Coherent mortality projections for the Netherlands taking into account mortality delay and smoking

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Mortality forecasts often extrapolation of past trends in age-specific mortality (e.g. Lee-Carter)

<table>
<thead>
<tr>
<th>Country</th>
<th>Type of method</th>
<th>Historical period</th>
<th>Forecasted period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>Direct extrapolation</td>
<td>1970-2008</td>
<td>2010-2050</td>
</tr>
<tr>
<td>Belgium</td>
<td>Direct extrapolation</td>
<td>1970-2007</td>
<td>1990-2060</td>
</tr>
<tr>
<td>Denmark</td>
<td>Lee-Carter</td>
<td>1990-2009</td>
<td>2010-2100</td>
</tr>
<tr>
<td>Italy</td>
<td>Lee-Carter</td>
<td>Unknown</td>
<td>2001-2051</td>
</tr>
<tr>
<td>Ireland</td>
<td>Target value, Expert opinion</td>
<td>1926-2005</td>
<td>2011-2041</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>Target value</td>
<td>1962-2005</td>
<td>2005-2055</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Cause of death, Direct extrapolation, Lee-Carter, Expert opinion</td>
<td>1970-2009</td>
<td>2010-2060</td>
</tr>
<tr>
<td>Norway</td>
<td>Lee-Carter</td>
<td>1900-2008</td>
<td>2010-2060</td>
</tr>
<tr>
<td>Poland</td>
<td>Target value</td>
<td>1950-2005</td>
<td>2008-2035</td>
</tr>
<tr>
<td>Spain</td>
<td>Direct extrapolation</td>
<td>1991-2007</td>
<td>2009-2049</td>
</tr>
<tr>
<td>Sweden</td>
<td>Lee-Carter</td>
<td>1990-2002</td>
<td>2003-2050</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>Target value, Expert opinion</td>
<td>1900-2008</td>
<td>2008-2083</td>
</tr>
</tbody>
</table>

Stoeldraijer et al 2013
Shortcomings current mortality forecasts

› Not robust

› Highly dependent on historical period

› Unrealistically large future differences between countries
Past mortality forecasts have repeatedly proven too pessimistic

Fig. 1. Record female life expectancy from 1840 to the present [suppl. table 2 (?)]. The linear-regression trend is depicted by a bold black line (slope = 0.243) and the extrapolated trend by a dashed gray line. The horizontal black lines show asserted ceilings on life expectancy, with a short vertical line indicating the year of publication (suppl. table 1). The dashed red lines denote projections of female life expectancy in Japan published by the United Nations in 1986, 1999, and 2001 (?): It is encouraging that the U.N. altered its projection so radically between 1999 and 2001.
E0 1950-2011 NL

Life expectancy at birth

Years


Women

Men

Highly dependent on historical period

Source data: Statistics Netherlands 2013
Unrealistically large future differences between countries

Eo 1950-2011 NL + other countries - women

Source: Statistics Netherlands  West European countries  The Netherlands  Spain

Stoeldraijer, van Duin and Janssen (2013)
LC forecast NL

› 2040
› 1970-2006

› $M_{e_0}$ 81.89
› $F_{e_0}$ 86.50
› Sex difference > 4.5 years
› Current sex difference => appr. 3.5 years

Janssen et al. 2013
In reaction to these shortcomings:

› Extensions to the Lee-Carter methodology (e.g. Lee 2004, Renshaw & Haberman 2006)

› Other models that include cohort as well (Cairns et al. 2011a, Reither et al. 2011)

› Approaches to detect and deal with structural change (e.g. Booth et al. 2002, Coelho & Nunes 2011, van Berkum et al. 2014)

› Coherent forecasts (e.g. Li & Lee, 2005; Cairns et al. 2011b; Antonio et al. 2015)
Recent mortality research

- Large impact of smoking

- Age at death distribution => mortality compression & mortality delay
Important role of smoking – past trends

› Within Europe, smoking most important determinant of mortality levels, trends and differences

› Non-linear pattern (does not fit LC approach); cohort dimension

› Highly predictable because of time lag between smoking behaviour and smoking-related mortality

› Example NL
Smoking: non-linear trends, lag time

Descriptive model smoking epidemic

Lopez et al. (1994)
Total life expectancy and life expectancy without smoking, the Netherlands

Stoeldraijer, van Duin and Janssen (2013)
Important role of smoking – future trends


› For NL, the added value of dealing with smoking in mortality projections has been demonstrated recently (Janssen et al. 2013) => nonlinearity, convergence btwn the sexes
Figure 1  Observed and projected life expectancy at birth for the projection of all-cause mortality vs the separate projection of non-smoking-related and smoking-related mortality, by sex, the Netherlands, 1970-2040

<table>
<thead>
<tr>
<th>Life expectancy at birth</th>
</tr>
</thead>
<tbody>
<tr>
<td>F_observed_allcause</td>
</tr>
<tr>
<td>F_allcause_indiv</td>
</tr>
<tr>
<td>F_ns+smoke_indiv</td>
</tr>
<tr>
<td>M_observed_allcause</td>
</tr>
<tr>
<td>M_allcause_indiv</td>
</tr>
<tr>
<td>M_ns+smoke_indiv</td>
</tr>
</tbody>
</table>

Janssen et al. 2013
Remaining life expectancy at age 80

- F_observed_allcause
- F_allcause_indiv
- F_ns+smoke_indiv
- M_observed_allcause
- M_allcause_indiv
- M_ns+smoke_indiv

Janssen et al. 2013
Recommendation

› Identify the most stable long-term mortality trend on which the projection should be based
  ⇒ Exclude the effects of important determinants with irregular trends, and predict them separately
  ⇒ Include the mortality experience of other – similar – countries and the opposite sex

› Is now used by Statistics Netherlands in their official forecast (Stoeldraijer et al. 2013)

Recent mortality research

› Large impact of smoking

› Age at death distribution => mortality compression & mortality delay
Changes in age at death distribution

Compression of mortality scenario (Fries 1980)
- Rectangularization
- Declining variability in the age of dying

Shifting mortality regime / mortality delay (e.g. Vaupel 2010)
- Increase in modal age at dying
- No changes in shape
Importance of delay vs compression

› Delay: a limit to life exp is unlikely for the near future

› Past trends:
  • Over time: delay increases in importance
  • Delay more important than compression
Contribution of delay and compression to change in $e_0$

1950-2009, 24 European countries + JP + USA

Janssen & de Beer (in preparation) Changes in the contribution of mortality delay versus compression before and after the mode to the recent increase in life expectancy
Importance of delay vs compression

› Delay: a limit to life exp is unlikely for the near future

› Past trends:
  • Over time: delay increases in importance
  • Delay more important than compression

› In some countries trends in modal age at dying run parallel to trends in e0
Japanese women – M increases parallel with eo

Source data: Human Mortality Database www.mortality.org
Importance of delay vs compression

› Delay: a limit to life exp is unlikely for the near future

› Past trends:
  • Over time: delay increases in importance
  • Delay more important than compression

› In some countries trends in modal age at dying run parallel to trends in $e_0$

› Mortality projections including age-at-death distribution (Bongaarts 2005; Terblanche 2015) are still scarce (only M, only single populations, do not take into account smoking)
Objective

› To estimate future life expectancy for the Netherlands by *simultaneously* taking into account:
  • the effect of smoking
  • the mortality experience of the opposite sex and in other countries
  • developments in mortality delay and compression
Schematically

Gradual mortality decline  Deviations / variations

› Medical improvements; socio-economic developments  › Smoking

Predict separately

Wider geographical context  Use of epidemiologic evidence

Delay of ageing
Data & methods

› NL; 1950-2012; 40+
› All-cause mortality and population numbers by sex and single year of age (Statistics Netherlands)
› Applying a mortality model which distinguishes delay and compression to mortality of the total population, mortality of non-smokers, and mortality of smokers
› Simplified CoDe mortality model (de Beer & Janssen, submitted)
› Calculation of mortality of nonsmokers (nsm), smokers (smm) =>
  • Smoking-attributable mortality (SAMF)(single year)
  • qnsm <- qall*(1-SAMF) ; qsmm <- qnsm*RR1
  • Adjusted indirect Peto & Lopez method (Peto et al. 1992; Janssen et al. 2013)
  • Lung-cancer deaths by sex and five-year age groups (WHOSIS)
Projections

Individual
› Projections using the parameters of the CoDe mortality model for non-smokers for NL up to 2050 (only delay; delay & compression)
› Combine with projection smoking-attributable mortality fractions
› Comparison with Lee-Carter

Coherent
› Trend delay non-smoking France women
› Comparison with individual forecast

Up to 2050
1950-2012; 1980-2012
Simplified CoDe mortality model, 40+

Modelling $q(x)$ with minimum number of interpretable parameters

$$q(x) = a + I(x \leq x_1) \left( \frac{b_1 e^{b_1(x-M)}}{1 + \frac{b_1}{g} e^{b_1(x-M)}} \right) + I(x_1 < x \leq x_2) \left( \frac{b_2 e^{b_2(x-M)}}{1 + \frac{b_2}{g} e^{b_2(x-M)}} + c_1 \right)$$

$$+ I(x > x_2) \left( \frac{b_3 e^{b_3(x-M)}}{1 + \frac{b_3}{g} e^{b_3(x-M)}} + c_2 \right)$$

background + adult age + middle age + old age

$x_2 = M; x_1 = M - h$

g (0.7) and $h$ (30) time invariant

five interpretable time-varying parameters: $a, b_1, b_2, b_3, M$

See: Janssen & de Beer (2016)
Effects of the parameters of the model

Increase in $M$ that corresponds with a 5 yrs increase in $e_{40}$

Increase in $b_1$ and $b_2$, and decrease in $b_3$ that all three correspond with a 0.5 yrs increase in $e_{40}$

Janssen & de Beer (2016)
Results
Age at death distributions

Janssen & de Beer (2016)
Model age of death

Janssen & de Beer (2016)
Additional parameters

Janssen & de Beer (2016)
## e40 2050, the Netherlands

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>men</td>
<td>women</td>
</tr>
<tr>
<td><strong>nonsmokers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(e40 2012 = 42.76 (M), 45.15 (F))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>extrapolation M; rest similar to 2012 ns</td>
<td>46.80</td>
<td>50.51</td>
</tr>
<tr>
<td>extrapolation a, b1, b2, b3, M</td>
<td>46.47</td>
<td>50.58</td>
</tr>
<tr>
<td>LC 40-100</td>
<td>45.94</td>
<td>49.23</td>
</tr>
</tbody>
</table>

**SAM** = smoking-attributable mortality

**APC** = age-period-cohort analyses

1950-2012

1980-2012

Janssen & de Beer (2016)
Difference with Lee-Carter

Age at death distribution 2050, NLM, nonsmokers, 1980-2012

Janssen & de Beer (2016)
# e40 2050, the Netherlands

<table>
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<tr>
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<tbody>
<tr>
<td></td>
<td>men</td>
<td>women</td>
<td>men</td>
<td>women</td>
</tr>
<tr>
<td><strong>nonsmokers</strong> (e40 2012 = 42.76 (M), 45.15 (F))</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>extrapolation M; rest similar to 2012 ns</td>
<td>46.80</td>
<td>50.51</td>
<td>46.37</td>
<td>49.62</td>
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<tr>
<td>extrapolation a, b1, b2, b3, M</td>
<td>46.47</td>
<td>50.58</td>
<td>46.00</td>
<td>50.02</td>
</tr>
<tr>
<td>LC 40-100</td>
<td>45.94</td>
<td>49.23</td>
<td>45.07</td>
<td>48.68</td>
</tr>
<tr>
<td><strong>total</strong> (e40 2012 = 40.22 (M), 43.57 (F))</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>extrapolation nonsmokers (M) + SAM (APC)</td>
<td>45.63</td>
<td>48.79</td>
<td>45.20</td>
<td>47.92</td>
</tr>
<tr>
<td>extrapolation nonsmokers (all parameters) + SAM (APC)</td>
<td>45.21</td>
<td>48.94</td>
<td>44.87</td>
<td>48.51</td>
</tr>
<tr>
<td>LC 40-100</td>
<td>42.69</td>
<td>47.54</td>
<td>44.89</td>
<td>46.39</td>
</tr>
</tbody>
</table>

SAM = smoking-attributable mortality  
APC = age-period-cohort analyses

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Janssen & de Beer (2016)  
For age-period-cohort projection of smoking-attributable mortality see Stoeldraijer et al (2014)
e40 2050, the Netherlands, coherent forecast

› Use of development M nsm among France women
› 1.9 years per decade (M)(equal for 1950-2009, 1980-2009, equal for M & F)
Modal age at death - Dutch and French women

preliminary results
e40 2050, the Netherlands, coherent forecast

› Use of development M nsm among France women
› 1.9 years per decade (M) (equal for 1950-2009, 1980-2009, equal for M & F)
› In comparison to e40 2050 for individual forecasts
  M 1950-2012 +3.0; M 1980-2012 +3.4
  F 1950-2012 +1.5; F 1980-2012 +2.4
› In comparison to Statistics Netherlands
  M +0.8; F +1.1; +1.5

preliminary results
Summary of results

› For non-smokers and smokers, mortality delay is more linear than for the total population, and more similar for M and W

› Extrapolation of mortality delay (and compression) => higher e40 compared to LC, more delay, and more deaths at higher ages

› Extrapolation of compression parameters resulted in slightly lower e40 for men, and a slightly higher e40 for women

› Adding projection of SAM => highest difference for women (all-nsm); Separate projection for men 1950-2012 highest effect.

› Using the development of M among French female nonsmokers resulted in another strong increase in projected e40, esp. among men
Conclusion

Projection by means of the modal age at death should – for NL – take into account smoking

Our coherent projection including smoking and delay led to higher e40 in 2050, and more deaths at higher ages compared to LC and SN

LC seems not able to fully capture the (continued) delay
Future plan

Novel mortality projection technique for Europe: trends in lifestyle-related mortality trends (smoking + obesity + alcohol) + trends in the age-at-death distribution + trends in other countries

Research grant Netherlands Organisation for Scientific Research (NWO) (grant no. 452-13-001)
Schematically

Gradual mortality decline  Deviations / variations

> Medical improvements; socio-economic developments  > **Lifestyle ‘epidemics’**

Predict separately

Wider geographical context

Delay of ageing

Use of epidemiologic evidence
Thank you for your attention!

www.futuremortality.com
References (1)

- Janssen, F. & J. de Beer (in preparation) Changes in the contribution of mortality delay versus compression before and after the mode to the recent increase in life expectancy
References (2)


Parameters of the CoDe model (for ages 40+)

<table>
<thead>
<tr>
<th></th>
<th>total population</th>
<th>nonsmokers</th>
<th>smokers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a</td>
<td>-0.0017</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>b1</td>
<td>0.0755</td>
<td>0.1103</td>
<td>0.1029</td>
</tr>
<tr>
<td>b2</td>
<td>0.1177</td>
<td>0.0948</td>
<td>0.1277</td>
</tr>
<tr>
<td>b3</td>
<td>0.1193</td>
<td>0.0880</td>
<td>0.1341</td>
</tr>
<tr>
<td>M</td>
<td>79.9984</td>
<td>77.5729</td>
<td>85.0469</td>
</tr>
<tr>
<td>Women</td>
<td></td>
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</tr>
<tr>
<td>a</td>
<td>0.0007</td>
<td>0.0002</td>
<td>-0.0003</td>
</tr>
<tr>
<td>b1</td>
<td>0.1133</td>
<td>0.1020</td>
<td>0.0916</td>
</tr>
<tr>
<td>b2</td>
<td>0.1211</td>
<td>0.1305</td>
<td>0.1535</td>
</tr>
<tr>
<td>b3</td>
<td>0.1150</td>
<td>0.1168</td>
<td>0.1548</td>
</tr>
<tr>
<td>M</td>
<td>80.3754</td>
<td>85.5382</td>
<td>89.0655</td>
</tr>
</tbody>
</table>
Past smoking intensities (40+)
Smoking-attributable mortality fractions, NL, past and future

Stoeldraijer et al. (2014)