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

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Outline

- Motivation and long term goals
- Data
- Comparison of US, Denmark and England
- US: deeper dive; cohort effects
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?
- Can we point to specific causes of death as responsible for growing inequality?
- Leading to: insight into mortality underpinning life insurance and pensions
Drivers

- Medical advances
- Health spending
- Public health initiatives
- Individual risk factors:
  - Controllable
    - e.g. smoking, diet, exercise, alcohol, sun, drugs, hygiene, risky sex, stress, environment...
    - leading to cohort effects
  - Not (easily) controllable
    - e.g. genetic, affluence, education, character/personality traits, ...
Socio-economic datasets

Cause of death data for:
- US (males and females)
  - by education level: low (≤ high school); high
- Denmark (males only):
  - by education level: low; medium; high
    (cohorts > 1920 only)
  - by individual affluence: 10 deciles
- England (males and females)
  - by small area *income deprivation*: 10 deciles
  - by region: 9 areas
## Cause of Death Groupings

<table>
<thead>
<tr>
<th>US1.1</th>
<th>US 1.2</th>
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</thead>
<tbody>
<tr>
<td><strong>Infectious diseases excl. HIV/AIDS</strong></td>
<td><strong>HIV/AIDS</strong></td>
</tr>
<tr>
<td>1</td>
<td>2</td>
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<tr>
<td>Infectious diseases</td>
<td>Cancer: mouth, gullet, stomach</td>
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<tr>
<td>3</td>
<td>4.1</td>
</tr>
<tr>
<td>Cancer: gut, rectum</td>
<td>Cancer: larynx</td>
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<tr>
<td>4.2</td>
<td>4.3</td>
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<tr>
<td>Cancer: trachea</td>
<td>Cancer: lung, bronchus</td>
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<tr>
<td>5</td>
<td>6.1</td>
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<tr>
<td>Cancer: breast</td>
<td>Cancer: uterus, cervix</td>
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<tr>
<td>6.2</td>
<td>6.3</td>
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<tr>
<td>Cancer: ovary</td>
<td>Cancer: other female genital</td>
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<tr>
<td>7.1</td>
<td>7.2</td>
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<tr>
<td>Cancer: prostate</td>
<td>Cancer: other male genital</td>
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<tr>
<td>8</td>
<td>9</td>
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<tr>
<td>Cancer: skin, bones and certain organs</td>
<td>Cancer: lymphatic</td>
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<tr>
<td>10</td>
<td>11</td>
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<tr>
<td>Benign tumours</td>
<td>Diseases: blood</td>
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<tr>
<td>12</td>
<td>13</td>
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<tr>
<td>Diabetes</td>
<td>Mental illness</td>
</tr>
<tr>
<td>14.1</td>
<td>14.2</td>
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<tr>
<td>Diseases of nervous system excl. Alzh.</td>
<td>Alzheimers</td>
</tr>
<tr>
<td>15</td>
<td>16</td>
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<tr>
<td>Blood pressure + rheumatic fever</td>
<td>Ischaemic heart diseases</td>
</tr>
<tr>
<td>17</td>
<td>18</td>
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<tr>
<td>Other heart diseases</td>
<td>Diseases: cerebrovascular</td>
</tr>
<tr>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td>Diseases: circulatory</td>
<td>Diseases: lungs, breathing</td>
</tr>
<tr>
<td>21</td>
<td>22</td>
</tr>
<tr>
<td>Diseases: digestive (excl. alcohol: 27)</td>
<td>Diseases: urine, kidney, ...</td>
</tr>
<tr>
<td>23</td>
<td>24(DU)</td>
</tr>
<tr>
<td>Diseases: skin, bone, tissue</td>
<td>Senility without mental illness</td>
</tr>
<tr>
<td>25</td>
<td>26</td>
</tr>
<tr>
<td>Road/other accidents</td>
<td>Other causes</td>
</tr>
<tr>
<td>27</td>
<td>28</td>
</tr>
<tr>
<td>Alcohol $\rightarrow$ liver disease</td>
<td>Suicide</td>
</tr>
<tr>
<td>29</td>
<td></td>
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<tr>
<td>Accidental Poisonings</td>
<td></td>
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</tbody>
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Detail $\Rightarrow$ able to separate causes with and without significant risk factors or inequality
Data – Other Details

- **US**
  - Deaths subdivided into 30 CoD groups
  - Single ages 40-89 and *born between 1914 and 1970*
  - Single years 1989-2015

- **Denmark**
  - 29 CoD groups
  - Age groups 31-35, 36-40, ..., 91-95

- **England**
  - 34 CoD groups
  - Age groups 20-24, 25-29, ..., 85-89
  - Single years 2001-2016
Multi-Country: Year 2007, Males, Ischaemic Heart Disease

US By Education 2007
Ischaemic heart diseases

US By Affluence 2007
Ischaemic heart diseases

Denmark By Education 2007
Ischaemic heart diseases

England by Deprivation 2007
Ischaemic heart diseases

US: slightly wider than Denmark
England similar to Denmark but higher

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Cause of Death Mortality
Multi-Country: Age 68, Males, Ischaemic Heart Disease

Significant improvements, but not throughout
Multi-Country: Age 68, Males, Lung Cancer

US by Education, Age 68
Cancer: lung, larynx, ..

Death Rate (log scale)

5e−04 2e−03 1e−02

Denmark by Education, Age 68
Cancer: lung, larynx, ..

Death Rate (log scale)

5e−04 2e−03 1e−02

Denmark by Affluence, Age 68
Cancer: lung, larynx, ..

Death Rate (log scale)

5e−04 2e−03 1e−02

England by Deprivation, Age 68
Cancer: lungs, bronchus

Death Rate (log scale)

5e−04 2e−03 1e−02

Significant inequality; improvements might be driven by smoking prevalence
Multi-Country: Age 68, Females, Lung Cancer

Significant inequality; deterioration driven by smoking prevalence

US By Education 2002
Accidental Poisonings

Denmark By Education 2002
Accidental Poisonings

Denmark By Affluence 2002
Accidental Poisonings

England by Deprivation 2002
Accidental poisonings

US, Denmark: significant

US By Education 2012
Accidental Poisonings

Denmark By Education 2012
Accidental Poisonings

Denmark By Affluence 2012
Accidental Poisonings

England by Deprivation 2012
Accidental poisonings

Growth: England > US > DK

US: evidence of a cohort effect

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US By Education 2002
Alcohol induced liver disease

Death Rate (log scale)

Denmark By Education 2002
Alcohol induced liver disease

Death Rate (log scale)

Denmark By Affluence 2002
Alcohol induced liver disease

Death Rate (log scale)

England by Deprivation 2002
Alcohol related liver disease

Death Rate (log scale)

Affluence a much bigger driver
Deaths of Despair: A Growing Problem?

US By Education 2007
Alcohol induced liver disease

Denmark By Education 2007
Alcohol induced liver disease

Denmark By Affluence 2007
Alcohol induced liver disease

England by Deprivation 2007
Alcohol related liver disease

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Cause of Death Mortality

US By Education 2012
Alcohol induced liver disease

Denmark By Education 2012
Alcohol induced liver disease

Denmark By Affluence 2012
Alcohol induced liver disease

England by Deprivation 2012
Alcohol related liver disease

US: possible cohort effect
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
Multi-Country: Age 68, Males, Prostate Cancer

US by Education, Age 68
Cancer: prostate, testicular

Denmark by Education, Age 68
Cancer: prostate, testicular

Denmark by Affluence, Age 68
Cancer: prostate, testicular

England by Deprivation, Age 68
Cancer: prostate

Death Rate (log scale)

No controllable risk factors; US improvements; DK vs US genetic factors?
Multi-Country: Age 68, Females, Breast Cancer

No controllable risk factors; US inequalities; England equality (?)
Variation in Reporting Practice: e.g. Mental Illness

US By Education 2007
Mental illness

Denmark By Education 2007
Mental illness

Denmark By Affluence 2007
Mental illness

England by Deprivation 2007
Mental illnesses

Alcohol & drug abuse; mental disorders; → vascular dementia
US Males Age 60: Stagnation

Males, Age 60, All Cause Mortality

Females, Age 60, All Cause Mortality

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Cause of Death Mortality
US Drivers of Change 1991-2003, Males Age 60 Low Education: Absolute changes in mortality

Three big gains, many small “losers”
Some continued gains, but several more substantial losers: no single “bad” CoD
US Drivers of Change 1991-2003, Females Age 60
Low Education: Absolute changes in mortality

Much smaller improvements than males
Some cancer progress
US Drivers of Change 1991-2003, Males Age 60
High Education: Absolute changes in mortality

Same three big gains, but many fewer losers

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Cause of Death Mortality
More modest gains, but still no significant losers
US Drivers of Change 1991-2003, Females Age 60
High Education: Absolute changes in mortality

Much smaller improvements than males
Some cancer progress
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.
Identifying Cohort Effects

Modelling approach:
- Model death rates for individual causes of death
- Step 1: estimate age and period effects
  \[ \log m(CoD, t, x) = \sum \text{age effect} \times \text{period effect} \]
- Step 2: estimate CoD-specific cohort effect
  \[ \log m(CoD, t, x) = \sum \text{age effect} \times \text{period effect} + \text{cohort effect} \]
- Cohort effects capture heterogeneity in the underlying population:
  e.g. smoking prevalence
Cohort Effects: Low Educated Males

All causes of death in one plot

Fitted Cohort Effects:
All Causes of Death

Very messy! Different underlying risk factors.
Drivers of Mortality

- Medical advances
- Health spending
- Public health initiatives
- Individual risk factors:
  - Controllable
    - e.g. smoking, diet, exercise, alcohol, sun, drugs, hygiene, risky sex, stress, environment... leading to cohort effects, and socio-economic differences
  - Not (easily) controllable
    - e.g. genetic, affluence, education, character/personality traits, ...
Cohort Effects: Low Educated Males

Specific causes of death

Common risk factor $\Rightarrow$ similar cohort effect
Identifying Cohort Effects

Low-Educated Females
Cohort Effects: Smoking

High-Educated Females
Cohort Effects: Smoking

1960 peak consistent with known smoking prevalence for females by cohort
Note: age-period effects can absorb steady trends in prevalence
Summary

- Work in progress!
- Cause of death data can provide insight into all cause mortality
  - time trends
  - inequality between groups
  - growing inequality
- US, England, Denmark
  - Many similarities
  - Some differences
  - No controllable risk factors $\Rightarrow$ Wider US inequality gap: accessible healthcare
- 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
Thank You!

Questions?

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