Socio-Economic Differences in Mortality by Cause of Death

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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
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
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 × Income
- Education
- Cause of Death
## Education and Affluence Levels

<table>
<thead>
<tr>
<th>Education</th>
<th>Affluence</th>
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<tbody>
<tr>
<td>Low education</td>
<td>Primary and lower secondary education</td>
</tr>
<tr>
<td>Medium education</td>
<td>Upper secondary education</td>
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<tr>
<td>High education</td>
<td>Tertiary education</td>
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<tr>
<td>Level 1</td>
<td>Low affluence decile</td>
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<tr>
<td>:</td>
<td>:</td>
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<tr>
<td>Level 10</td>
<td>High affluence decile</td>
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</tbody>
</table>
Model-Inferred Underlying Death Rates 2012

Males Crude m(t,x); 2012

Males CBD–X Fitted m(t,x); 2012
Point Estimates
**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 ⇒**
  - 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.
Education as an Alternative Covariate

Age Standardised Mortality Rates per 1000
Ages 45–54; European Standard Population (1976)

- Affluence Group 1
- Low Education
- High Education
- Affluence Group 10
Cause of Death Data – Health Inequalities

- Deaths subdivided into 29 CoD groups
- Age groups 31-35, 36-40, ..., 91-95
- Compare affluence groups
- Compare education groups
<table>
<thead>
<tr>
<th></th>
<th>Cause of Death Data – Health Inequalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Infectious diseases incl. tuberculosis</td>
</tr>
<tr>
<td>2</td>
<td>Cancer: mouth, gullet, stomach</td>
</tr>
<tr>
<td>3</td>
<td>Cancer: gut, rectum</td>
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<tr>
<td>4</td>
<td>Cancer: lung, larynx, ..</td>
</tr>
<tr>
<td>5</td>
<td>Cancer: breast</td>
</tr>
<tr>
<td>6</td>
<td>Cancer: uterus, cervix</td>
</tr>
<tr>
<td>7</td>
<td>Cancer: prostate, testicular</td>
</tr>
<tr>
<td>8</td>
<td>Cancer: bones, skin</td>
</tr>
<tr>
<td>9</td>
<td>Cancer: lymphatic, blood-forming tissue</td>
</tr>
<tr>
<td>10</td>
<td>Benign tumours</td>
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<tr>
<td>11</td>
<td>Diseases: blood</td>
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<tr>
<td>12</td>
<td>Diabetes</td>
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<tr>
<td>13</td>
<td>Mental illness</td>
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<tr>
<td>14</td>
<td>Meningitis + nervous system (Alzh.)</td>
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<tr>
<td>15</td>
<td>Blood pressure + rheumatic fever</td>
</tr>
<tr>
<td>16</td>
<td>Ischaemic heart diseases</td>
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<tr>
<td>17</td>
<td>Other heart diseases</td>
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<tr>
<td>18</td>
<td>Diseases: cerebrovascular</td>
</tr>
<tr>
<td>19</td>
<td>Diseases: circulatory</td>
</tr>
<tr>
<td>20</td>
<td>Diseases: lungs, breathing</td>
</tr>
<tr>
<td>21</td>
<td>Diseases: digestive</td>
</tr>
<tr>
<td>22</td>
<td>Diseases: urine, kidney,...</td>
</tr>
<tr>
<td>23</td>
<td>Diseases: skin, bone, tissue</td>
</tr>
<tr>
<td>24</td>
<td>Senility without mental illness</td>
</tr>
<tr>
<td>25</td>
<td>Road/other accidents</td>
</tr>
<tr>
<td>26</td>
<td>Other causes</td>
</tr>
<tr>
<td>27</td>
<td>Alcohol → liver disease</td>
</tr>
<tr>
<td>28</td>
<td>Suicide</td>
</tr>
<tr>
<td>29</td>
<td>Accidental Poisonings</td>
</tr>
</tbody>
</table>
Compare education with affluence as covariates:

**Danish Males by Education**

**Ischaemic heart diseases**

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Death Rate (log scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>1e−05</td>
</tr>
<tr>
<td>50</td>
<td>1e−03</td>
</tr>
<tr>
<td>60</td>
<td>1e−02</td>
</tr>
<tr>
<td>70</td>
<td>1e−01</td>
</tr>
<tr>
<td>80</td>
<td>1e−00</td>
</tr>
<tr>
<td>90</td>
<td>1e+00</td>
</tr>
</tbody>
</table>

- Low Edu
- Medium
- High

**Danish Males by Affluence**

**Ischaemic heart diseases**

<table>
<thead>
<tr>
<th>Affluence</th>
<th>Death Rate (log scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1e−05</td>
</tr>
<tr>
<td>2</td>
<td>1e−03</td>
</tr>
<tr>
<td>3</td>
<td>1e−01</td>
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<tr>
<td>4</td>
<td>1e+00</td>
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<tr>
<td>5</td>
<td>1e+01</td>
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<tr>
<td>6</td>
<td>1e+02</td>
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<tr>
<td>7</td>
<td>1e+03</td>
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<tr>
<td>8</td>
<td>1e+04</td>
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<tr>
<td>9</td>
<td>1e+05</td>
</tr>
<tr>
<td>10</td>
<td>1e+06</td>
</tr>
</tbody>
</table>

**Affluence ⇒ wider spread**
Affluence ⇒ much wider
Danish Males by Education
Cancer: lung, larynx, ...

Danish Males by Affluence
Cancer: lung, larynx, ...

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Socio-Economic Differences in Mortality by Cause of Death
Low affluence $\Rightarrow$ over 20× at young ages
Many causes of death have known risk factors or drivers
e.g. smoking, diet, healthy lifestyle etc.
⇒ clear socio-economic differences

Biggest differences at ages < 60

Affluence ⇒ stronger predictor than education
(sometimes very much stronger)

Other diseases do not have strong differences:
Denmark: Cause of Death Data 2007

Danish Males by Education
Cancer: prostate, testicular

Danish Males by Affluence
Cancer: prostate, testicular
Denmark: Cause of Death Data 2007

Danish Males by Education
Cancer: lymphatic, blood–forming tissue

Danish Males by Affluence
Cancer: lymphatic, blood–forming tissue

Education \(\Rightarrow\) no effect
Affluence \(\Rightarrow\) small effect
Denmark: Cause of Death Data 2007

Danish Males by Education
Cancer: gut, rectum

Danish Males by Affluence
Cancer: gut, rectum

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Socio-Economic Differences in Mortality by Cause of Death
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 ⇒ inequalities

Possible explanations (a very non-expert view)

- *onset* is not dependent on lifestyle/affluence/education
- BUT less affluent/educated ⇒
  - ??? later diagnosis
  - ??? engage less well with treatment process
  - ??? lower quality housing
CoD Death Rates: Different Shapes & Patterns

Infectious diseases incl. tuberculosis

Meningitis + nervous system (Alzh.)

Ischaemic heart diseases

Diseases: circulatory

Diseases: lungs, breathing

Diseases: urine, kidney,...

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CoD Death Rates: Different Shapes & Patterns

Cancer: gut, rectum

Cancer: lung, larynx, ...

Cancer: prostate, testicular

Cancer: bones, skin
Shapes: Conclusions

- Typically:
  - Non-cancerous diseases $\Rightarrow$ approximately exponential growth
  - Neoplasms (cancers) $\Rightarrow$ subexponential polynomial

- What does this reveal about different disease mechanisms?
Which CoD’s are significantly affected by socio-economic status?

- $H_0$: Affluence groups all have the same CoD death rate $m_i(c, t, x) = m_j(c, t, x) \ \forall i \neq j$

versus

- $H_1$: Affluence groups do not all have the same CoD death rates
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, $t$
$R(i, t) = \text{rank of } m(i, t) \text{ out of } m(1, t), \ldots, m(10, t)$
Rank 1: highest death rate
Rank 10: lowest death rate
Data $(i, R(i, t))$
Test statistic, $S = \text{cor}(i, R(i, t))$
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
Cause of Death Inequalities: \( p \)-values

Very low or zero mortality: CoD 5, 6, 24 & low ages
High age convergence
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)
US Males All Cause Mortality
Ratio of Low to High Education Mortality
Year 1989–2015

Age

Year 1989–2015

US Education Data: Growing Inequality
Recall: Denmark ⇒ very narrow gap
Widening gap
Widening gap
US Education Data

Year 2000
Accidental Poisonings

Year 2015
Accidental Poisonings

Case & Deaton (2015) ⇒ Accidental poisoning
US Education Data

Year 2000
Alcohol -> liver

Year 2015
Alcohol -> liver

Widening gap
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. $> \text{high edu. mort.}$)
- $29 \times 4 = 116$ 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 $< 10^{-6}$
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

Mortality Improvement Rates (%)
Period 1987–2009; Age Band 45–54
By Affluence and Education Group

<table>
<thead>
<tr>
<th>Affluence Group</th>
<th>LOW</th>
<th>MED</th>
<th>HIGH</th>
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