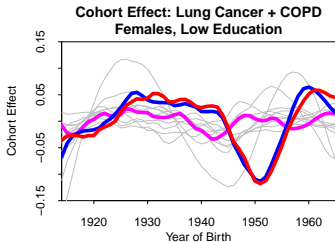
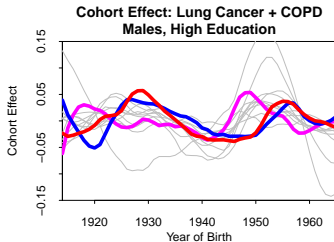
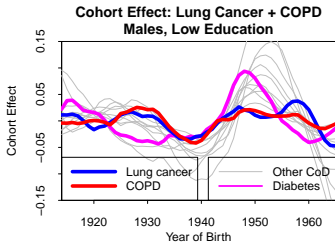
Very similar shape to lung cancer: **single risk driver = smoking!**

# Smoking vs diet/exercise/alcohol

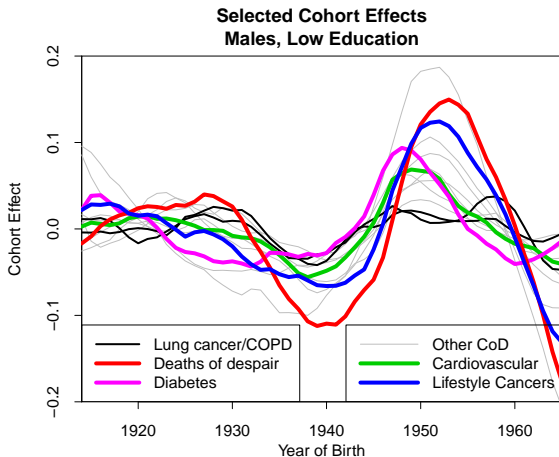


Cohort effect for diabetes is distinctly different

# Smoking vs other cohort effects



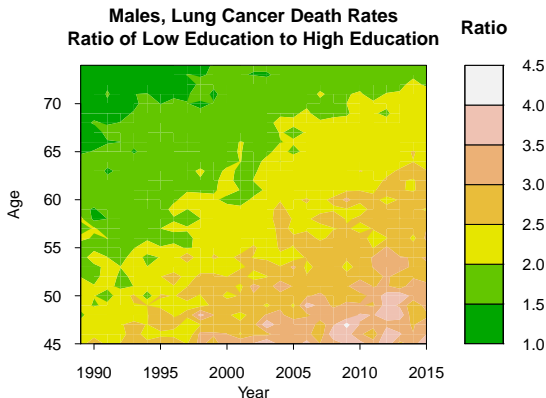
# Smoking vs diet/exercise/alcohol



Possibly 3 distinct cohort effects: smoking; despair; other lifestyle factors  
Early 1950's peak might be linked to peak in education levels



# Smoking: Low versus High Education; Lung Cancer



$$\text{Ratio} = m(\text{low}, t, x) / m(\text{high}, t, x)$$

Cohort effects: older  $\rightarrow$  younger cohorts

Pattern  $\Rightarrow$  high education prevalence has fallen much faster

**Widening smoking prevalence gap  $\Rightarrow$  increased all-cause mortality inequality**

# Summary

- Work in progress!
- Data by education level requires multiple sources
- Cause of death data can provide insight into all cause mortality
  - time trends
  - inequality between groups
  - very significant inequality for some causes of death
  - (growing inequality)
- The US slow down is complex  
Partly due to a 1940-50's cohort effect
- Shape of cohort effect varies by cause of death  
linked to different underlying risk factors by cohort
- Broader understanding is also complex  
*there is no simple story to tell*



# Thank You!

## Questions?

E: A.J.G.Cairns@hw.ac.uk

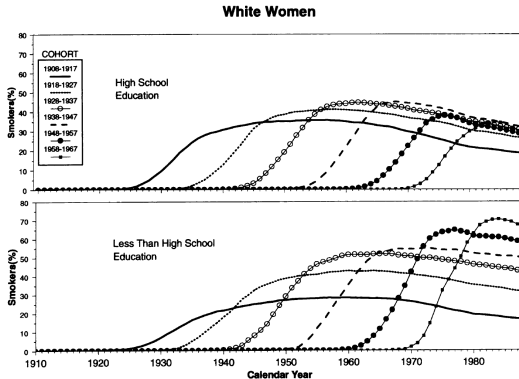
W: [www.macs.hw.ac.uk/~andrewc/ARCResources](http://www.macs.hw.ac.uk/~andrewc/ARCResources)







# Females smoking prevalence

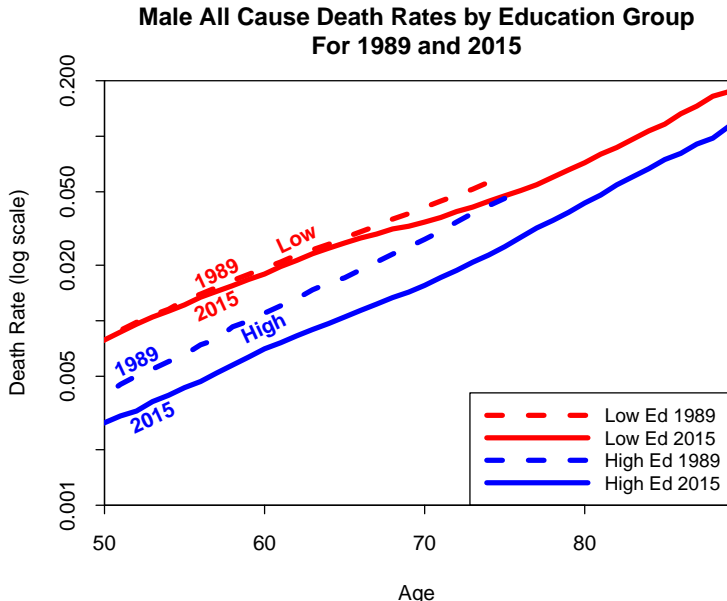


**FIGURE 1—Smoking prevalence among birth cohorts of Whites, by sex and educational attainment, 1978–1980, 1987, and 1988 National Health Interview Surveys.**

Source: Escobedo et al. (1996)

Note: Different definition of low/high education & ethnic group

# All cause mortality: males 1989 → 2015





# All cause mortality: females 1989 → 2015

## Female All Cause Death Rates by Education Group For 1989 and 2015

