Longevity Risk Research

Modelling, Measurement and Management of Longevity and Morbidity Risk

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The Actuarial Research Centre (ARC)

A gateway to global actuarial research

The Actuarial Research Centre (ARC) is the Institute and Faculty of Actuaries' (IFoA) network of actuarial researchers around the world.
The ARC seeks to deliver cutting-edge research programmes that address some of the significant, global challenges in actuarial science, through a partnership of the actuarial profession, the academic community and practitioners.
The 'Modelling, Measurement and Management of Longevity and Morbidity Risk' research programme is being funded by the ARC, the SoA and the CIA.

`www.actuaries.org.uk/arc`

Plan for this Session

- Introduction to the Actuarial Research Centre longevity and morbidity research programme
  - Our sponsors
  - Research themes
  - Impact
- General background
- Research so far: a taster
  - Case study: Danish mortality
  - Health (mortality) inequalities
  - Drivers: Cause-of-death inequalities
- Developing a Mortality Database
- Emerging themes

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Modelling, Measurement and Management of Longevity and Morbidity Risk

Our Sponsors:

- Institute and Faculty of Actuaries:
  Actuarial Research Centre
- Society of Actuaries
- Canadian Institute of Actuaries

Specific activities tailored to each.

Programme objectives

- development of the next generation of single and multi-population mortality models that are robust, straightforward to apply and that are designed explicitly to push back the barriers to financial innovation;
- understanding and modelling of the key drivers of mortality such as smoking, obesity and other lifestyle factors and understanding how these interact with all-cause mortality and cause-of-death mortality data;
- development of a robust, scientific approach that helps key stakeholders to understand better the wider range of options for managing longevity risk;
- development of new methods for pricing and reserving for Critical Illness Insurance.

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Outputs and knowledge exchange

- Papers and articles → journals, magazines

  open access

  `www.macs.hw.ac.uk/~andrewc/ARCresources`
- Data: open access where feasible
- Events:
  - Sessional meetings: October 2017, *29 January 2018* and beyond
  - IFoA conferences: life, pensions, health & care, risk
  - IFoA specialised conferences and regional events
  - ARC training/CPD events including webinars
  - North America: SoA, CIA
  - IAA conferences: ICA 2018 + section colloquia
  - Very willing to discuss research at individual organisations

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Case studies and impact

Various forms of impact to be pursued including

- Adoption of new models by users:
  - assessment of the impact of longevity risk
  - facilitated through training events
  - increased confidence in use of models
- Regulation
- Innovation in risk management

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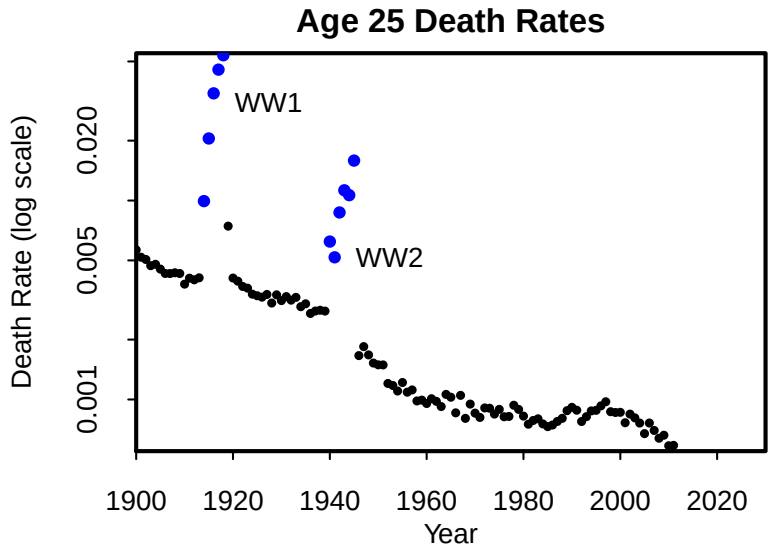
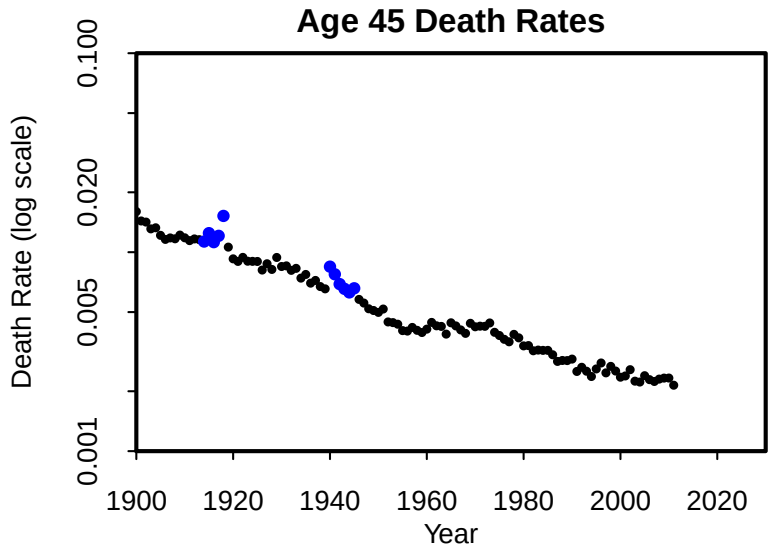
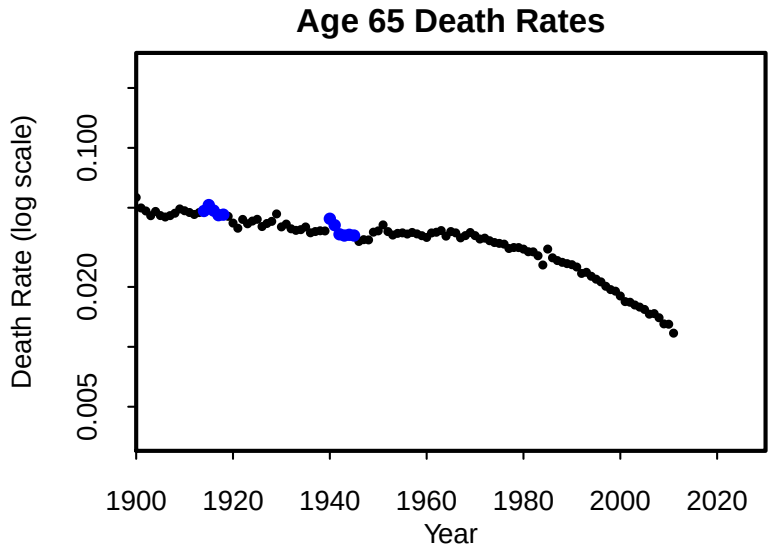
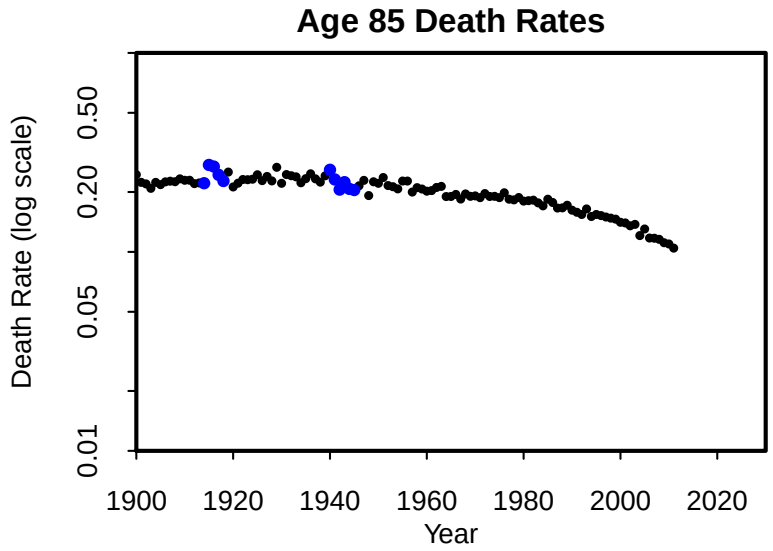
Historical Death Rates: Males, England and Wales









Future forecasts $\Rightarrow$ need for stochastic mortality models

Motivation for Stochastic Mortality Models

- Data $\Rightarrow$ uncertain future
- Modelling and measuring longevity risk is important in many actuarial applications
  - General risk assessment
  - Pricing: margin for systematic risk
  - Reserving: systematic risk in runoff
  - Reserving: systematic reserving risk over a 1-year horizon
  - Reserving: diversification benefit between two populations
  - Assessment of risk reduction in longevity hedges

Mortality and Longevity Modelling & Risk Assessment

What are we trying to achieve?

- Central forecasts
- How much uncertainty around central forecasts?
- New single population models: e.g.
  - wider age range
  - flexible and robust estimation procedures
  - greater flexibility in modelling central forecasts
- New multipopulation models: e.g.
  - Data driven modelling
  - How to handle smaller populations?
  - Robust models
  - Realistic correlation term structure

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Models $\longrightarrow$ Longevity Risk Management

Questions:

- What options for managing longevity risk including index-based hedges?
- How to model and assess the impact?
- Impact of risk management on regulatory and economic capital
- Impact of risk management on economic value
- What barriers to innovation?
  - Data accuracy
  - Active pension plan members
  - Price disagreements
  - Regulatory approval: admissible; fair

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Danish Data

Data from Statistics Denmark national register database

Many potential covariates

- Income and wealth $\rightarrow$ affluence
- Educational attainment
- Marital status, occupation, health information, cause of death, ...
- Much richer dataset than other countries e.g. UK: mortality by occupation group only; or by Index of Multiple Deprivation areas

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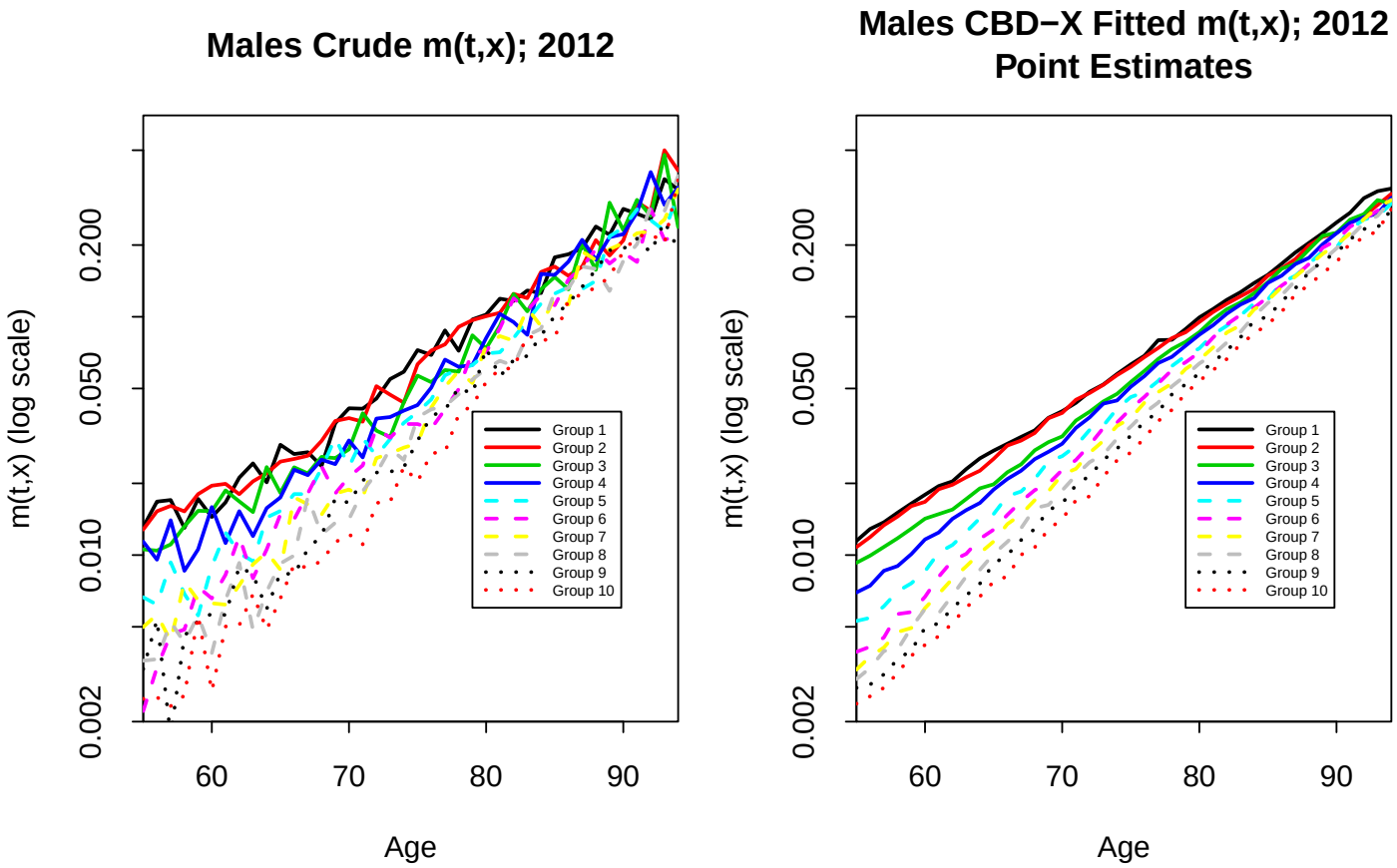
Core Study: Subdivide into 10 Affluence Groups

Death rates, $m(t, x)$ for affluence groups 1 to 10



- CBD-X: Extended Cairns-Blake-Dowd model
- Similar pictures for each of 1985-2012

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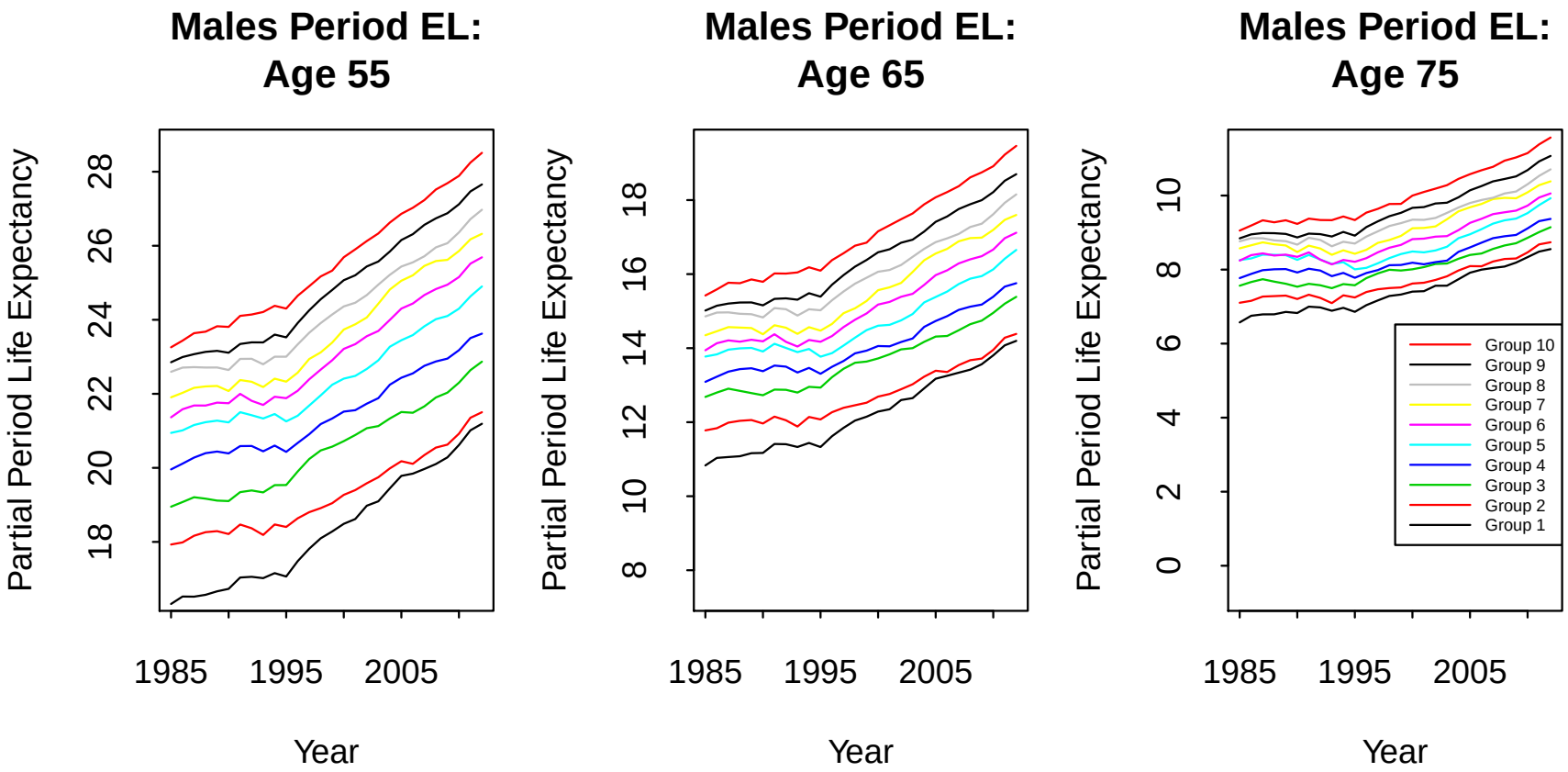
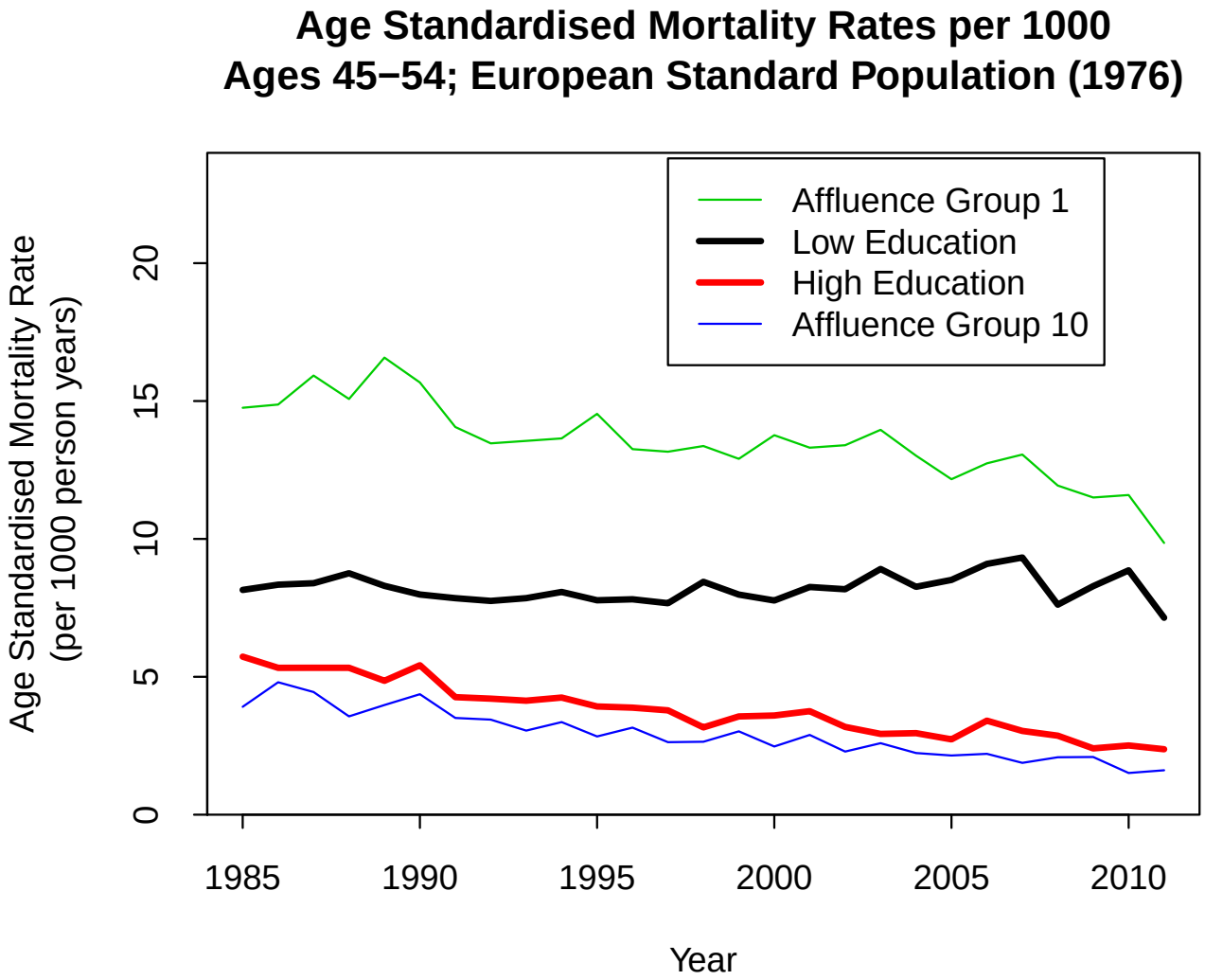
Partial Period Life Expectancy for Groups 1-10



("Partial" $\Rightarrow$ up to age 95.)

Education as an Alternative Covariate

Education levels: low, medium, high



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Education as an Alternative Covariate

- Education $\Rightarrow$ work in progress
- Affluence is a stronger predictor
- But education seems to be increasing in importance
- E.g. high/low education diverging more than affluence
  similar divergence in other countries e.g. US

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Cause of Death Data – Health Inequalities

- Deaths subdivided into 29 CoD groups
- Age groups

  31-35, 36-40, ..., 91-95
- Calendar 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	Nervous system (Alzh. & Meningitis)
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 (excl. liver)	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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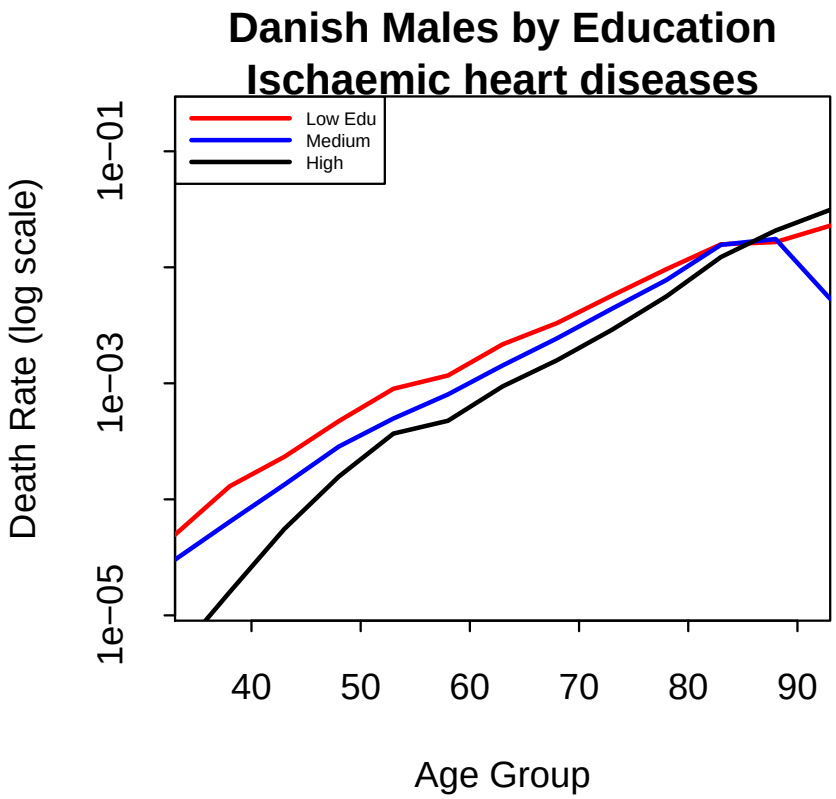
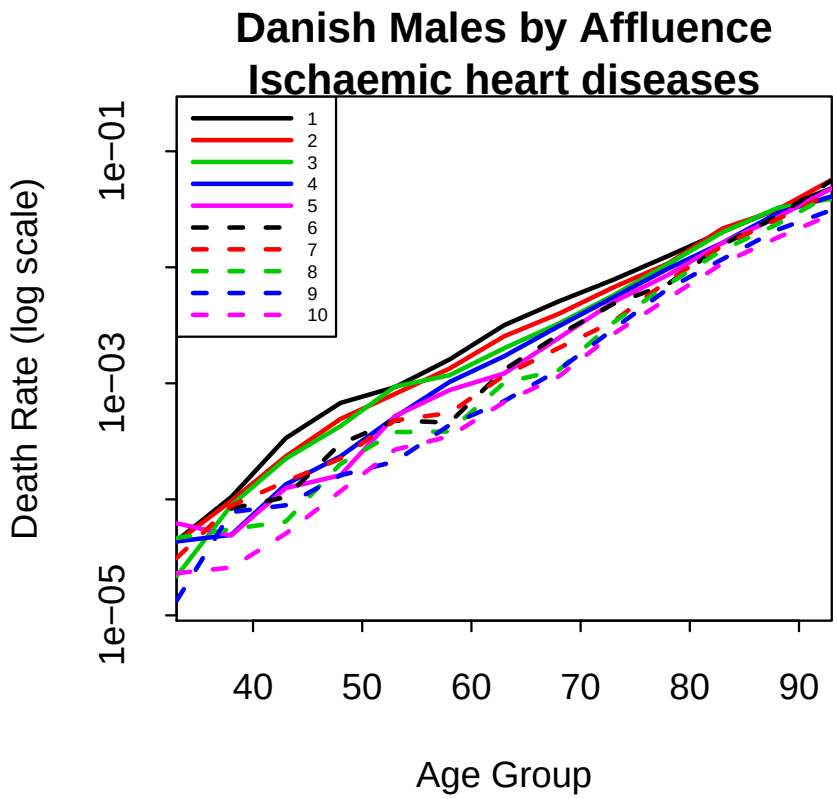
Denmark: Cause of Death Data 2007 (empirical)

Compare education with affluence as covariates:





Affluence $\Rightarrow$ slightly wider spread

Significant levels of "inequality"

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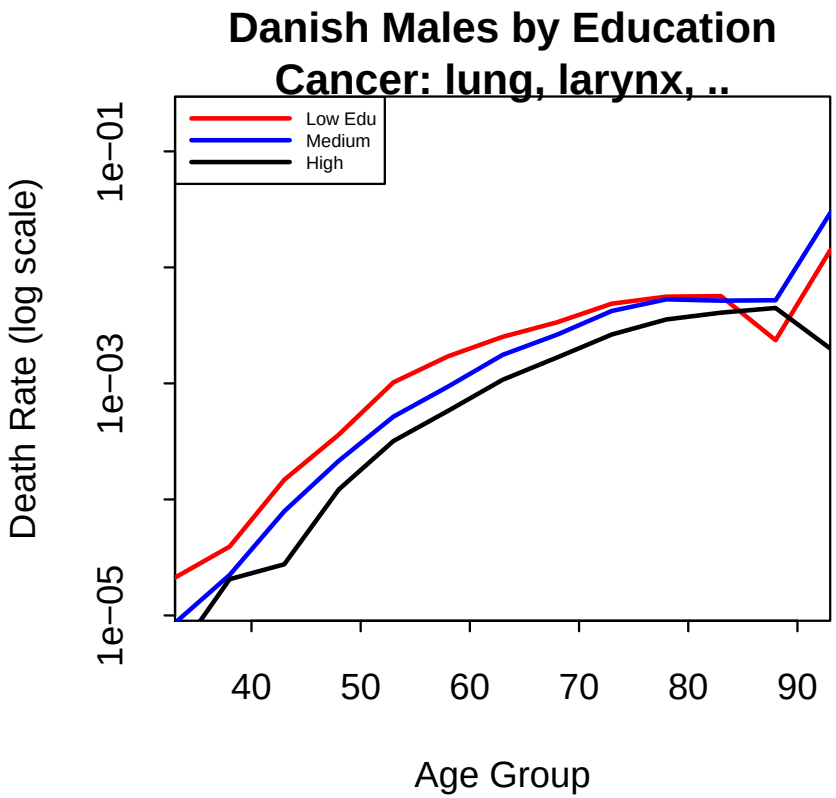
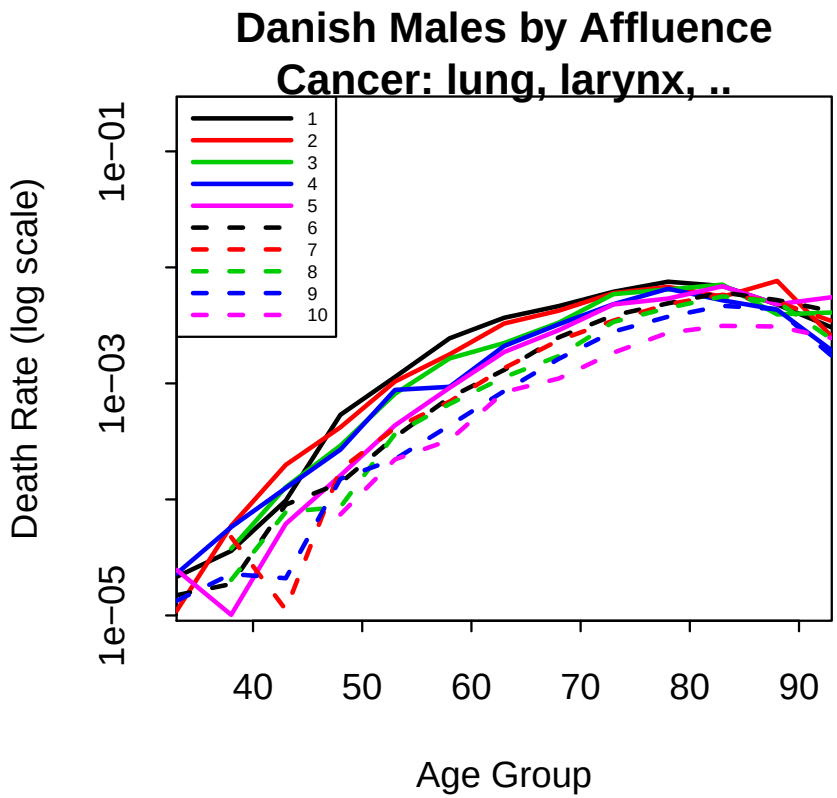
Denmark: Cause of Death Data 2007





Affluence $\Rightarrow$ wider spread

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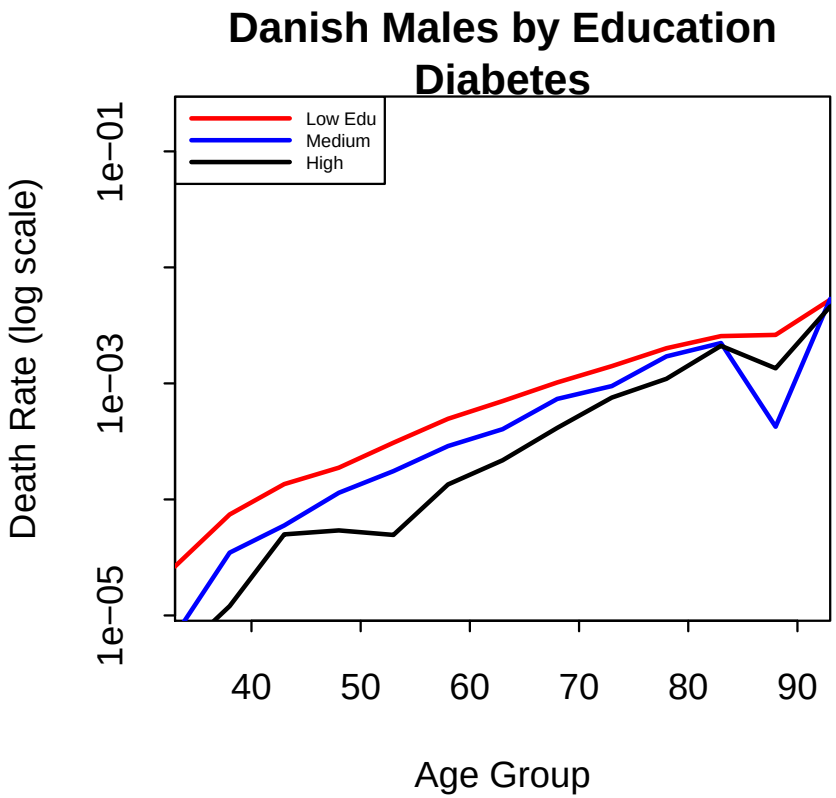
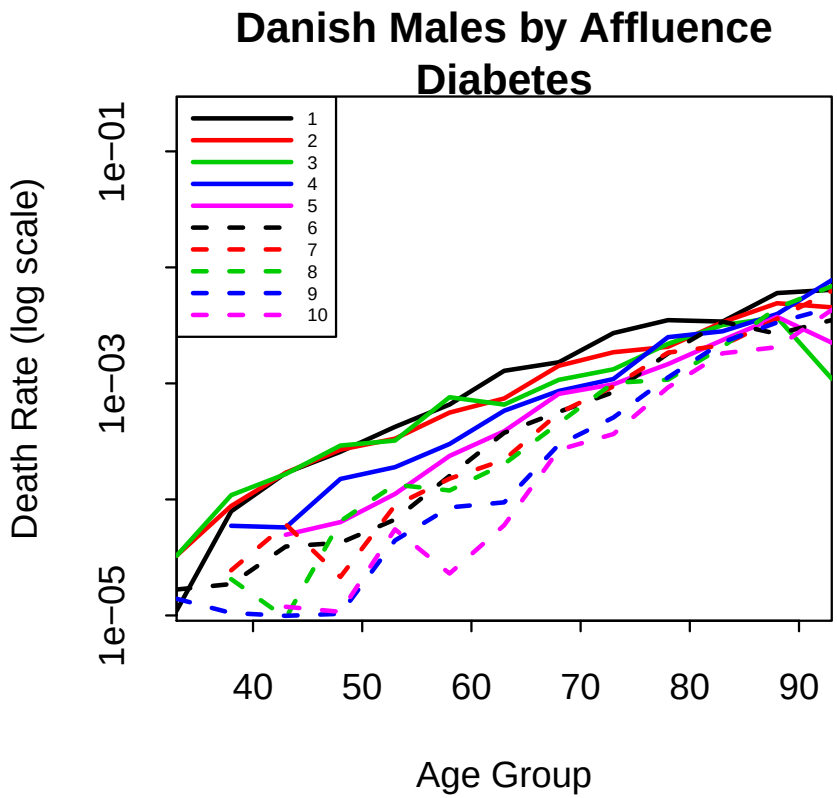
Denmark: Cause of Death Data 2007





Affluence $\Rightarrow$ much wider

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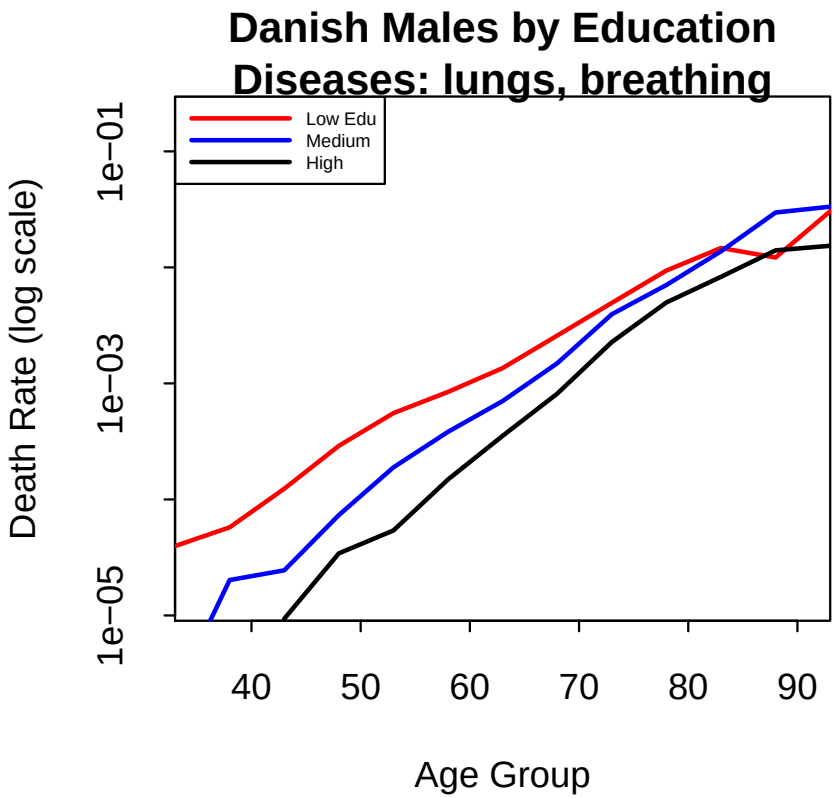
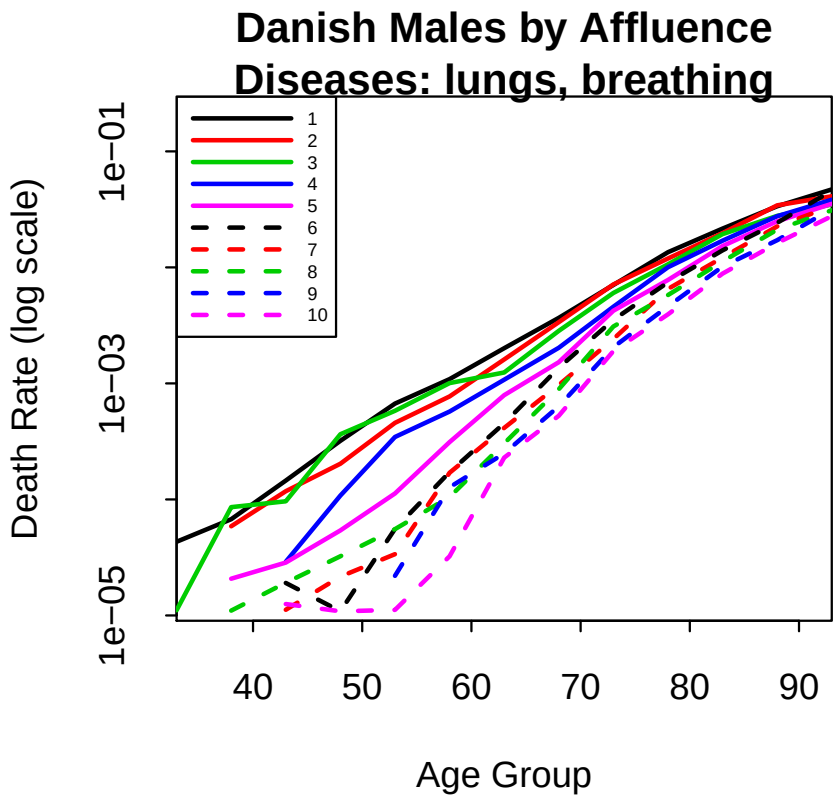
Denmark: Cause of Death Data 2007





Affluence $\Rightarrow$ wider spread

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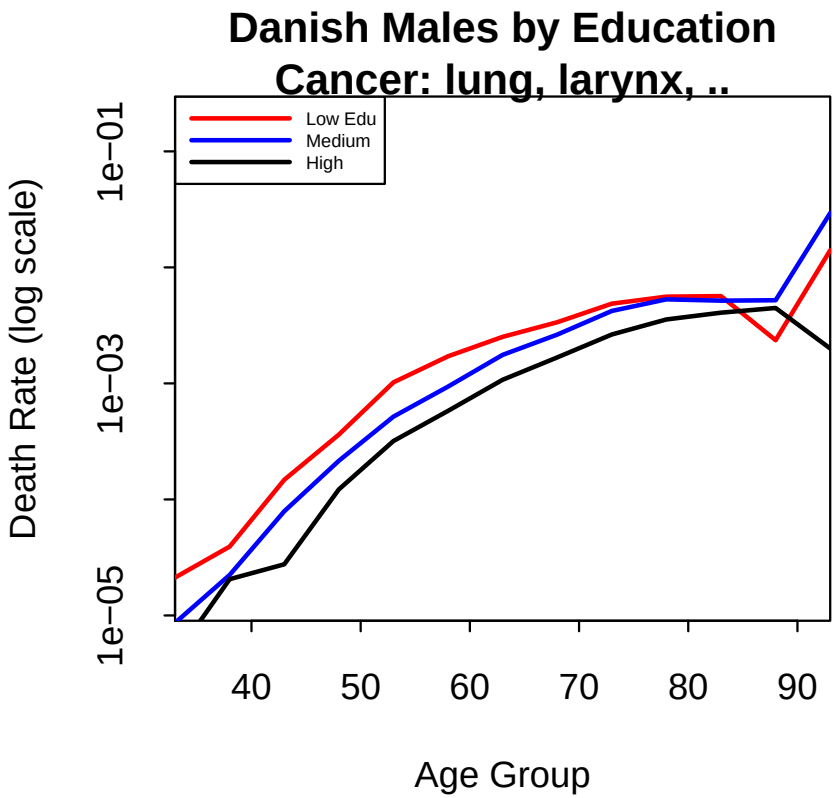
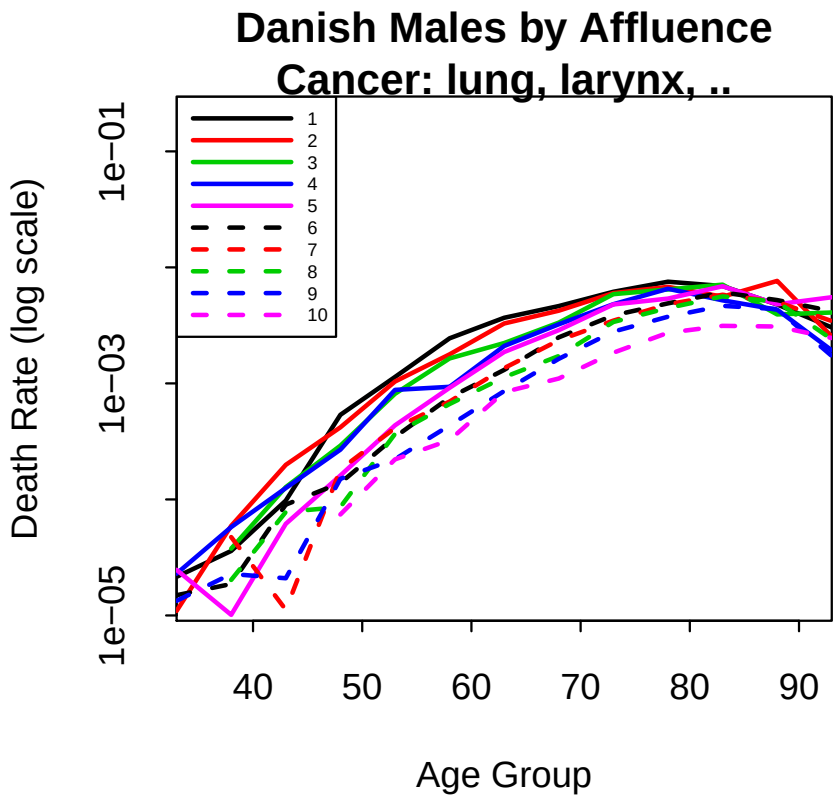
Denmark: Cause of Death Data 2007





Affluence $\Rightarrow$ wider spread

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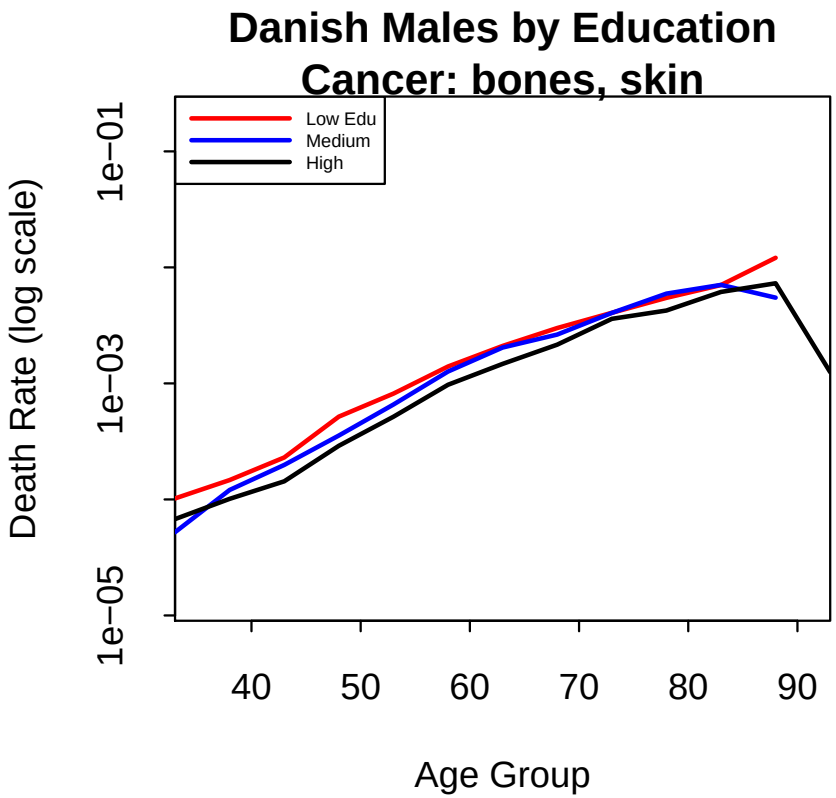

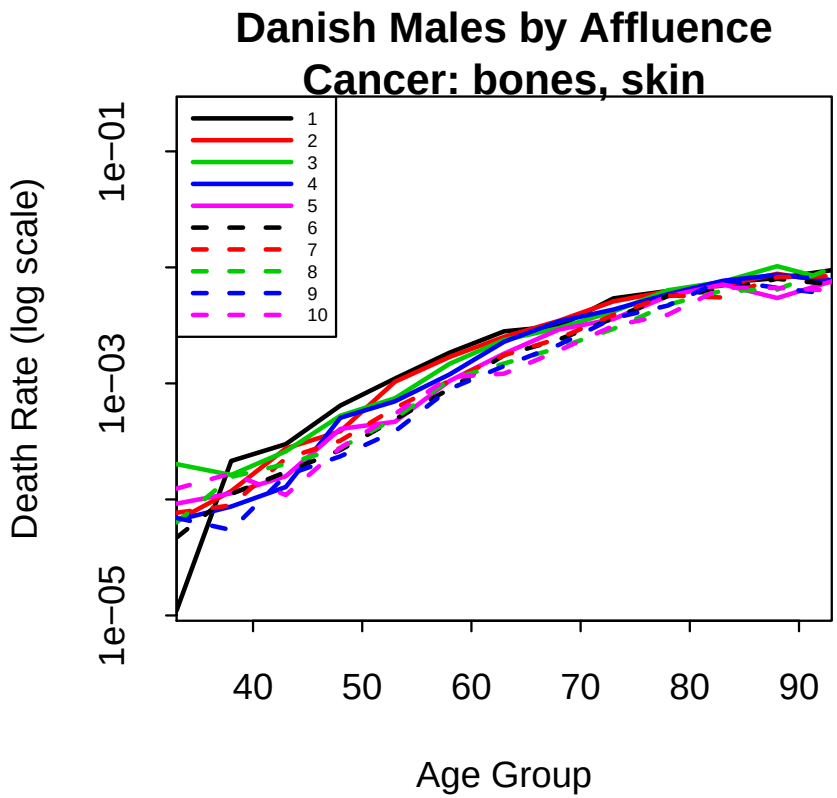

Affluence $\Rightarrow$ wider spread

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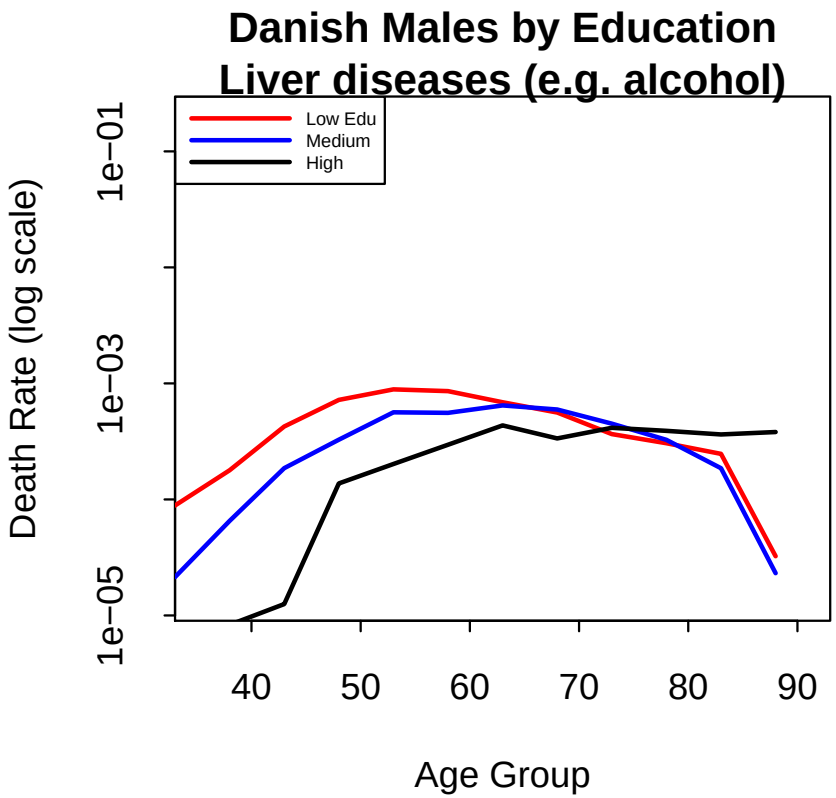

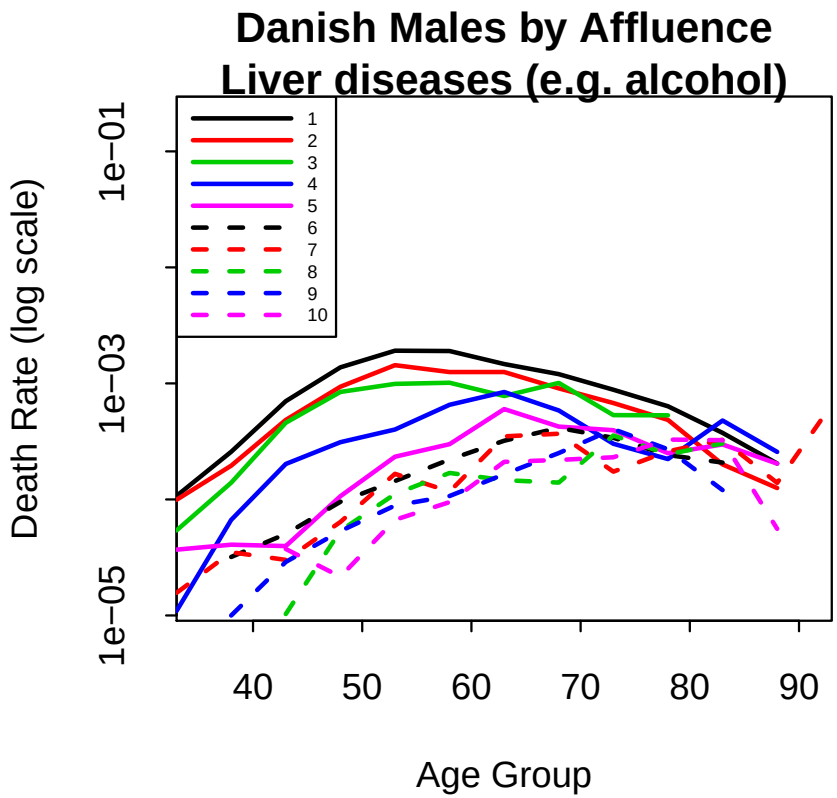

Affluence $\Rightarrow$ much wider spread than education

Low affluence $\Rightarrow$ over 20$\times$ high aff. at younger ages

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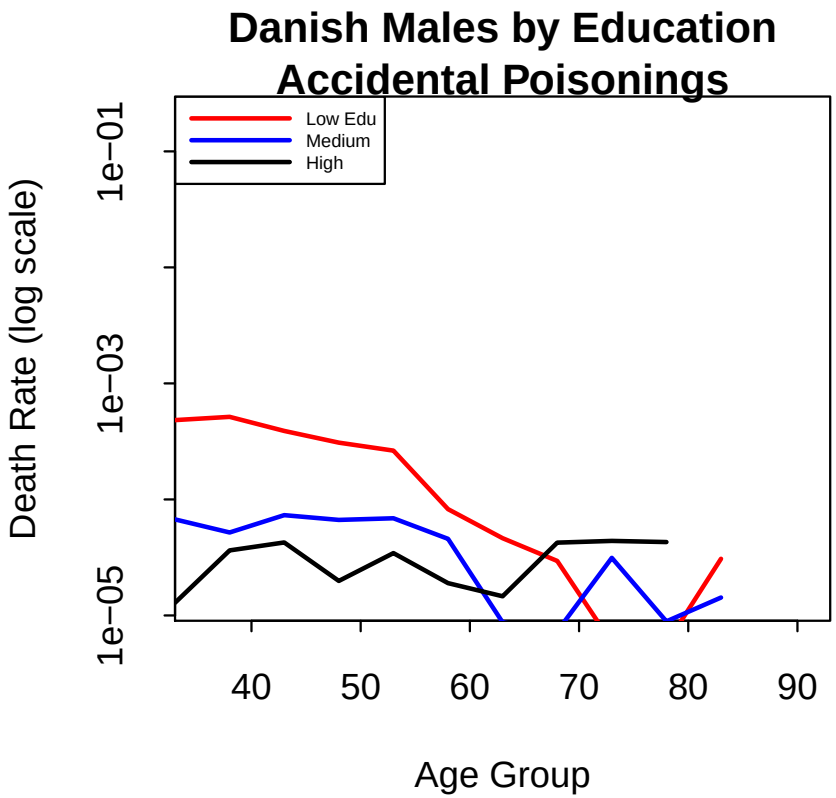
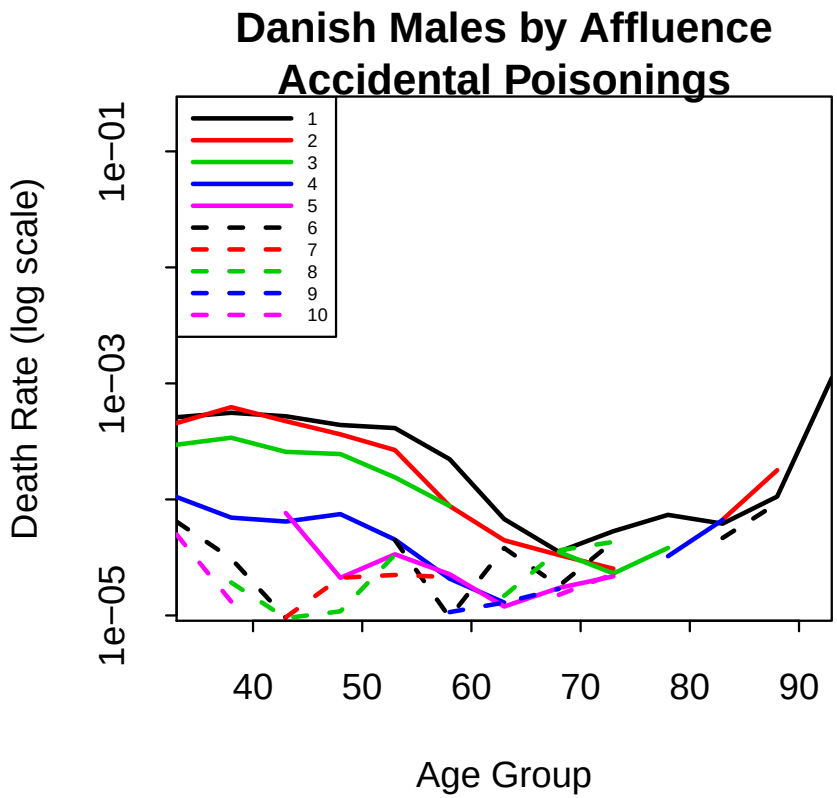
Denmark: Cause of Death Data 2007





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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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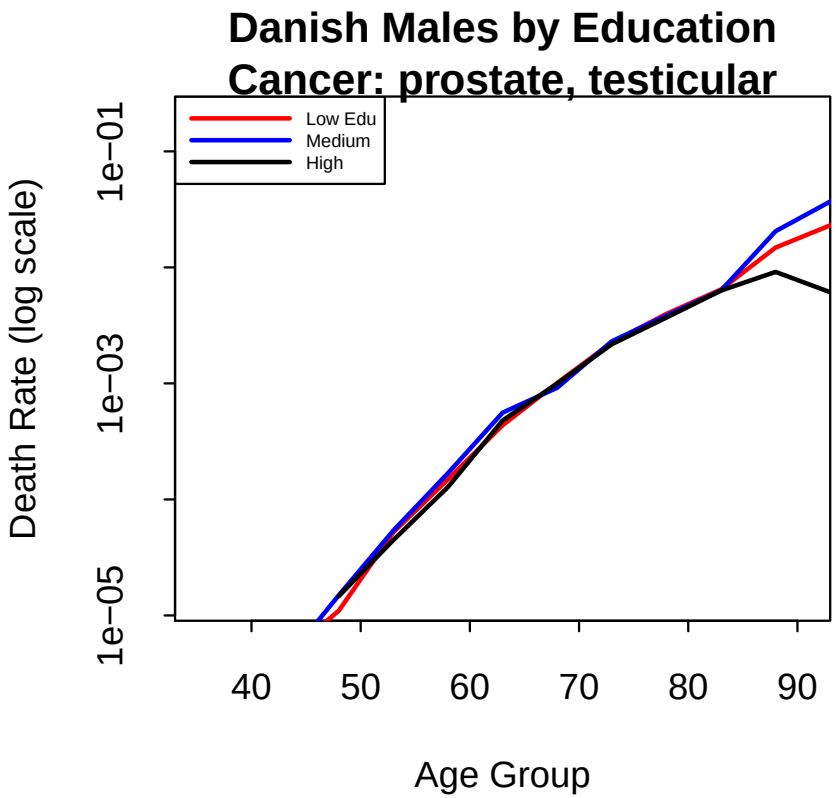
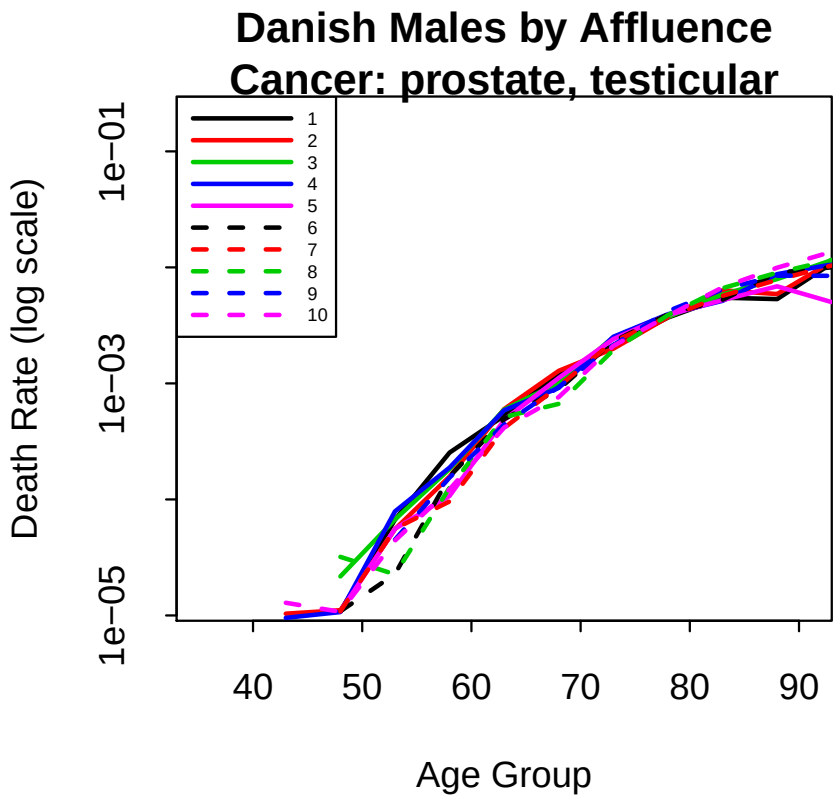
Denmark: Cause of Death Data 2007





Education $\Rightarrow$ no effect

Affluence $\Rightarrow$ small effect

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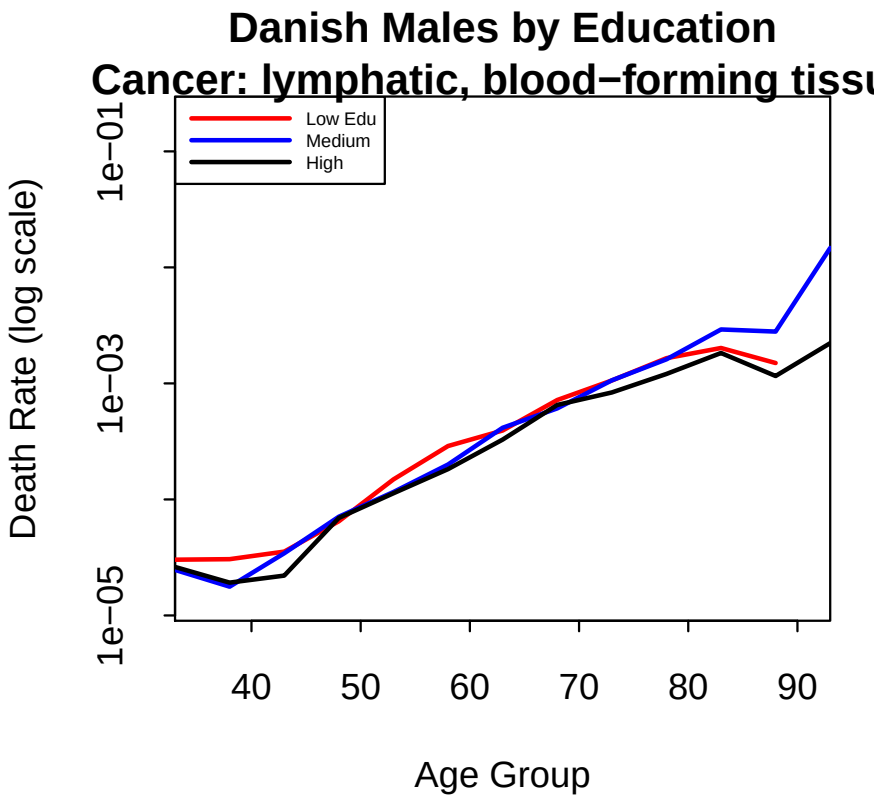
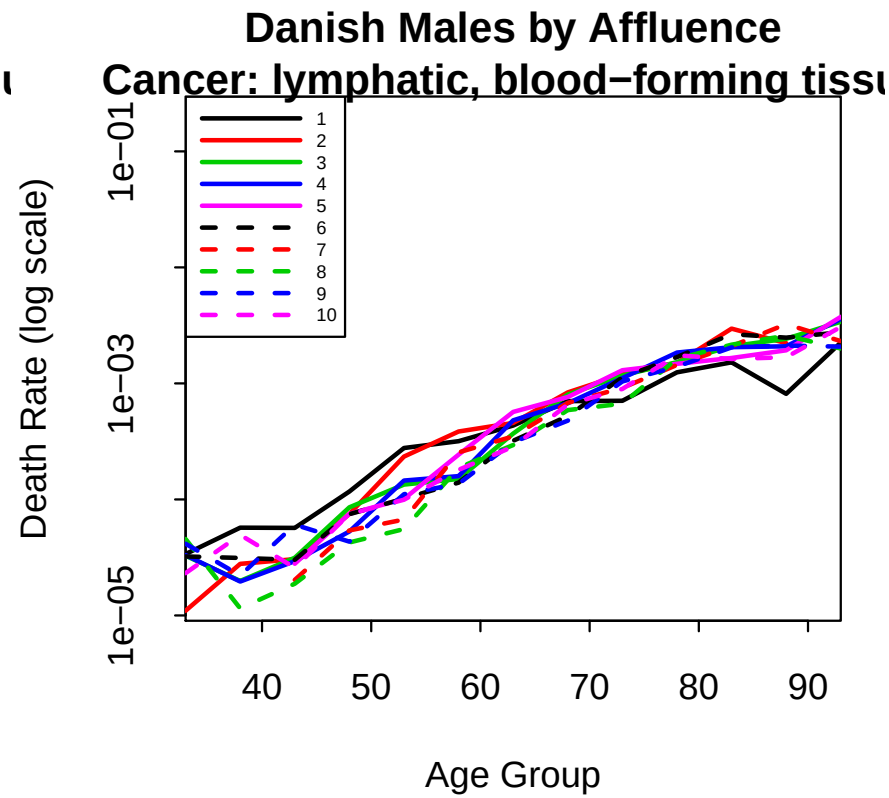
Denmark: Cause of Death Data 2007





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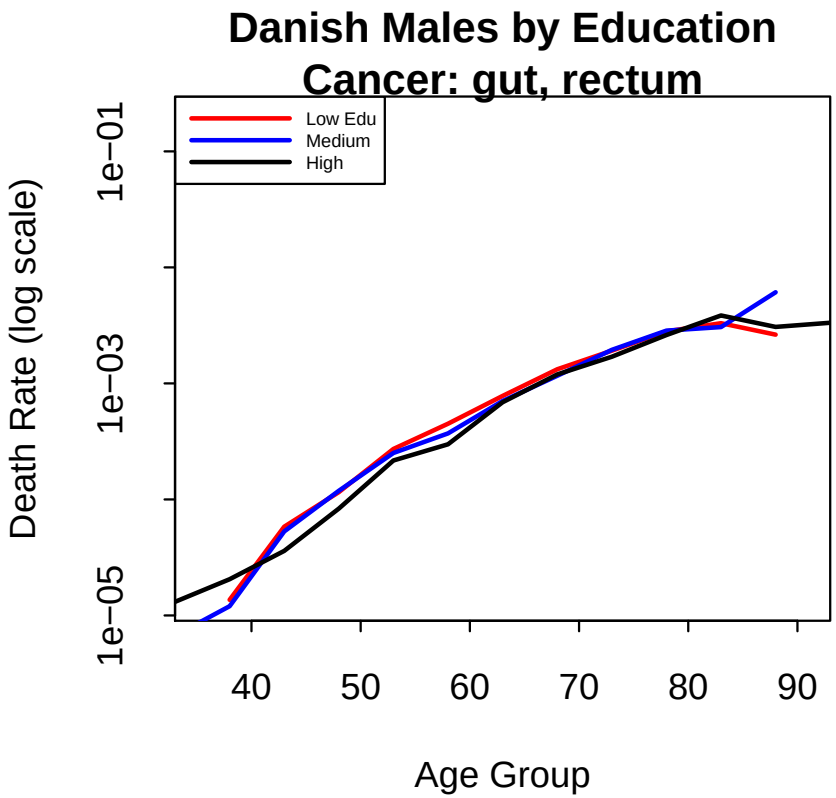

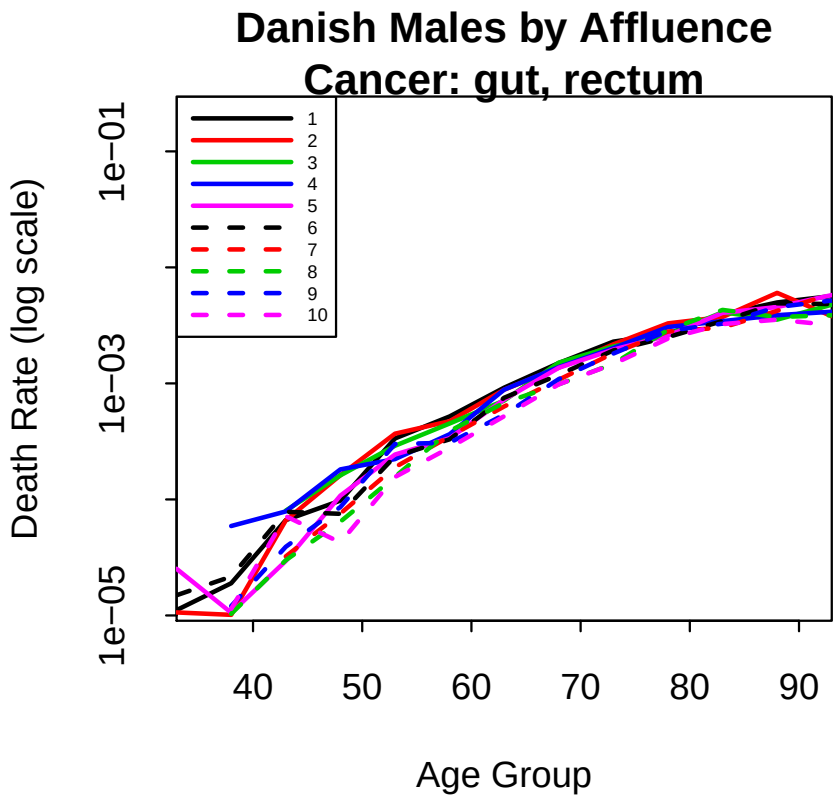

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Denmark: Cause of Death Data – Health Inequalities

- 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
  - Denmark has a universal healthcare system
  - BUT less affluent/educated $\Rightarrow$
    ??? later diagnosis
    ??? engage less well with treatment process
    ??? lower quality housing

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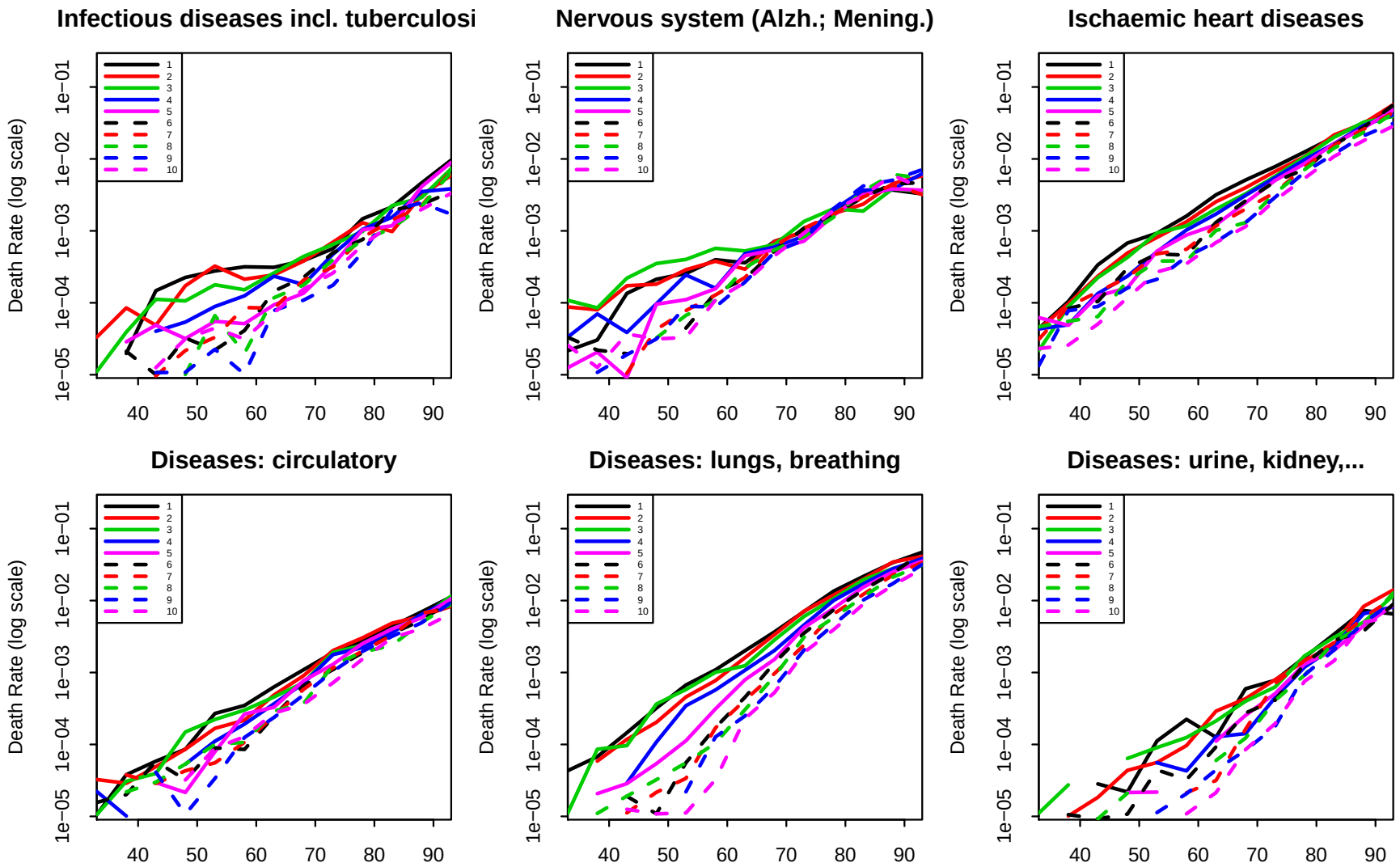
CoD Death Rates: Different Shapes & Patterns



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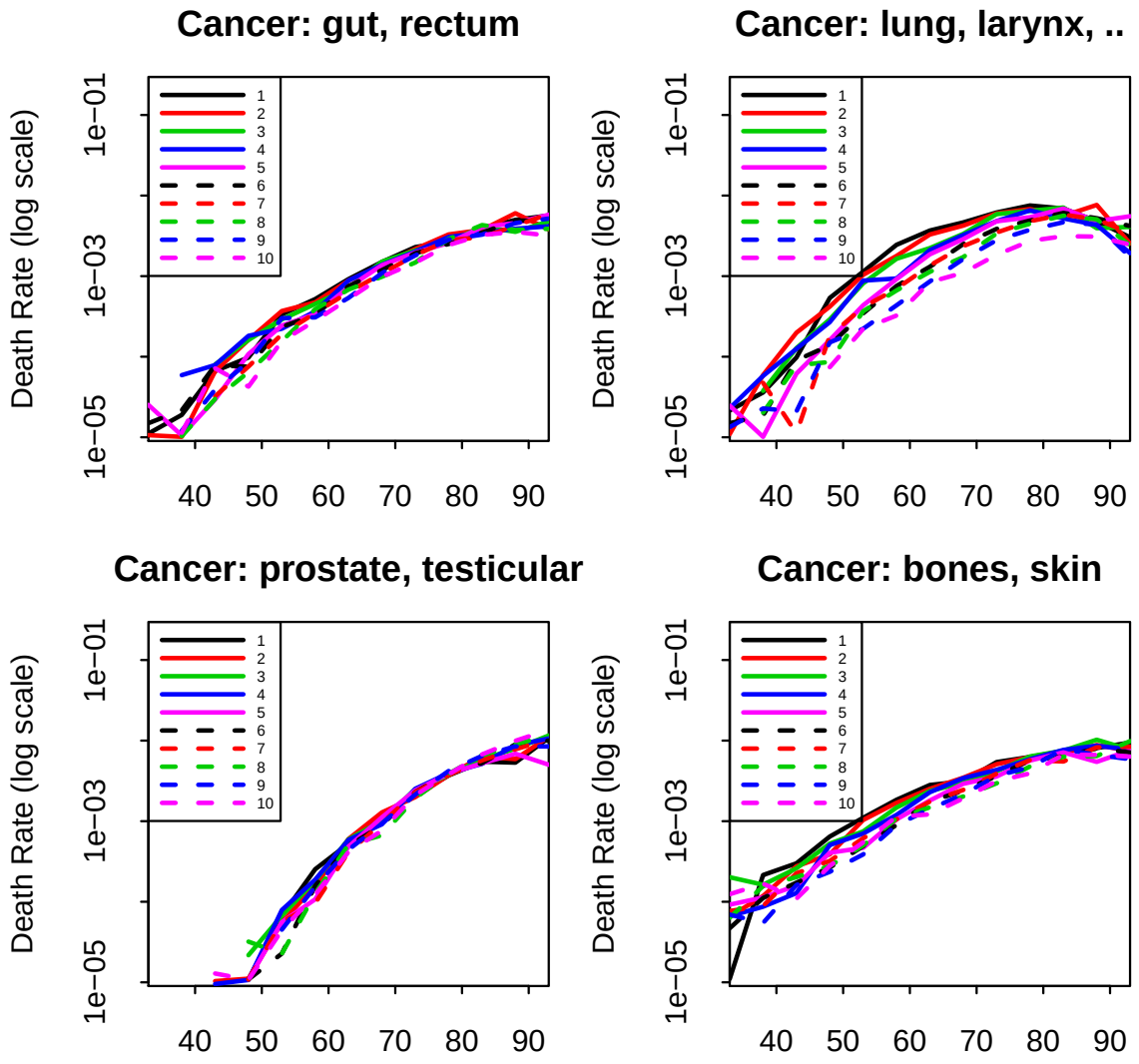
CoD Death Rates: Different Shapes & Patterns



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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?

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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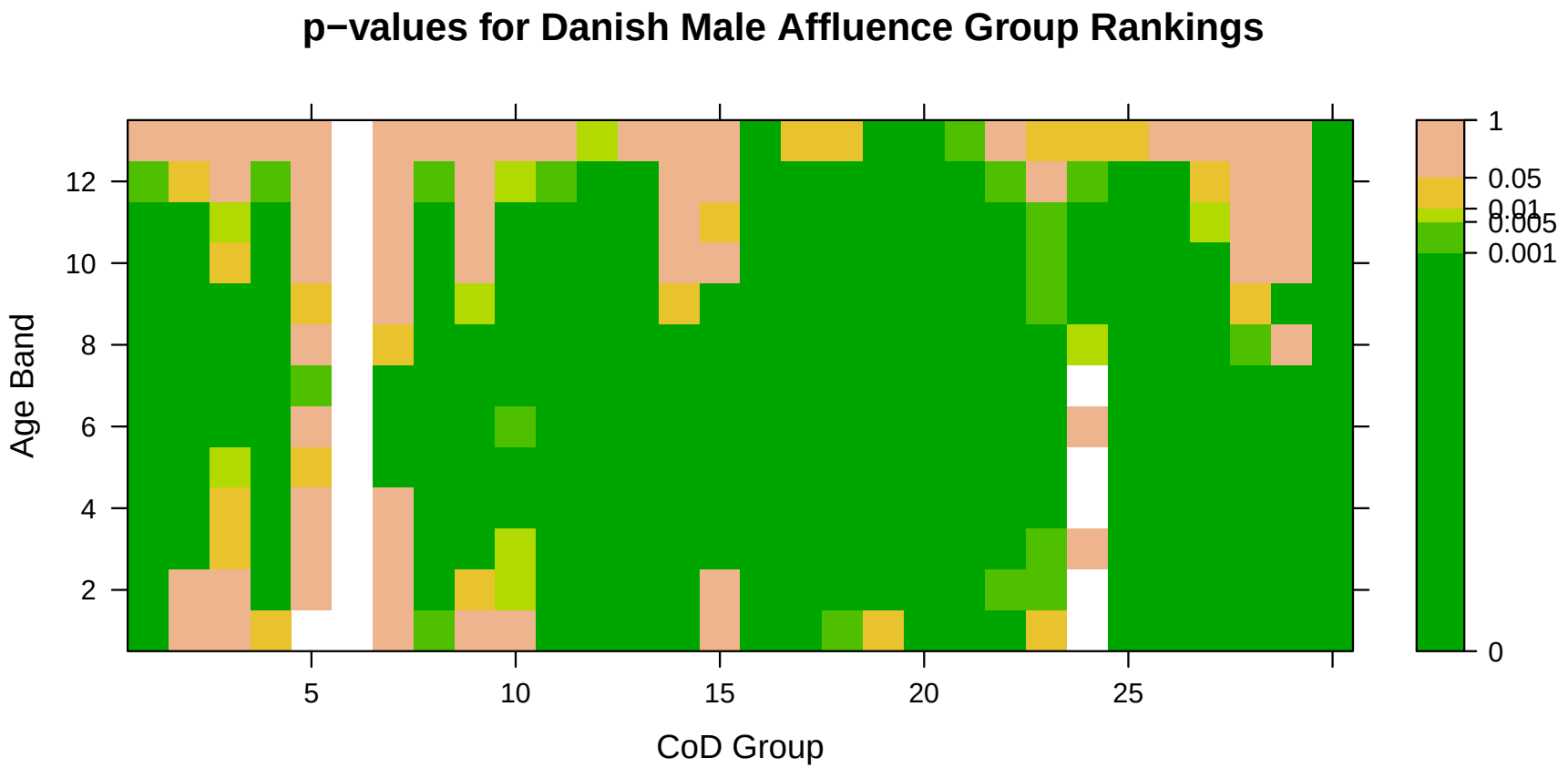
Cause of Death Inequalities: *p*-values



White ⇒ insufficient data

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

High age convergence

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Denmark: Cause of Death Data – Health Inequalities

- Deaths subdivided into 29 CoD groups
- Compare affluence groups
- Biggest differences at younger age groups e.g. 51-55
- Causes of death linked to lifestyle
  $\Rightarrow$ some CoD death rates are up to 20$\times$ higher for low affluence groups
- Growing gaps: liver diseases; diabetes
- *Almost all CoD groups have a strong statistically significant difference*

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Next Steps: Develop Mortality Database

Key point

- Requirement for good quality and appropriate data $\Rightarrow$
  - sub-populations with various socio-economic characteristics
  - sub-populations of different sizes
  - different countries or regions (e.g. Denmark, UK, Canada, US)
- more effective road tests for new (and old) models
- users can have greater confidence in the models they might use

- Resource for other model developers
- How to de-sensitise commercially sensitive data?
- What types of data would be useful?

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Emerging themes $\longrightarrow$ research

E.g.

- Understanding the recent trend change in the UK and Canada and other countries
  - Can we gain some insights into the underlying reasons?
    e.g. socio-economic data
    e.g. cause of death data
  - How do we allow for this in stochastic models?
  - Short term blip or permanent slow down?
- Other emerging themes: role for industry!

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Thank You!

Questions

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W: www.macs.hw.ac.uk/~andrewc/ARCresources