Socio-Economic Differences in Mortality by Cause of Death

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Joint work with D. Blake, K. Dowd, M. Kallestrup-Lamb, C. Rosenskjold, C. Redondo, A.S. Macdonald

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The 'Modelling, Measurement and Management of Longevity and Morbidity Risk' research programme is being funded by the ARC, the SoA and the CIA.

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Outline

- Danish data:
  - affluence
  - education
  - cause of death
- Statistical significance
- US cause of death data by education group

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:
  - by education;
  - by affluence?
- Beware of
  - changes in ICD classification of deaths
  - drift in how deaths are classified
  - changing education levels (grade inflation)
- Insight into mortality underpinning life insurance and pensions

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Danish Data: Cairns et al. Longevity 11, Lyon

- Statistics Denmark National Register Database

- Key data (amongst others) for each individual:
  - Date of birth ($\Rightarrow$ age)
  - Date of death
  - Wealth
  - Income
  - Affluence=Wealth+15$\times$Income
  - Education
  - Cause of Death

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Education and Affluence Levels

Education	
Low education	Primary and lower secondary education
Medium education	Upper secondary education
High education	Tertiary education

Affluence	
Level 1	Low affluence *decile*
⋮	⋮
Level 10	High affluence *decile*

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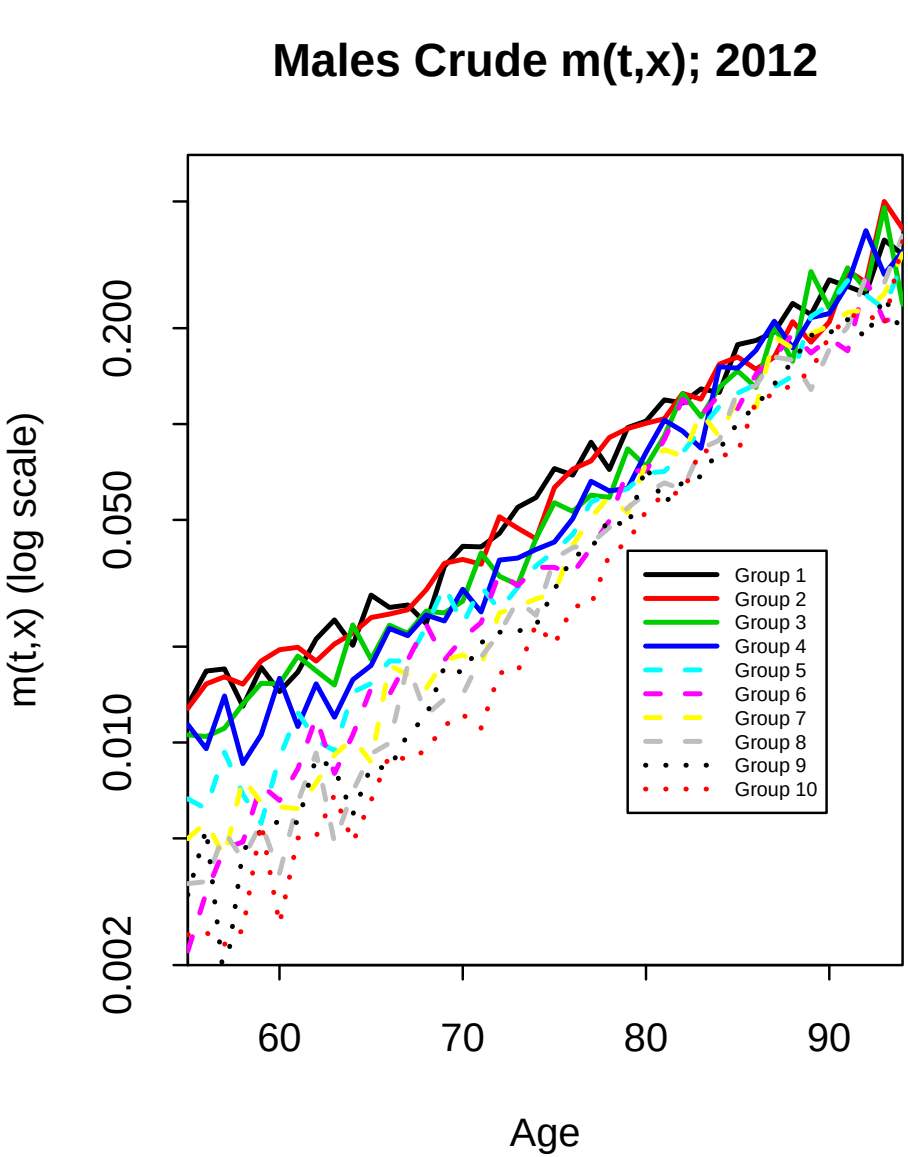
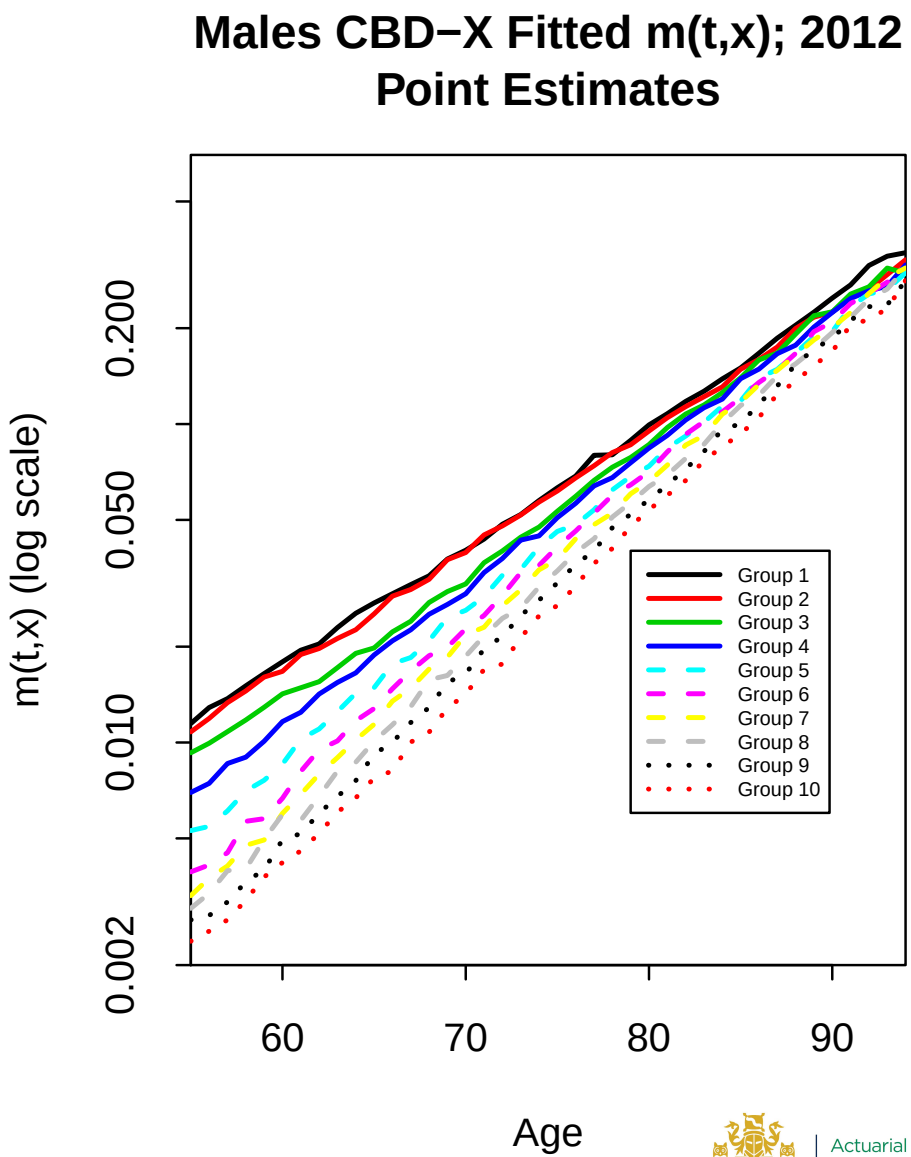
Model-Inferred Underlying Death Rates 2012





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Education as an Alternative Covariate

- Level of Educational Attainment also known to be a good predictor
  - Various US studies
  - Mackenbach et al. (2003) including Denmark: Std. Mortality Rates
  - Brønnum-Hansen and Baadsgaard (2012) Denmark: $LE(x = 30)$
- As close as possible on a *like for like* basis:

  Crude death rates; age 30+; matching years.

  Affluence $\Rightarrow$
  - Wider spread of SMR's than M. et al. (2003)
  - Wider spread of $LE(30)$ than BHB (2012)
- Issue: "grade inflation" distorts results
- More to be done.

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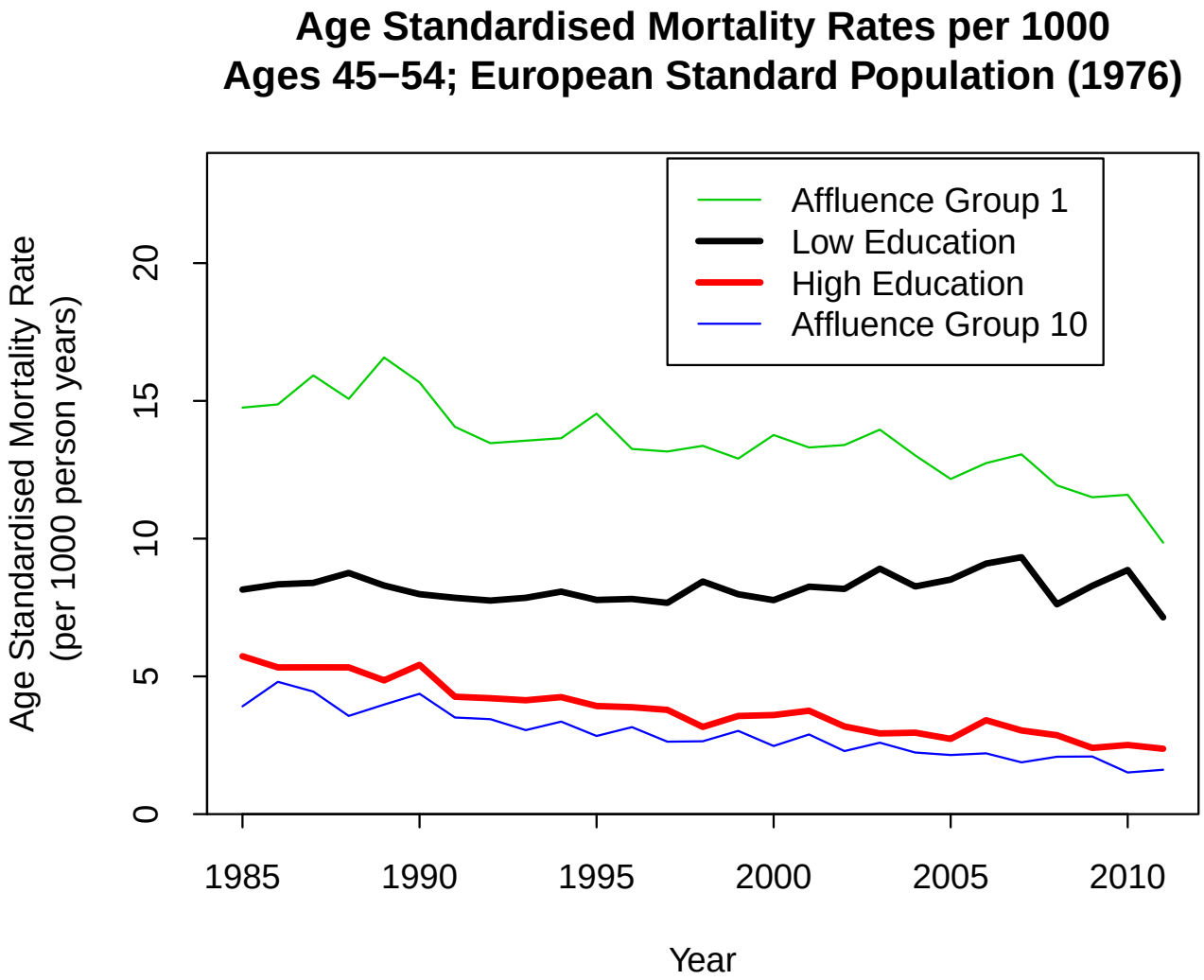
Education as an Alternative Covariate



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Cause of Death Data – Health Inequalities

- Deaths subdivided into 29 CoD groups
- Age groups 31-35, 36-40, ..., 91-95
- Year groups 1985-89, 1990-94, 1995-99, 2000-2004, 2005-2009
- Compare affluence groups
- Compare education groups

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Cause of Death Data – Health Inequalities

1	Infectious diseases incl. tuberculosis	2	Cancer: mouth, gullet, stomach
3	Cancer: gut, rectum	4	Cancer: lung, larynx, ..
5	Cancer: breast	6	Cancer: uterus, cervix
7	Cancer: prostate, testicular	8	Cancer: bones, skin
9	Cancer: lymphatic, blood-forming tissue	10	Benign tumours
11	Diseases: blood	12	Diabetes
13	Mental illness	14	Meningitis + nervous system (Alzh.)
15	Blood pressure + rheumatic fever	16	Ischaemic heart diseases
17	Other heart diseases	18	Diseases: cerebrovascular
19	Diseases: circulatory	20	Diseases: lungs, breathing
21	Diseases: digestive	22	Diseases: urine, kidney,...
23	Diseases: skin, bone, tissue	24	Senility without mental illness
25	Road/other accidents	26	Other causes
27	Alcohol $\rightarrow$ liver disease	28	Suicide
29	Accidental Poisonings		

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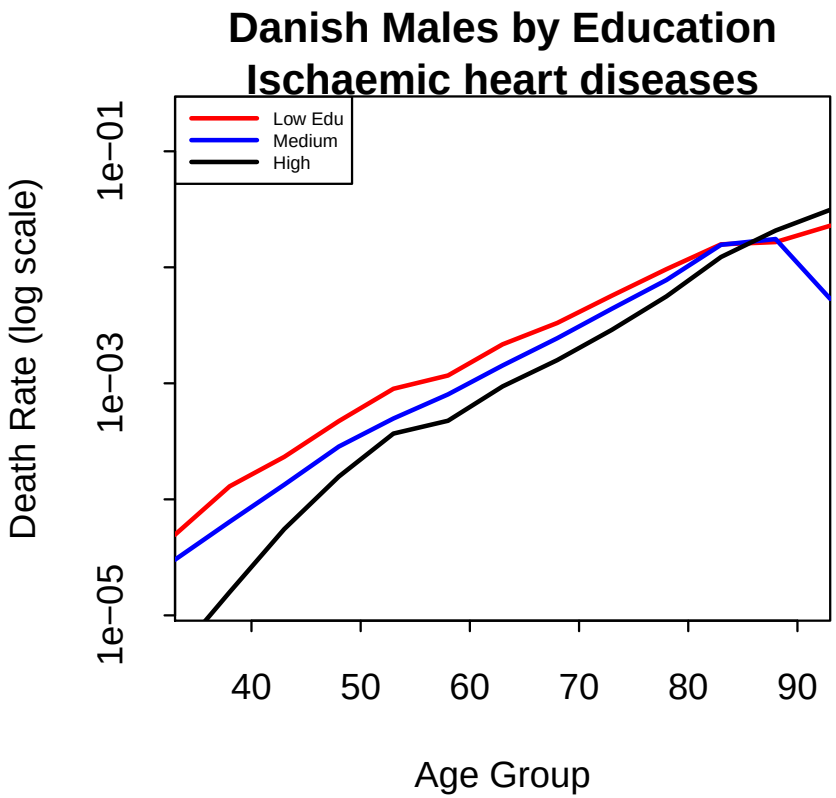
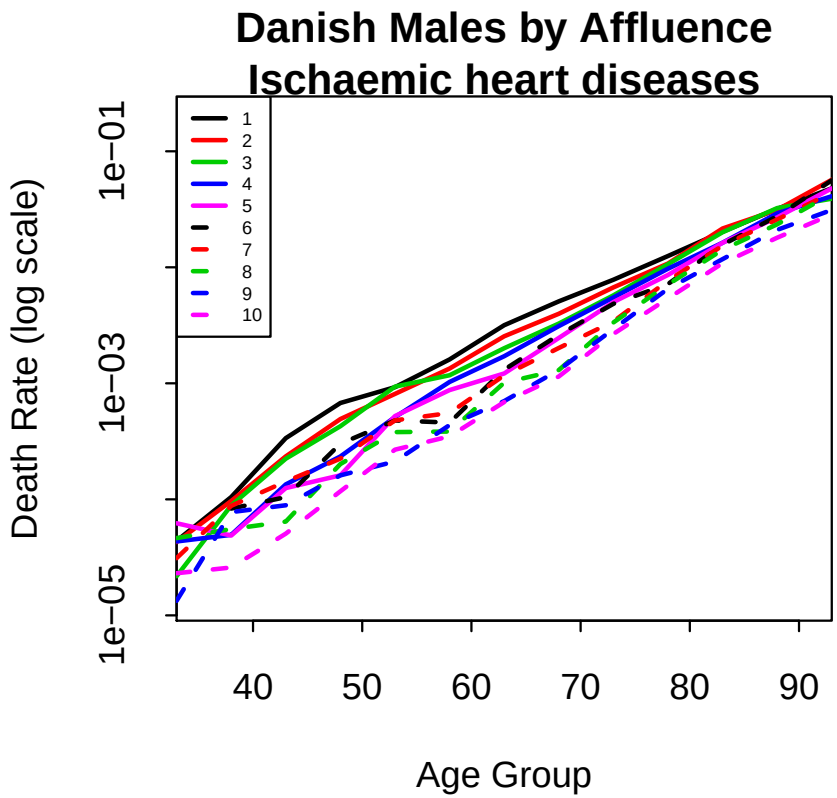
Denmark: Cause of Death Data 2007

Compare education with affluence as covariates:





Affluence $\Rightarrow$ wider spread

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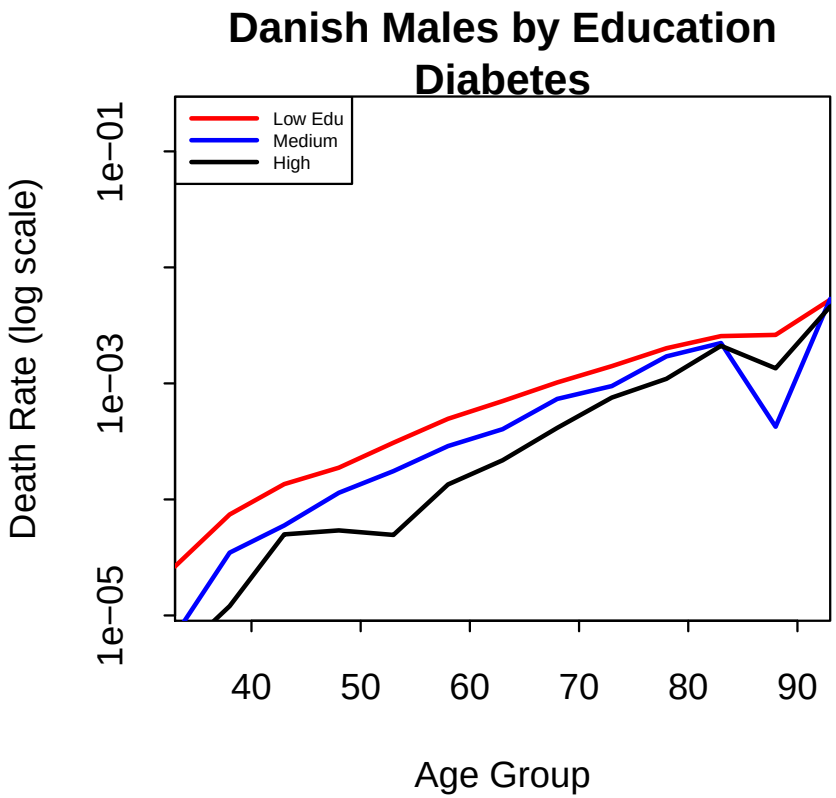
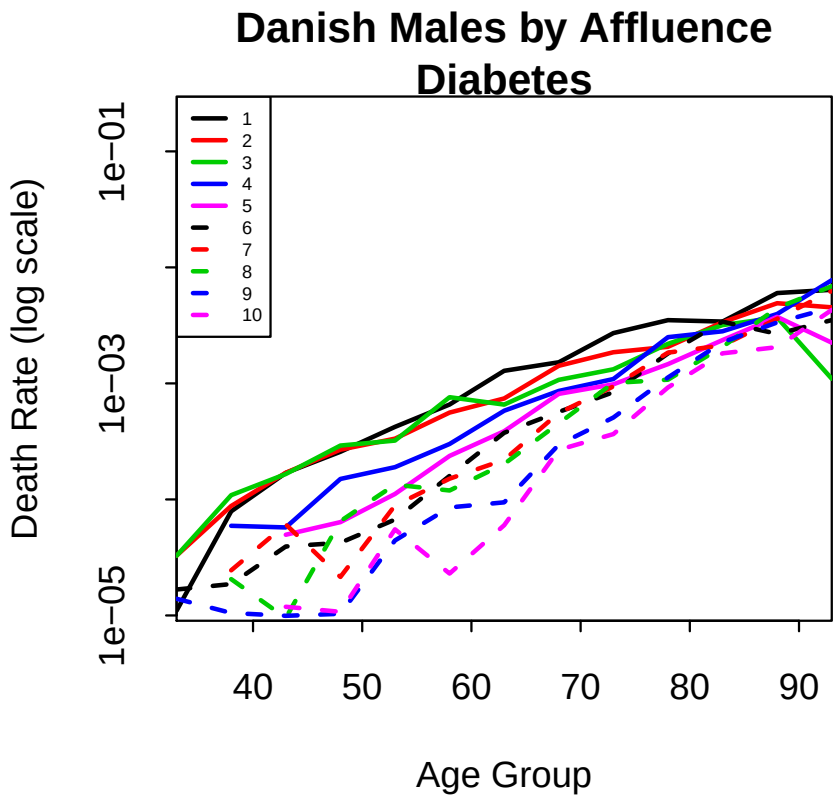
Denmark: Cause of Death Data 2007





Affluence $\Rightarrow$ much wider

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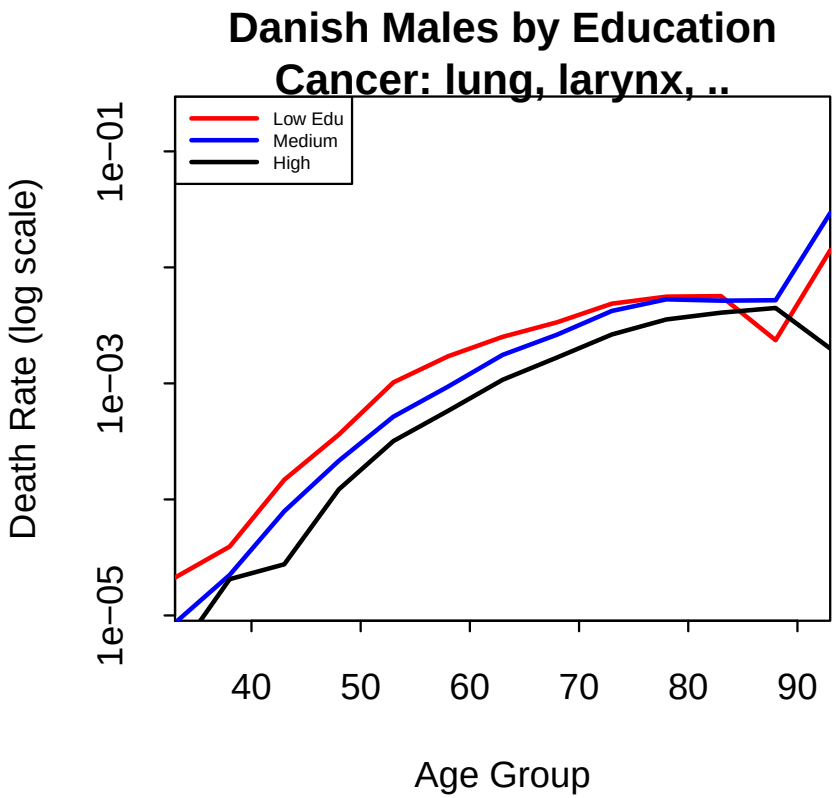
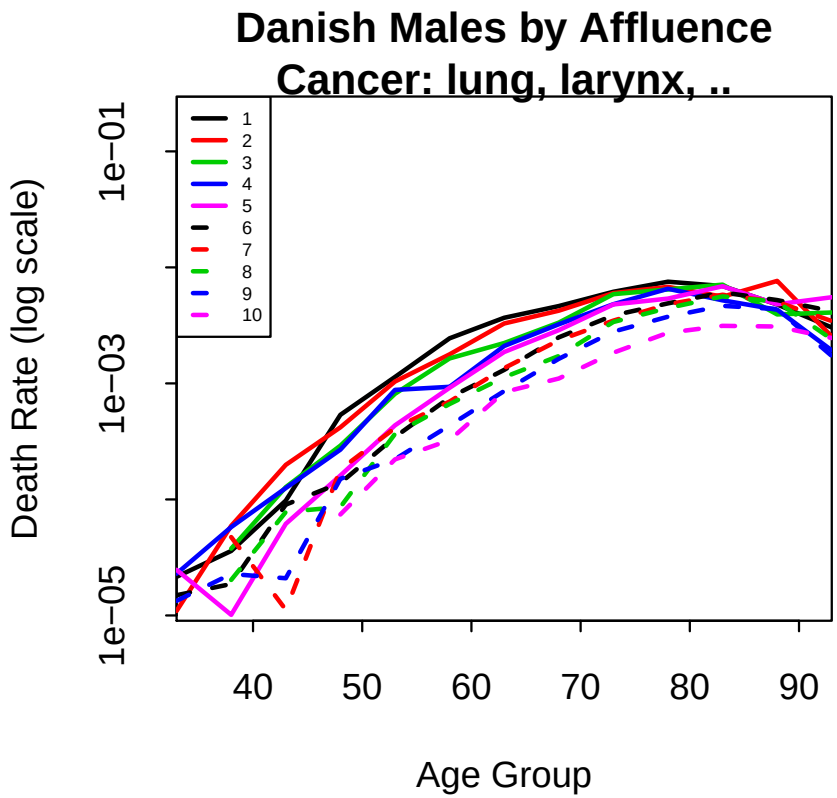
Denmark: Cause of Death Data 2007





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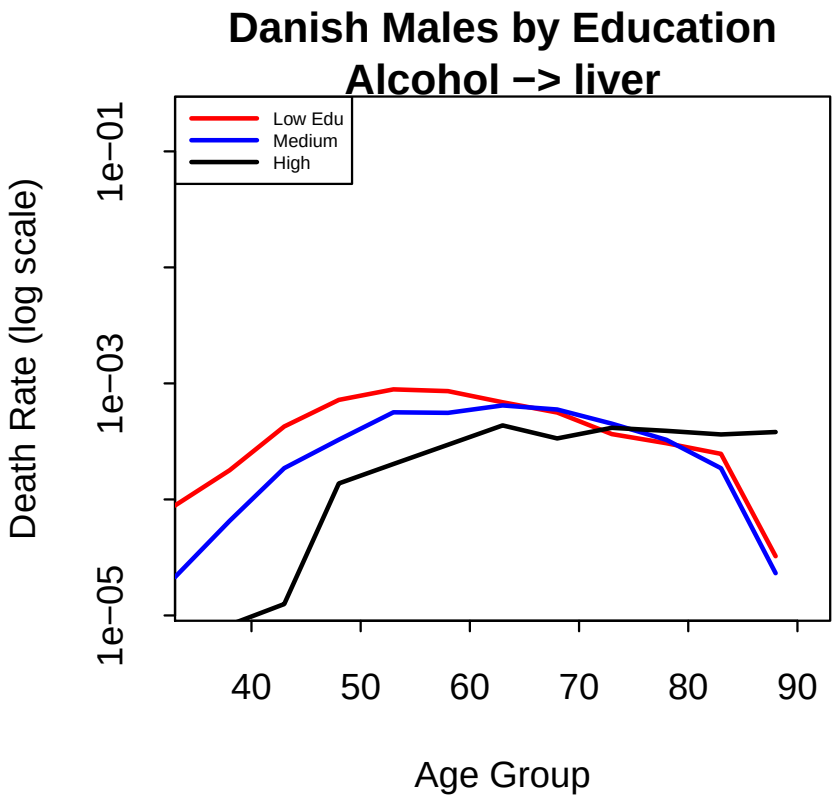

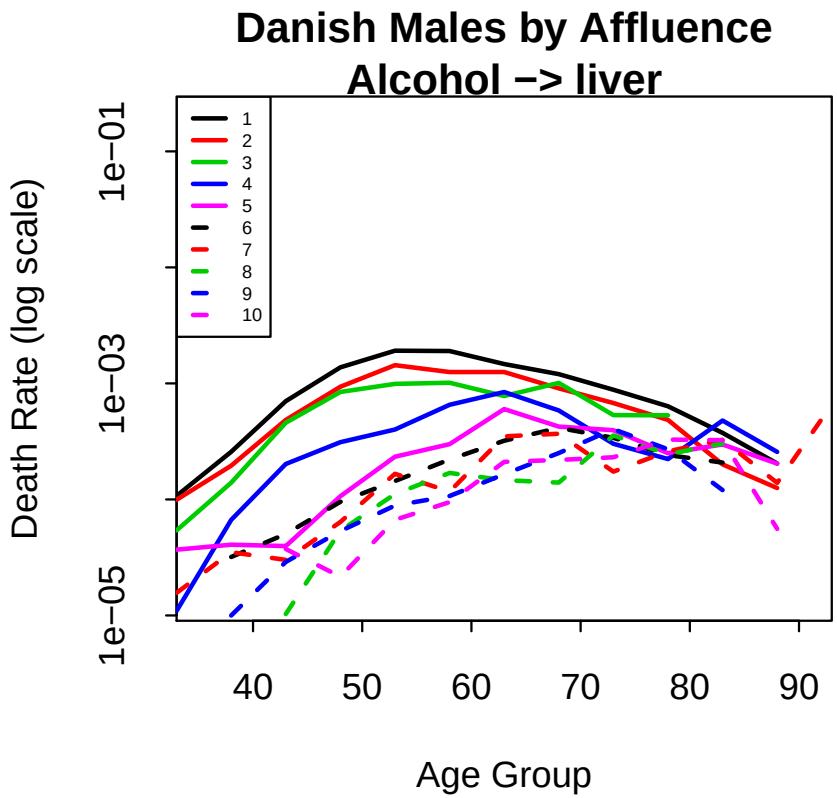

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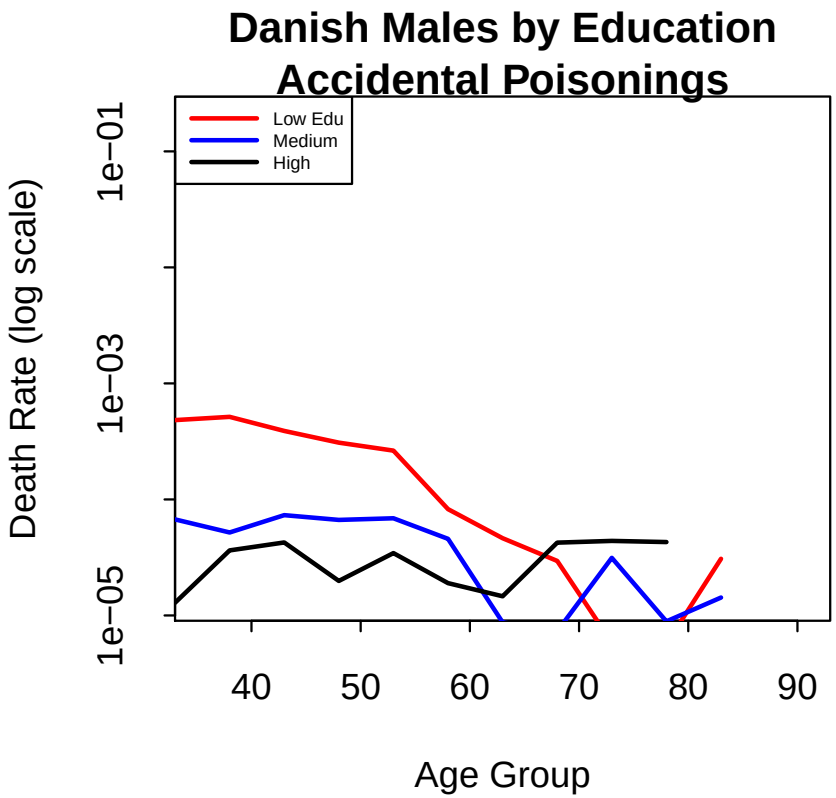

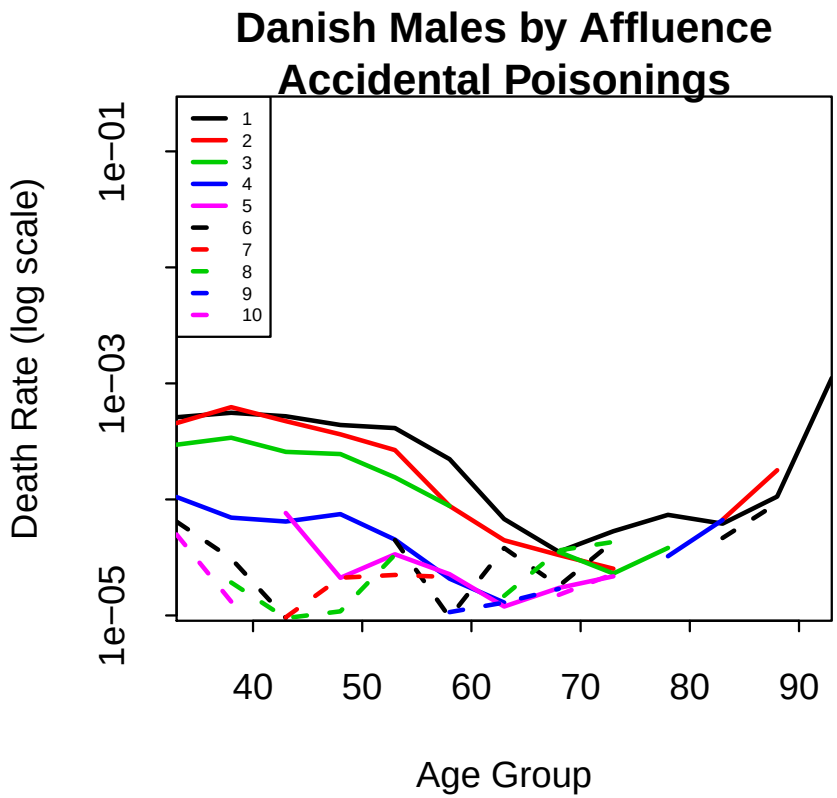

Low affluence $\Rightarrow$ over 20$\times$ at young ages

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Denmark: Cause of Death Data 2007

- Many causes of death have known risk factors or drivers

  e.g. smoking, diet, healthy lifestyle etc.

  $\Rightarrow$ clear socio-economic differences
- Biggest differences at ages < 60
- Affluence $\Rightarrow$ stronger predictor than education (sometimes very much stronger)
- Other diseases do not have strong differences:

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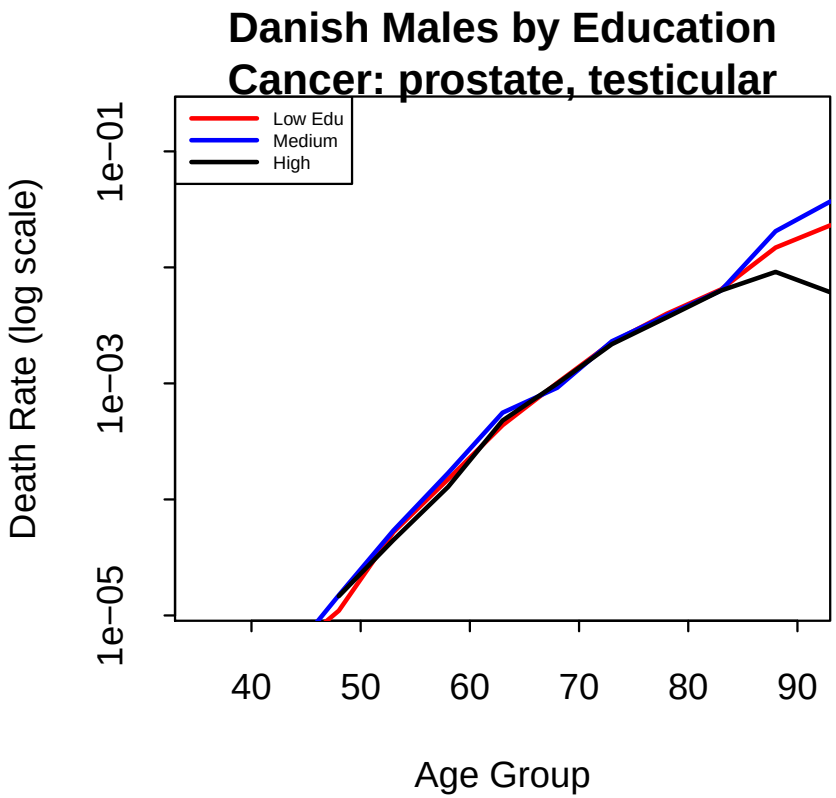
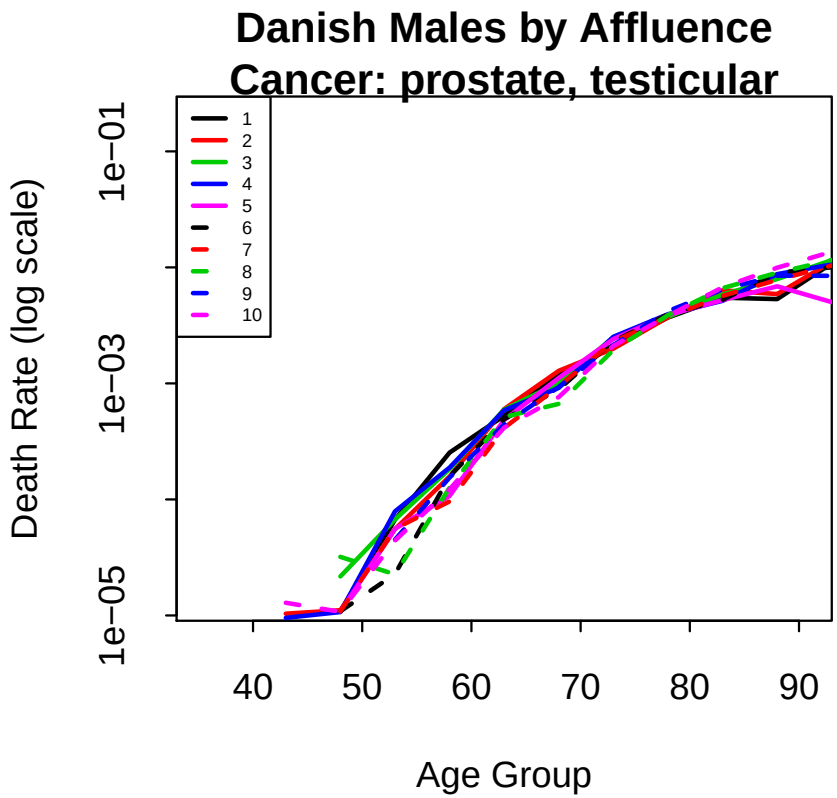
Denmark: Cause of Death Data 2007





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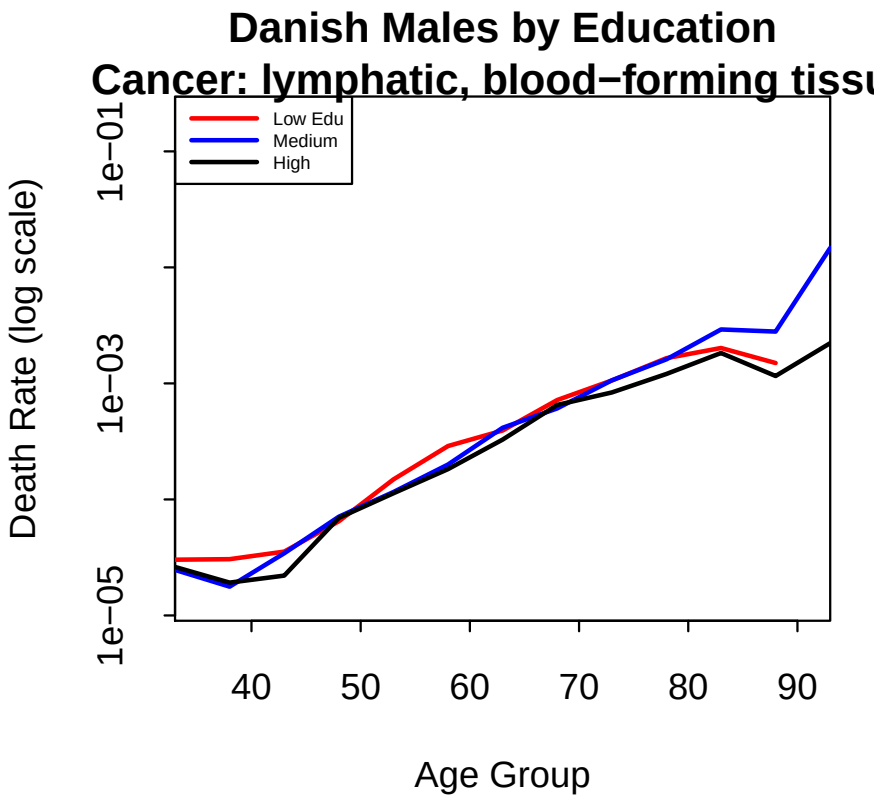

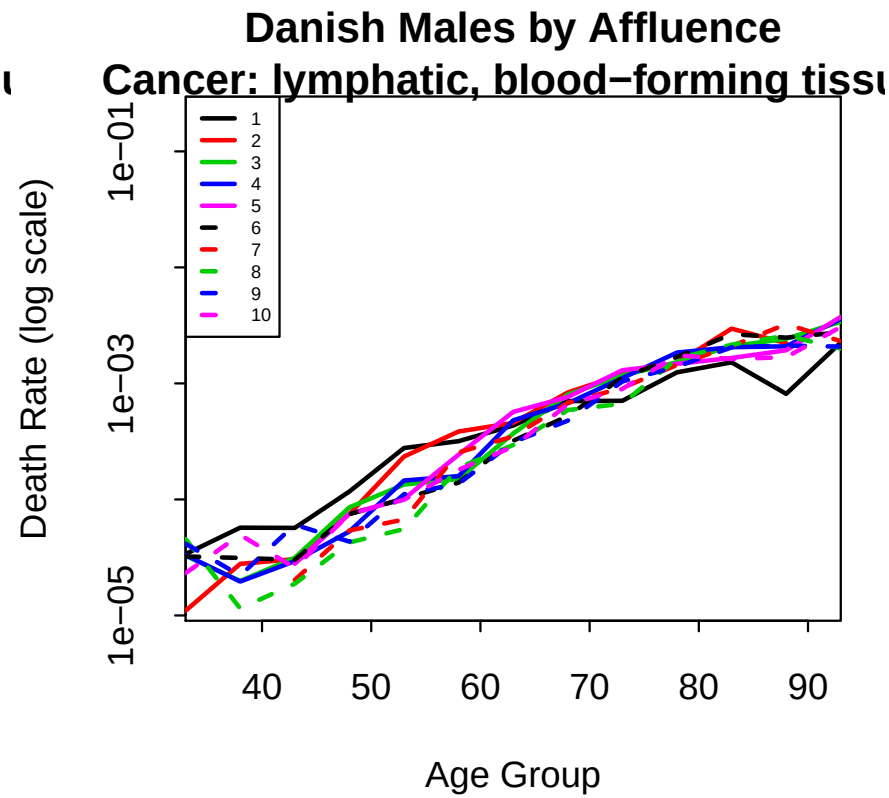

Education $\Rightarrow$ no effect

Affluence $\Rightarrow$ small effect

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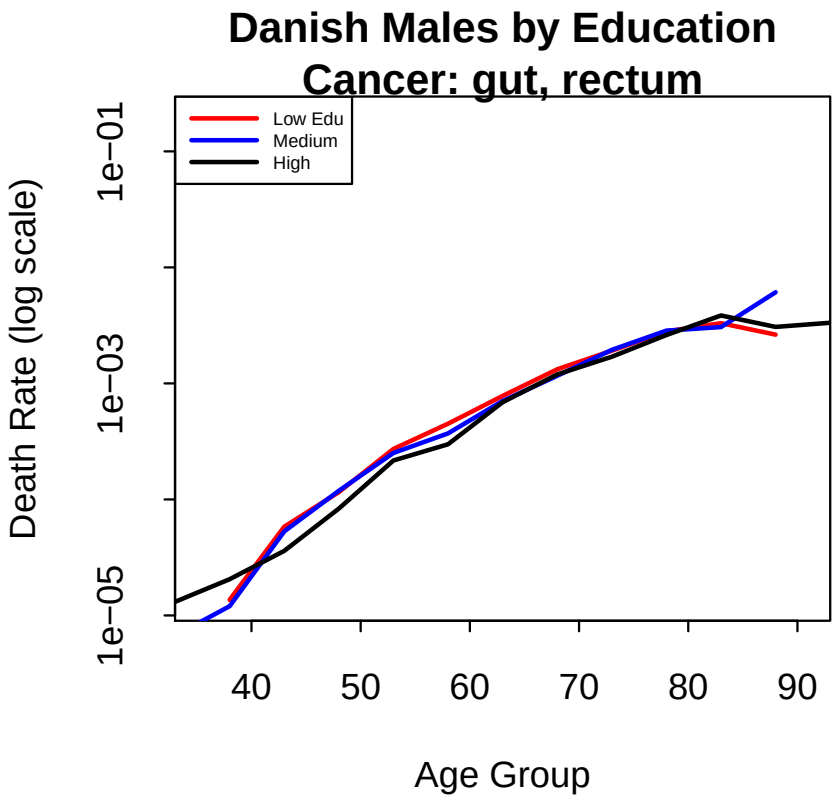
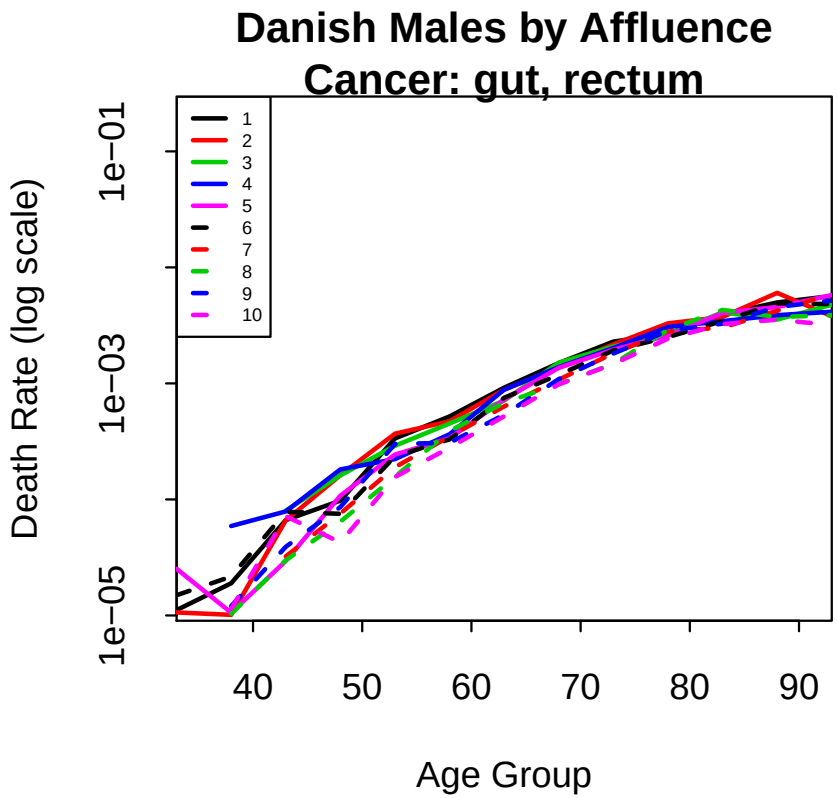
Denmark: Cause of Death Data 2007





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Denmark: Cause of Death Data – Health Inequalities

- Some causes of death have no obvious link to lifestyle/affluence/education
  e.g. Prostate Cancer
  CancerUK:*Prostate cancer is not clearly linked to any preventable risk factors.*
- But Affluence $\Rightarrow$ inequalities
- Possible explanations (a very non-expert view)
  - *onset* is not dependent on lifestyle/affluence/education
  - BUT less affluent/educated $\Rightarrow$
    ??? later diagnosis
    ??? engage less well with treatment process
    ??? lower quality housing

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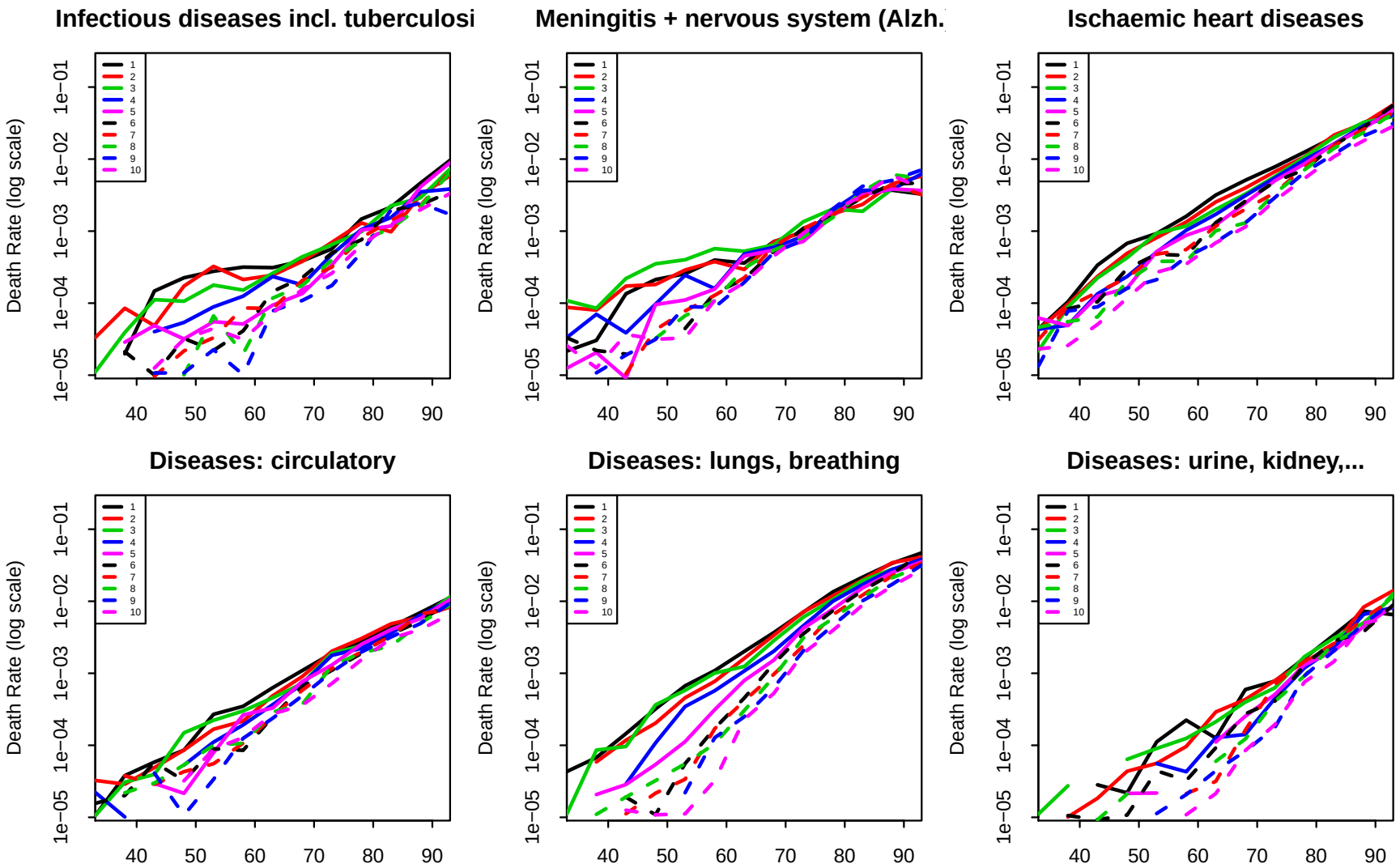
CoD Death Rates: Different Shapes & Patterns



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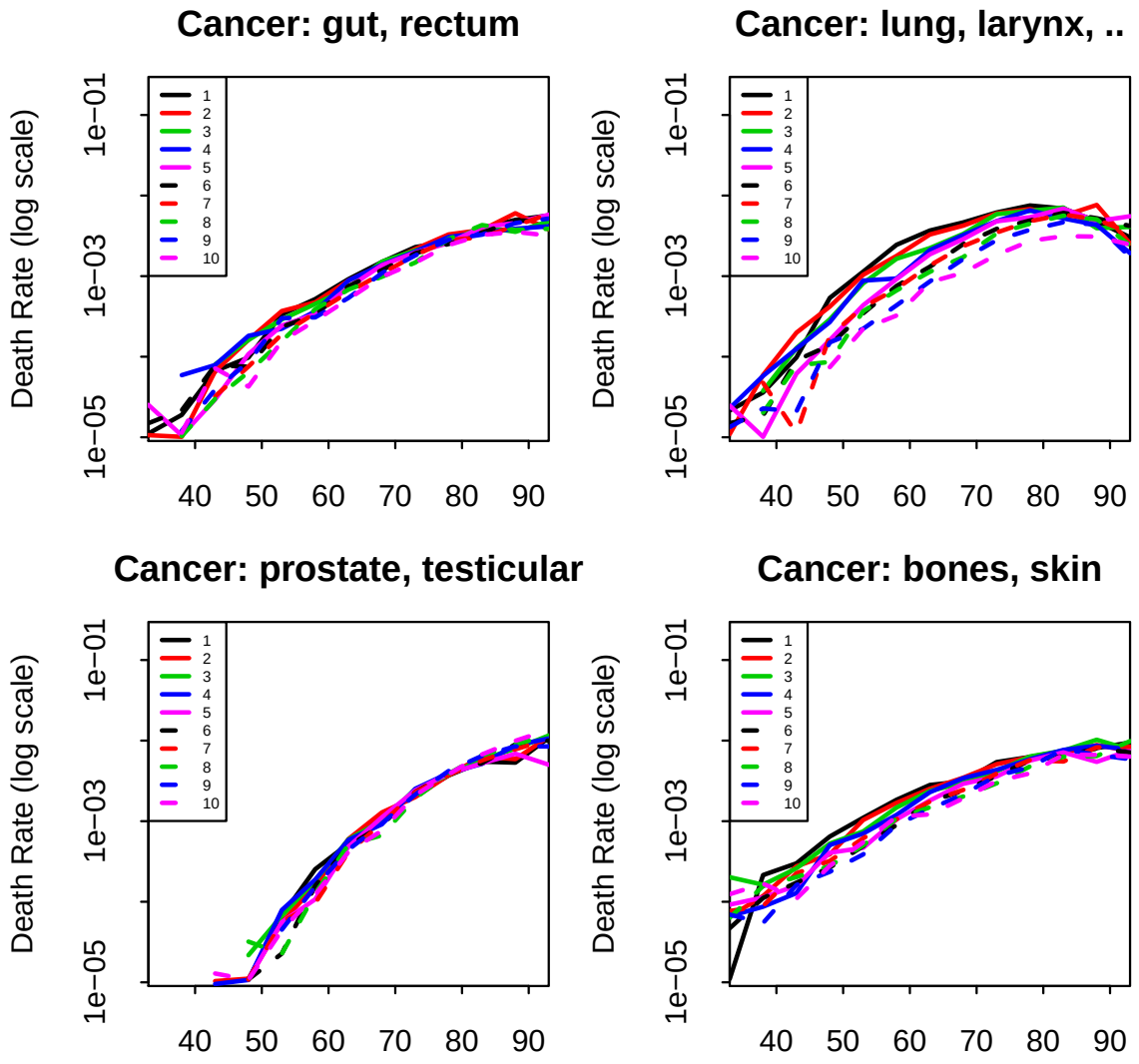
CoD Death Rates: Different Shapes & Patterns



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Shapes: Conclusions

- Typically:
  - Non-cancerous diseases $\Rightarrow$ approximately exponential growth
  - Neoplasms (cancers) $\Rightarrow$ subexponential ??? polynomial
- What does this reveal about different disease mechanisms?

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Denmark Males: Statistical Significance

Which CoD's are significantly affected by socio-economic status?

- H_0: Affluence groups all have the same CoD death rate $m_i(c,t,x) = m_j(c,t,x) \quad \forall i \neq j$ versus
- H_1: Affluence groups do not all have the same CoD death rates

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Denmark Males: Statistical Significance

- For each cause of death (29), and age group (13)
- Rank the death rates for the 10 groups $i = 1, \ldots, 10$
- For each year group, t
  $R(i,t)$ = rank of $m(i,t)$ out of $m(1,t), \ldots, m(10,t)$
  Rank 1: highest death rate
  Rank 10: lowest death rate
- Data $(i, R(i,t))$
- Test statistic, $S = \text{cor}\Big(i, R(i,t)\Big)$
- Under H_0 the ranks are a random permutation of $1, \ldots, 10$
- Under H_0, S is approximately $N(0, \sigma^2)$ where $\sigma = 0.149$.
- One-sided test: Reject H_0 if $S > \sigma\Phi^{-1}(\alpha)$
- Large $S \Rightarrow$ low affluence $\sim$ high CoD mortality

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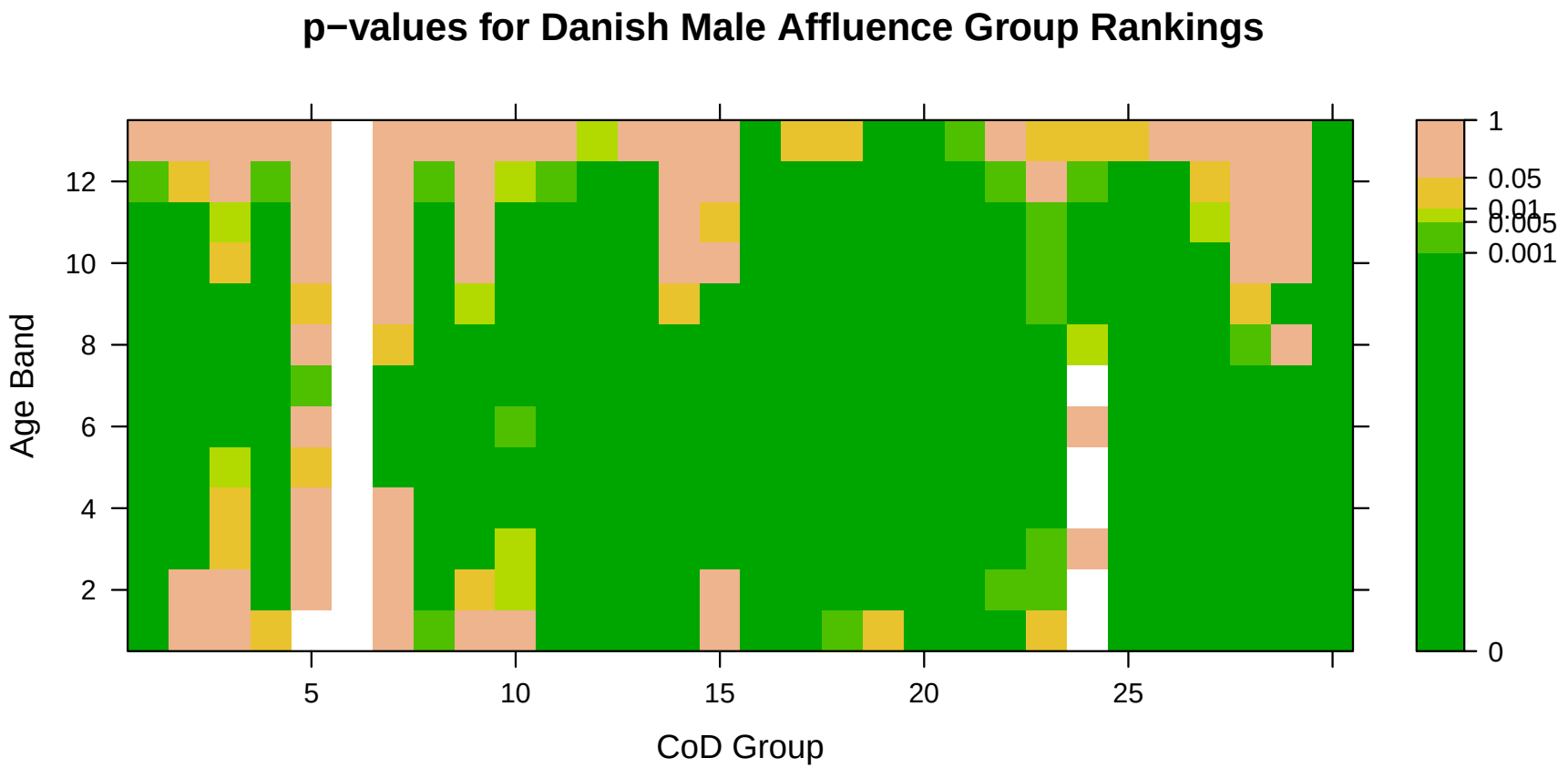
Cause of Death Inequalities: *p*-values



Very low or zero mortality: CoD 5, 6, 24 & low ages
High age convergence

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US Education Data

- Males and Females (2)
- Single ages 55-75 (21)
- Single years 1989-2015 (27)
- Causes of death (29)
- Low, medium & high education level (3)

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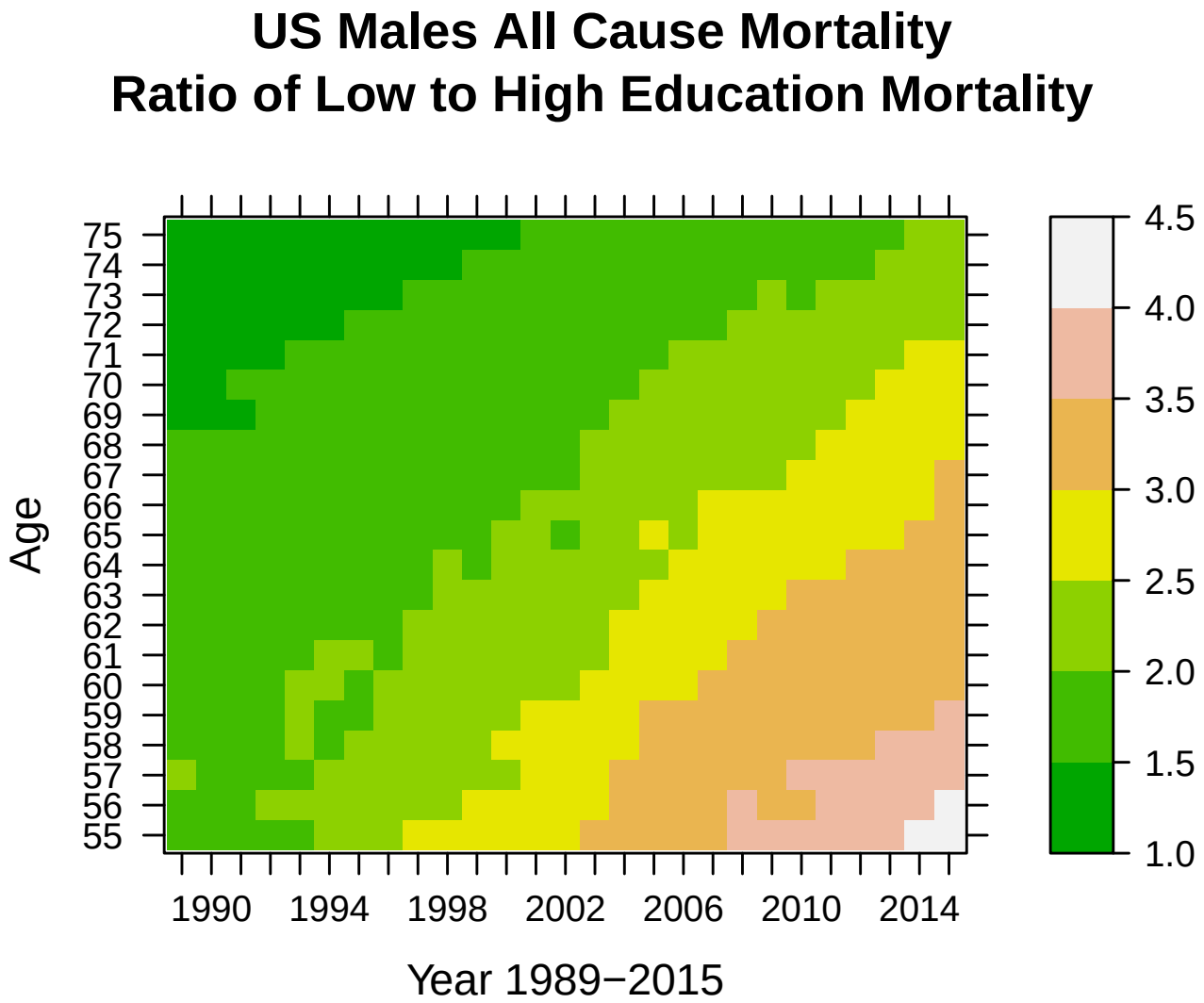
US Education Data: Growing Inequality



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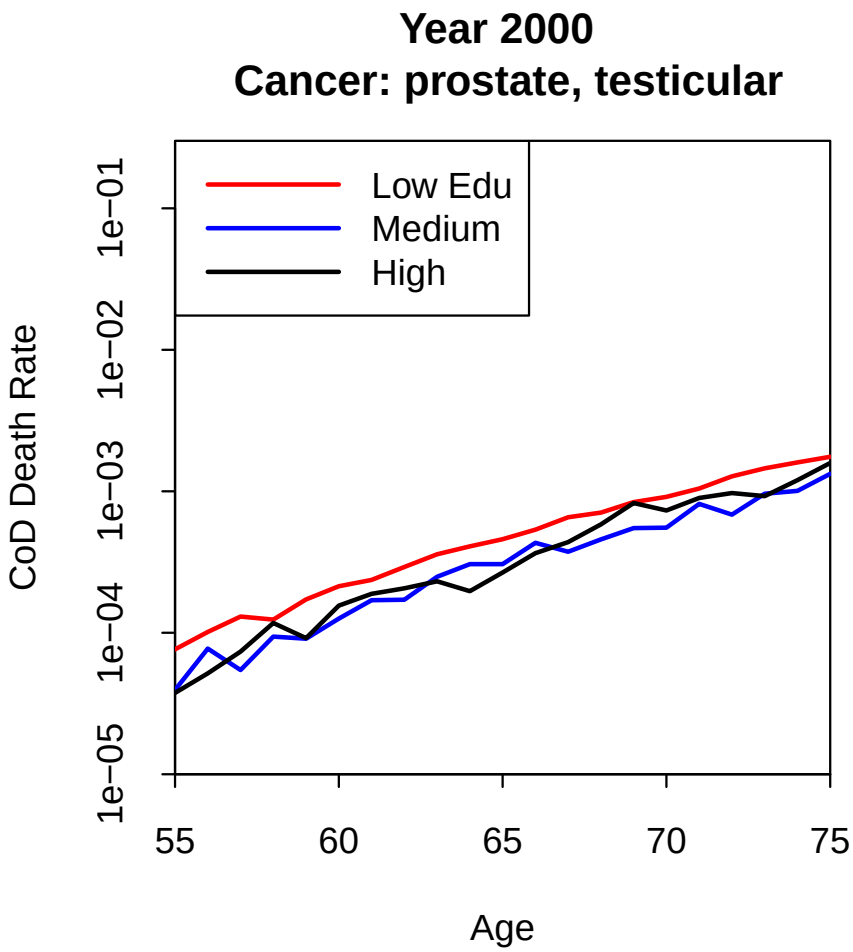
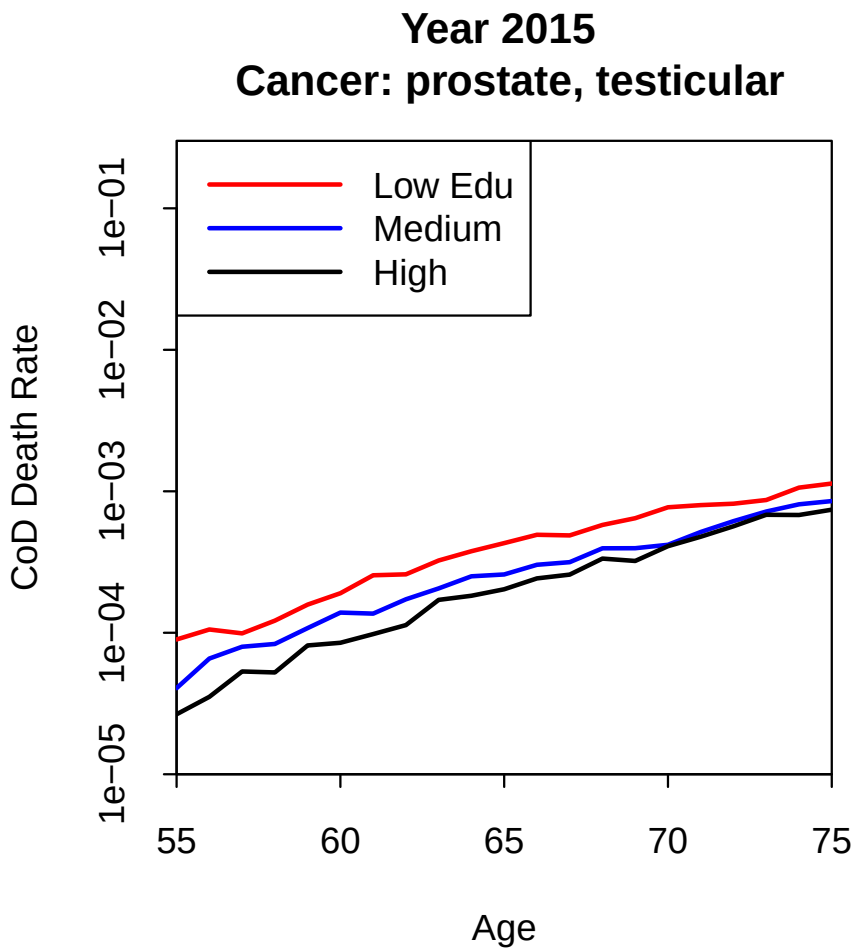
US Education Data





Recall: Denmark ⇒ very narrow gap

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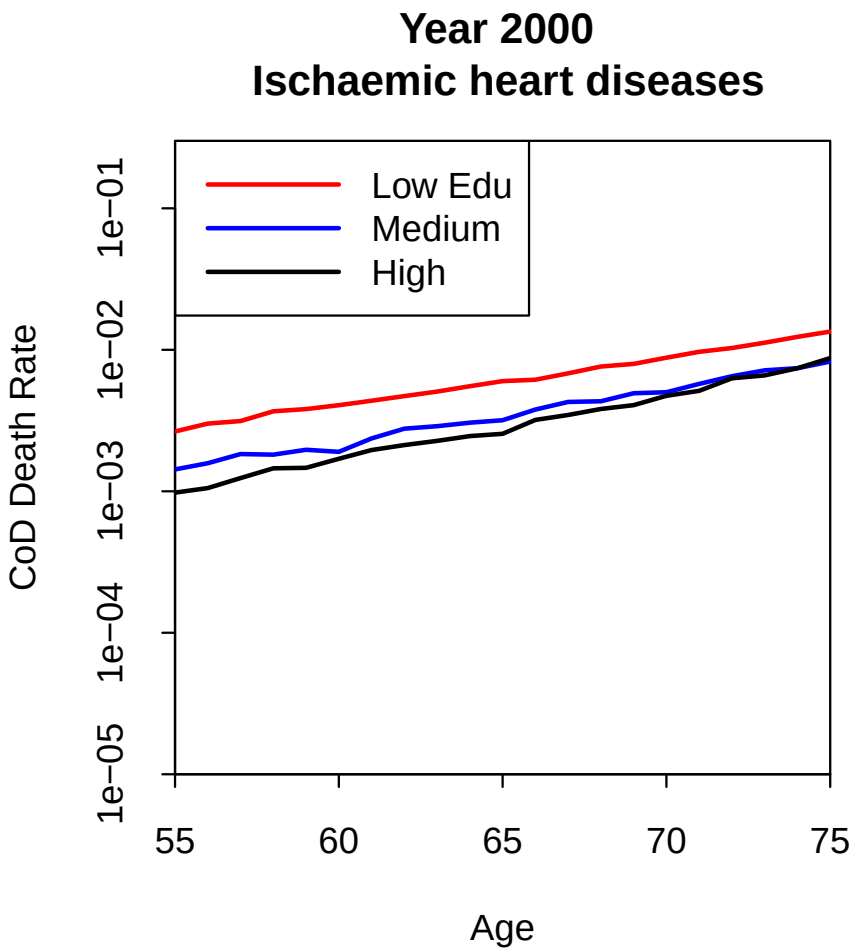
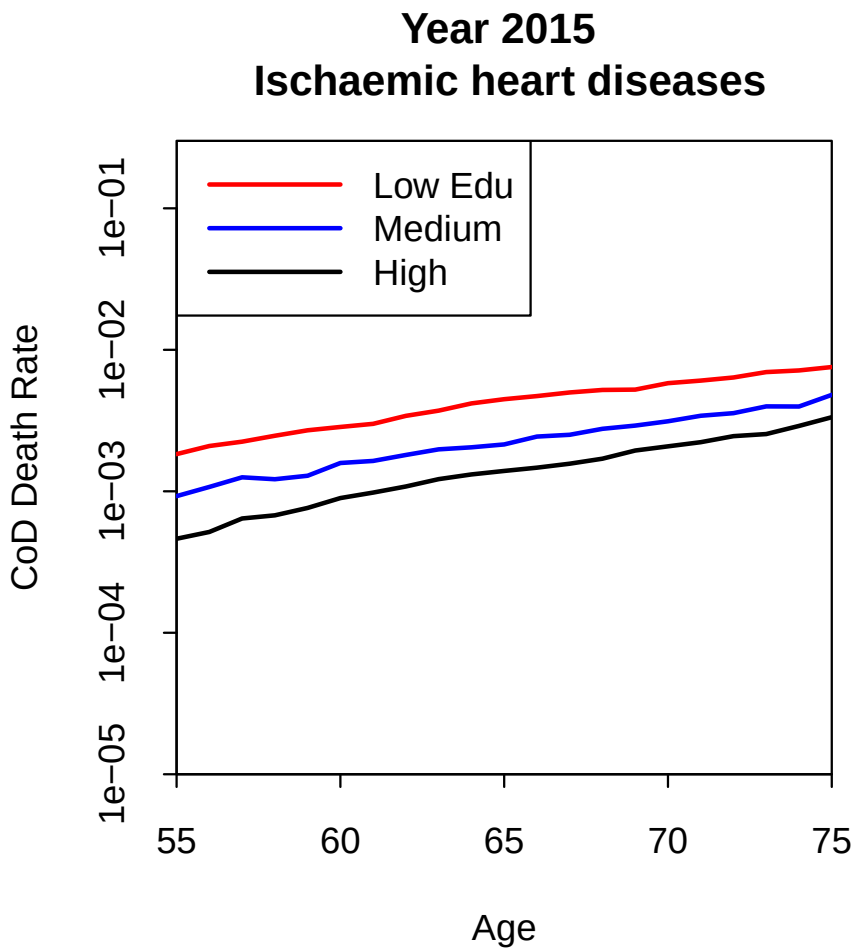
US Education Data





Widening gap

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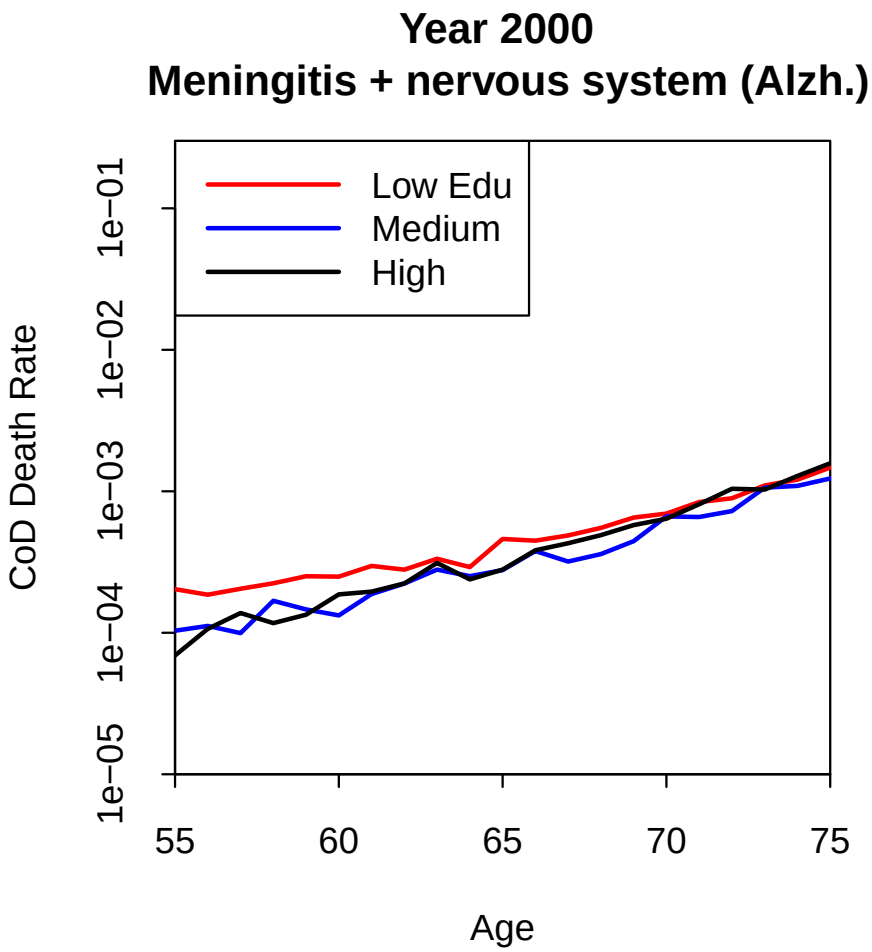
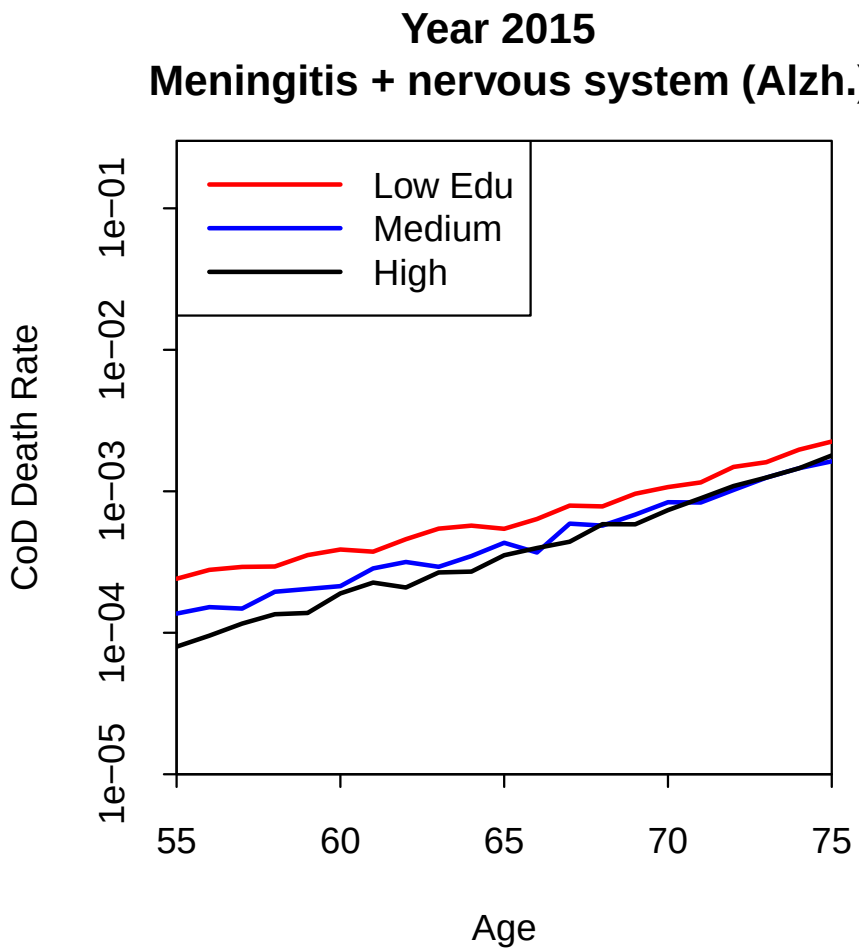
US Education Data





Widening gap

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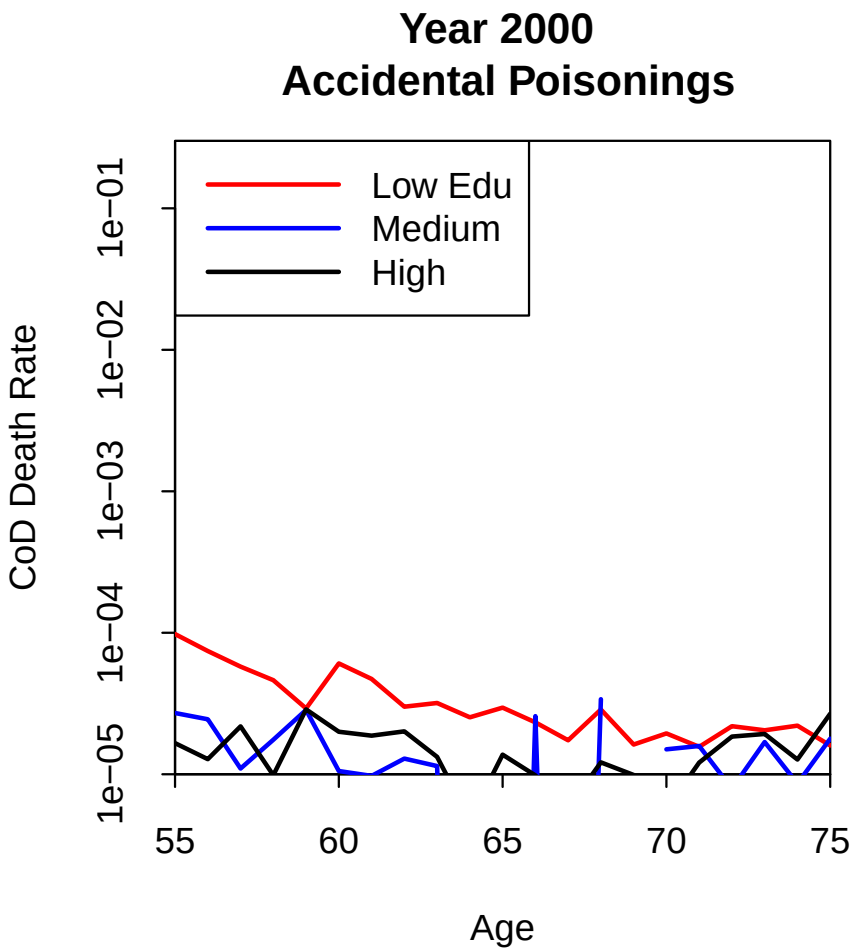

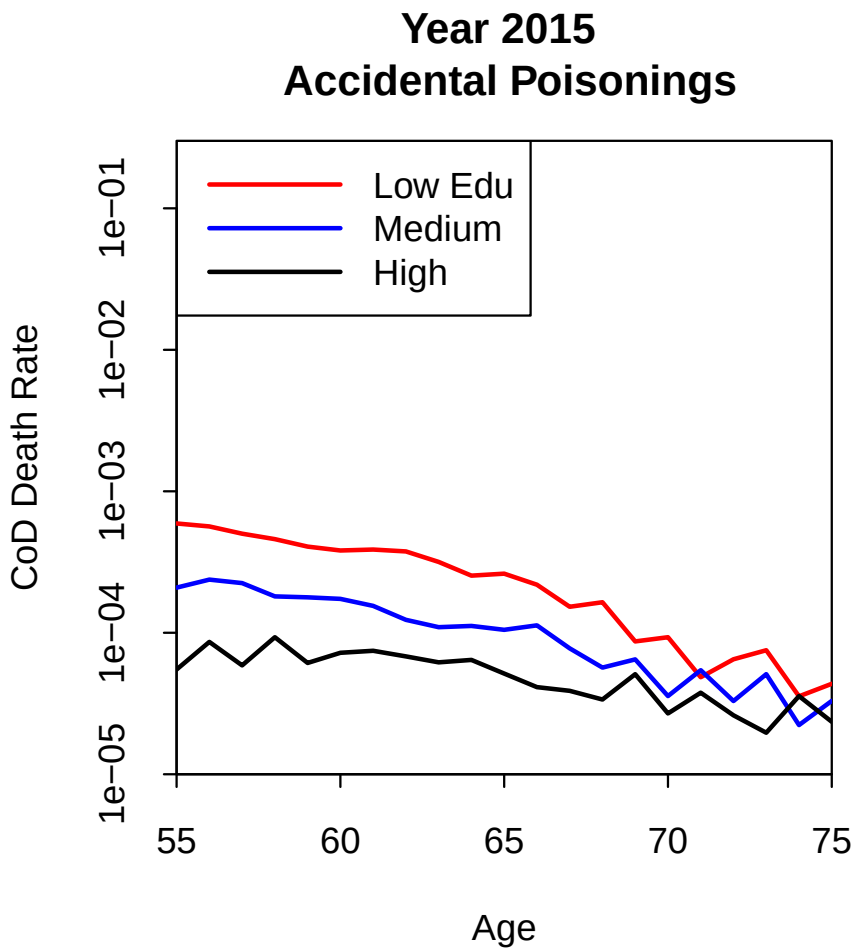

Case & Deaton (2015) $\Rightarrow$ Accidental poisoning ↗

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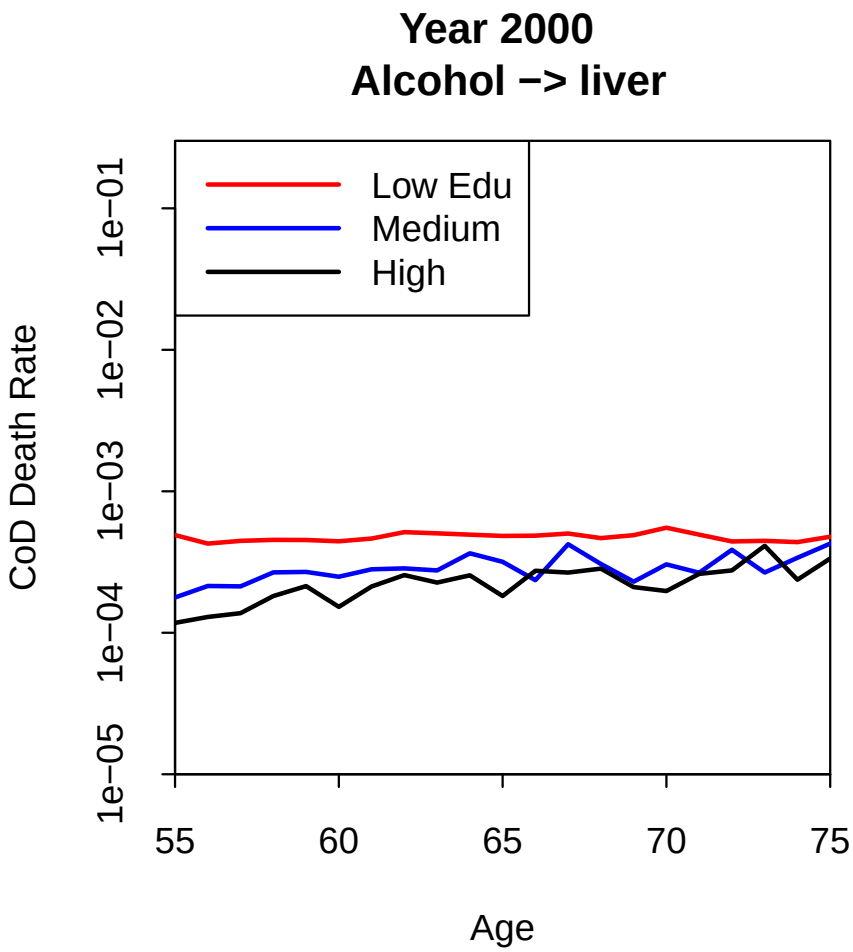
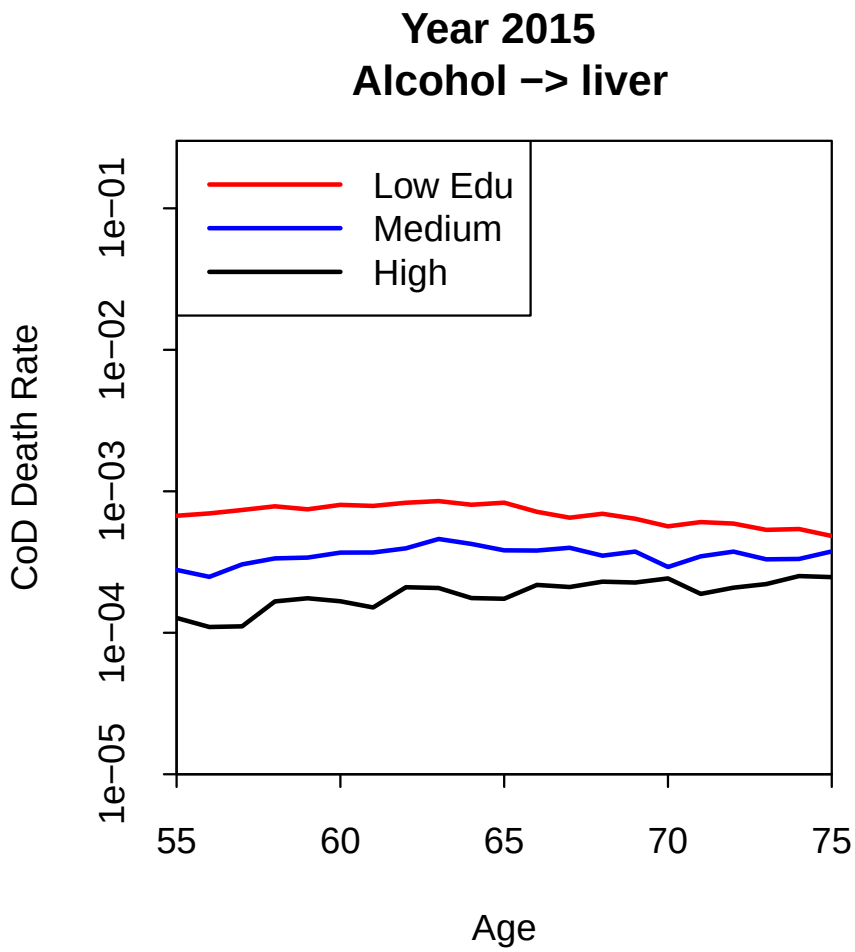
US Education Data





Widening gap

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US Males: Low versus High Education

Do Low and High education groups have the same CoD rate?

- Four $\times$ 5-year age groups
- 29 causes of death
- Signs Test (count low edu. $>$ high edu. mort.)
- $29 \times 4 = 116$ individual tests
- $115/116 \Rightarrow$ reject H_0 equality
- Accept H_0 ($p = 0.08$) for only one pairing (Meningitis + nervous system (Alzh.), 70-74)
- Most p-values $< 10^{-6}$

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4. Summary

- Affluence better than education for all CoD if you have the data
- Impact of affluence/education varies with CoD
- Different growth patterns cancers versus other diseases
- Work in progress!

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Thank You!

Questions?

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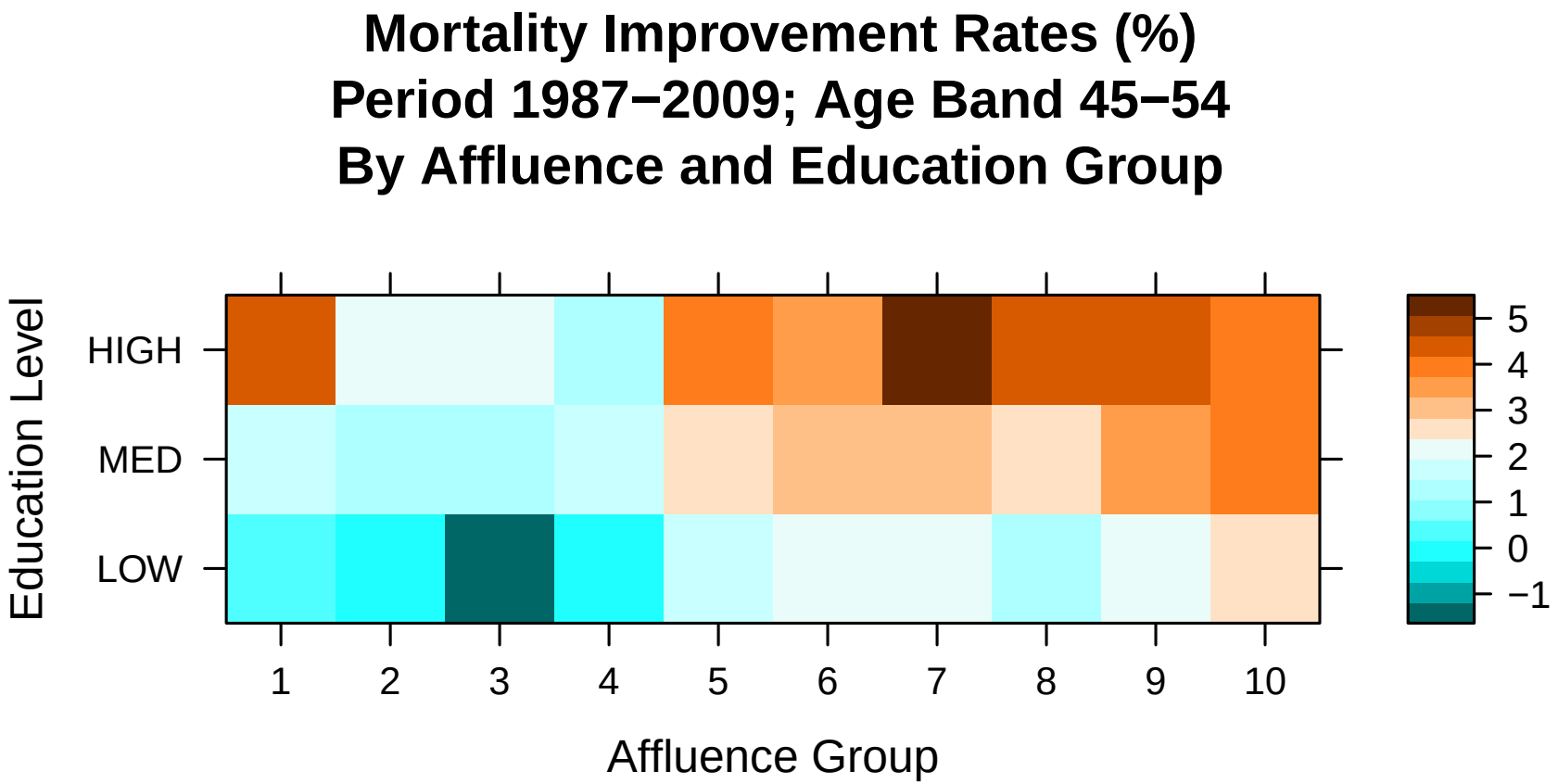
Education as an Alternative Covariate

Dig a bit deeper:
Affluence + Education: average ASMR's over 5 years



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