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

Fanny Janssen[1,2] & Joop de Beer[2]

[1] Population Research Centre, University of Groningen

[2] Netherlands Interdisciplinary Demographic Institute (NIDI), The Hague

Research project "Smoking, alcohol and obesity - ingredients for improved and robust mortality projections" funded by Netherlands Organisation for Scientific Research (NWO)(grant no. 452-13-001)

university of groningen

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

Country	Type of method	Historical period	Forecasted period
Austria	Direct extrapolation	1970-2008	2010-2050
Belgium	Direct extrapolation	1970-2007	1990-2060
Denmark	Lee-Carter	1990-2009	2010-2100
France	Direct extrapolation, Expert opinion	1988-2002	2007-2060
Italy	Lee-Carter	Unknown	2001-2051
Ireland	Target value, Expert opinion	1926-2005	2011-2041
Luxembourg	Target value	1962-2005	2005-2055
Netherlands	Cause of death, Direct extrapolation, Lee-Carter, Expert opinion	1970-2009	2010-2060
Norway	Lee-Carter	1900-2008	2010-2060
Poland	Target value	1950-2005	2008-2035
Portugal	Lee-Carter, Expert opinion	1980-2007	2008-2060
Spain	Direct extrapolation	1991-2007	2009-2049
Sweden	Lee-Carter	1990-2002	2003-2050
United Kingdom	Target value, Expert opinion	1900-2008	2008-2083

Stoeldraijer et al 2013

Shortcomings current mortality forecasts

- Not robust
- Highly dependent on historical period
- Unrealistically large future differences btwn countries

university of

Past mortality forecasts have repeatedly proven too pessimistic

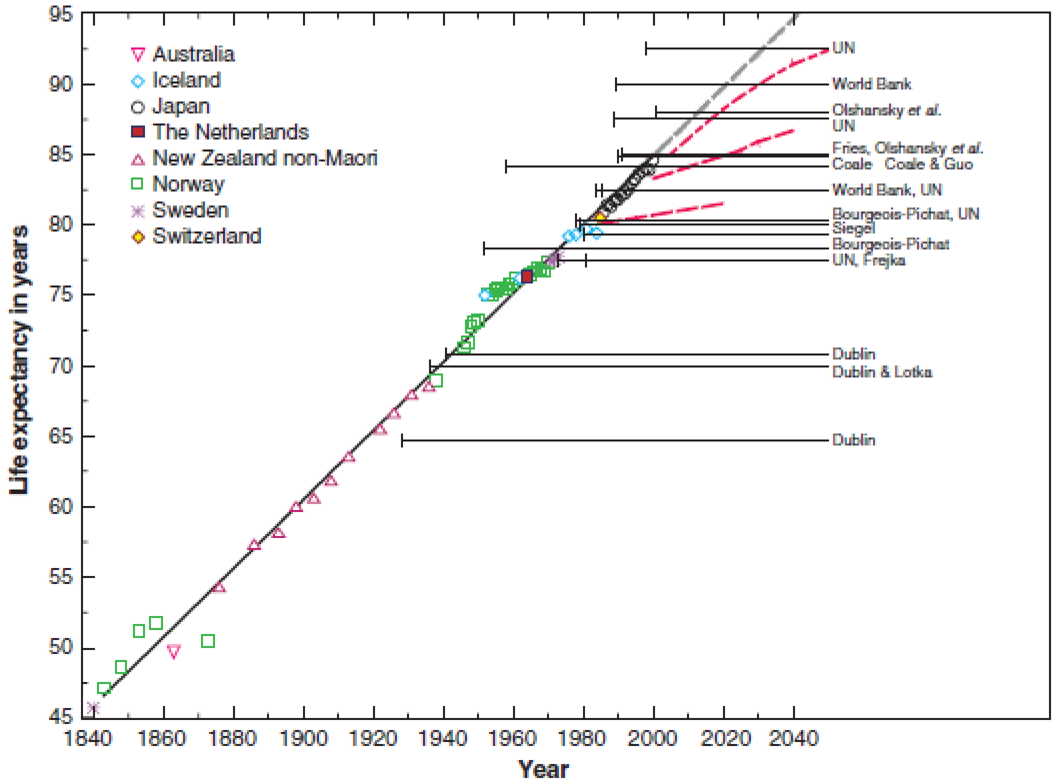


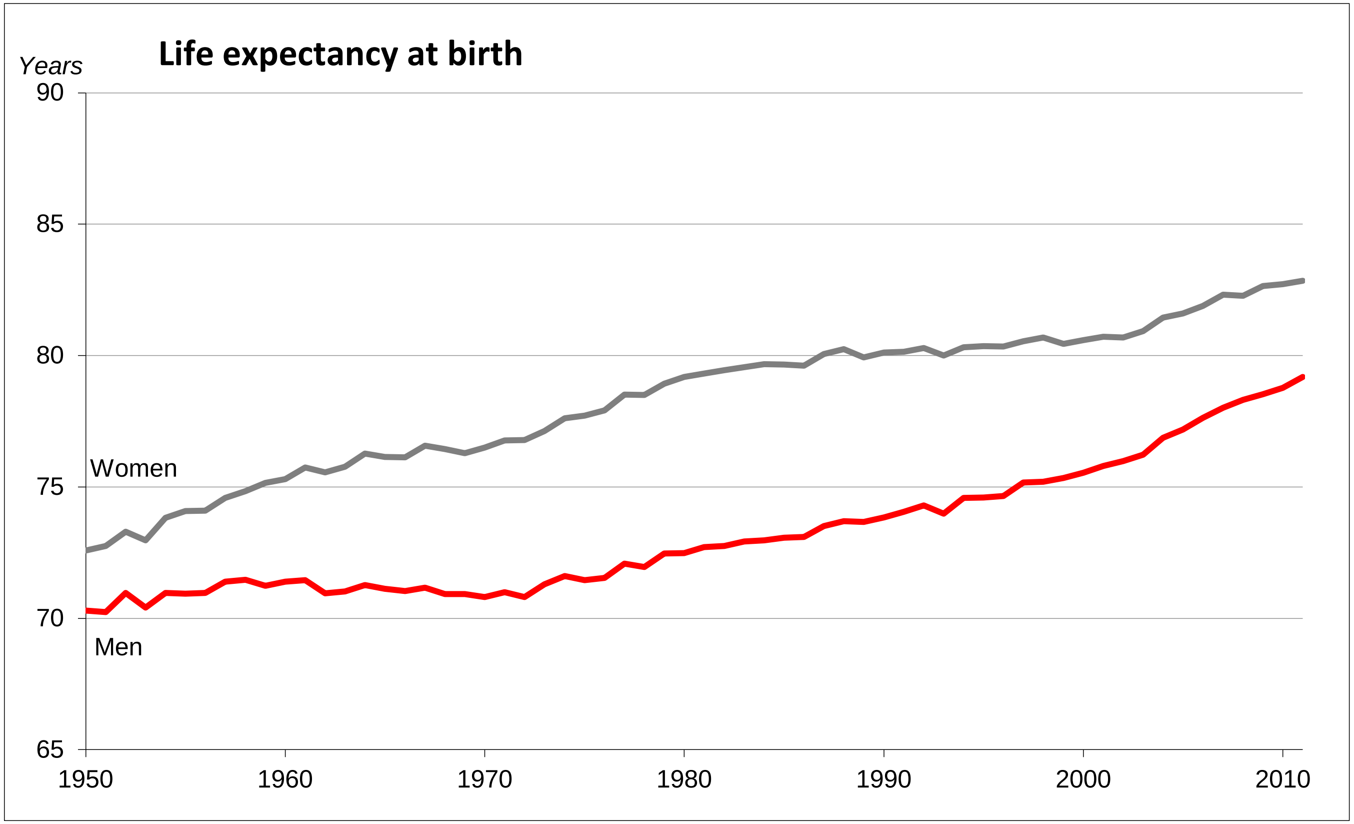
Fig. 1. Record female life expectancy from 1840 to the present [suppl. table 2 (1)]. The linear-regression trend is depicted by a bold black line (slope = 0.243) and the extrapolated trend by a dashed gray line. The horizontal black lines show asserted ceilings on life expectancy, with a short vertical 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 (1): It is encouraging that the U.N. altered its projection so radically between 1999 and 2001.

Oeppen and Vaupel (2002)

university of

Highly dependent on historical period

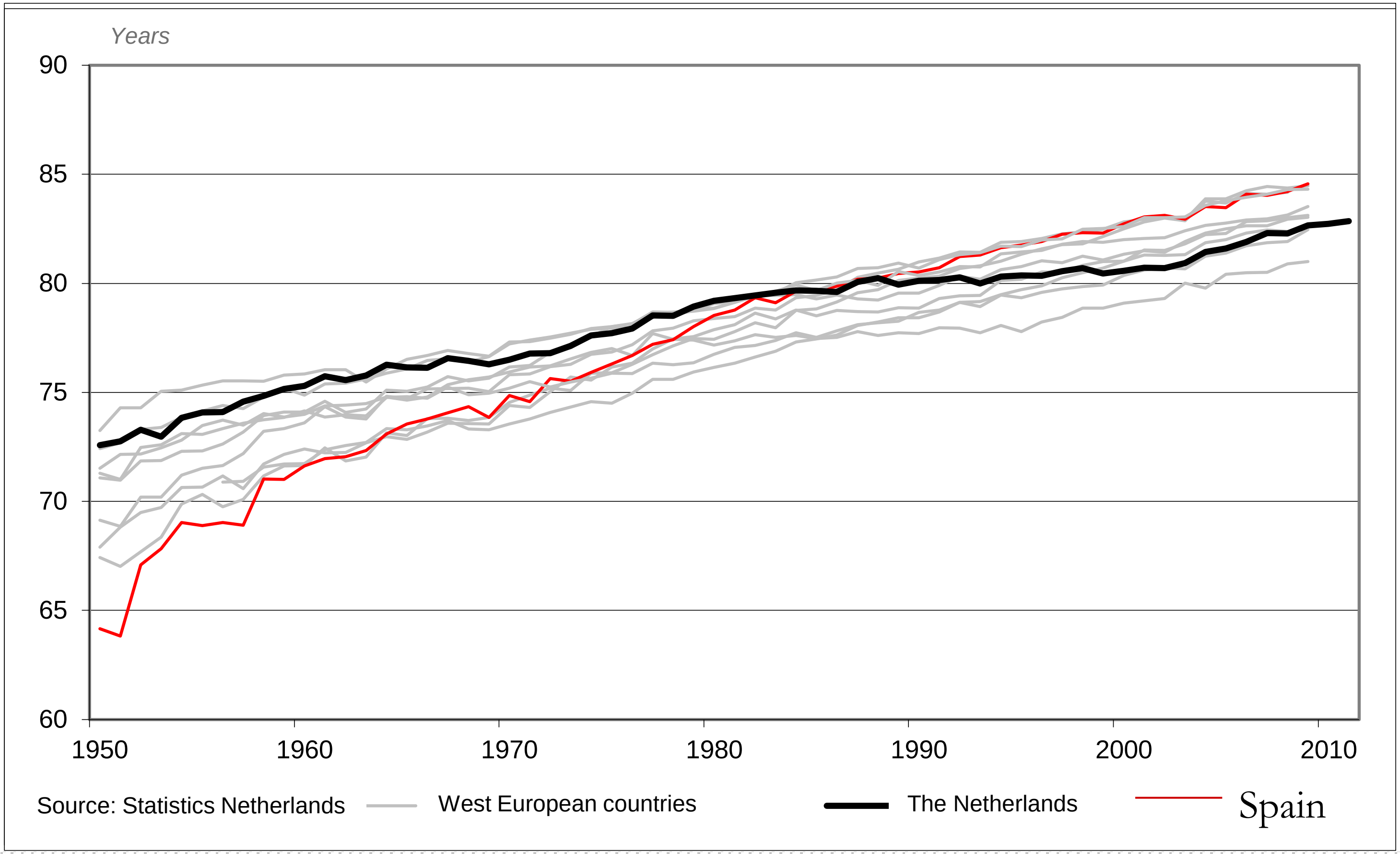
E0 1950-2011 NL



Source data: Statistics Netherlands 2013

Unrealistically large future differences between countries

E0 1950-2011 NL + other countries - women



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

university of groningen

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

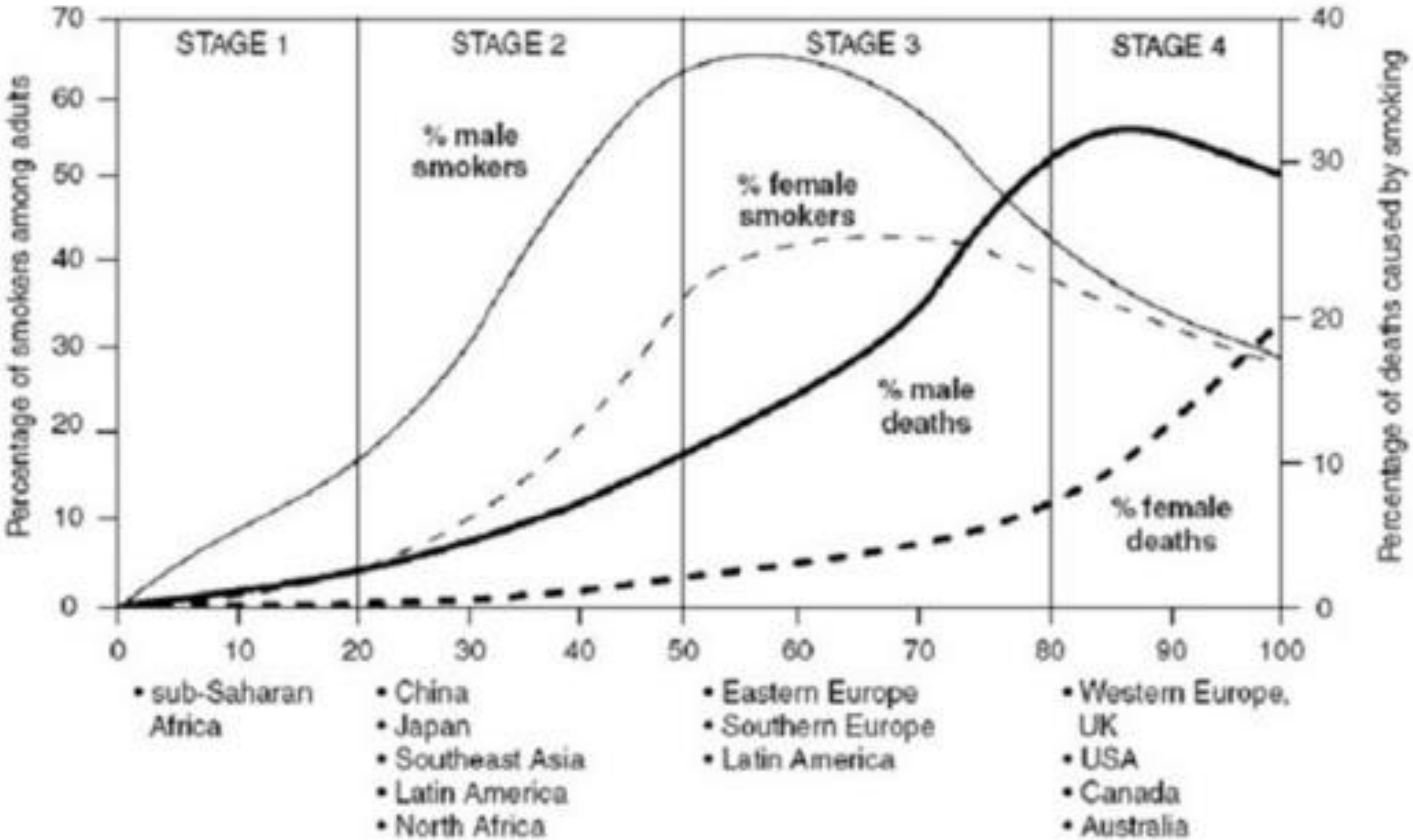
- Large impact of smoking
- Age at death distribution => mortality compression & mortality delay

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

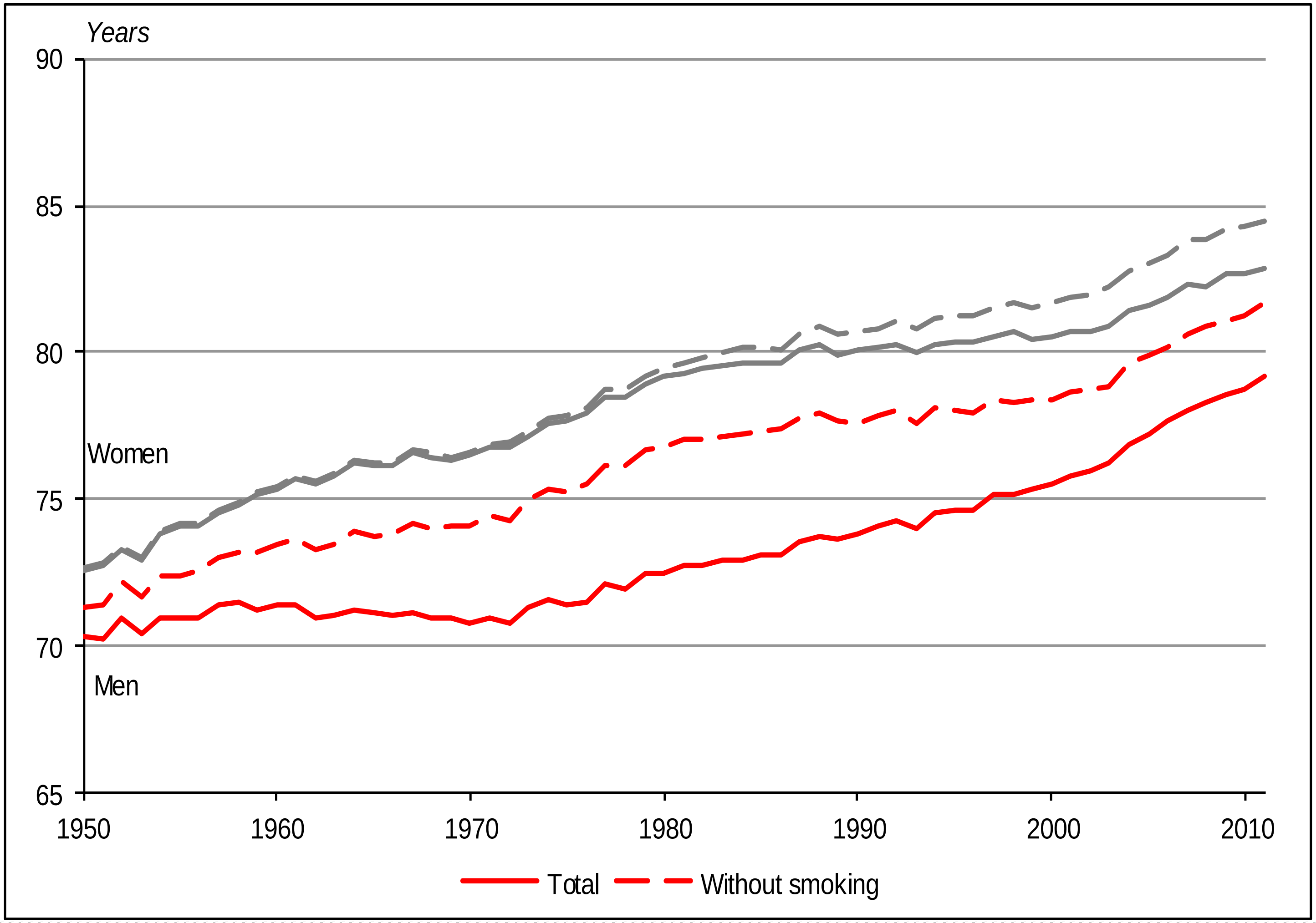
Descriptive model smoking epidemic



Lopez et al. (1994)

university of groningen

Total life expectancy and life expectancy without smoking, the Netherlands



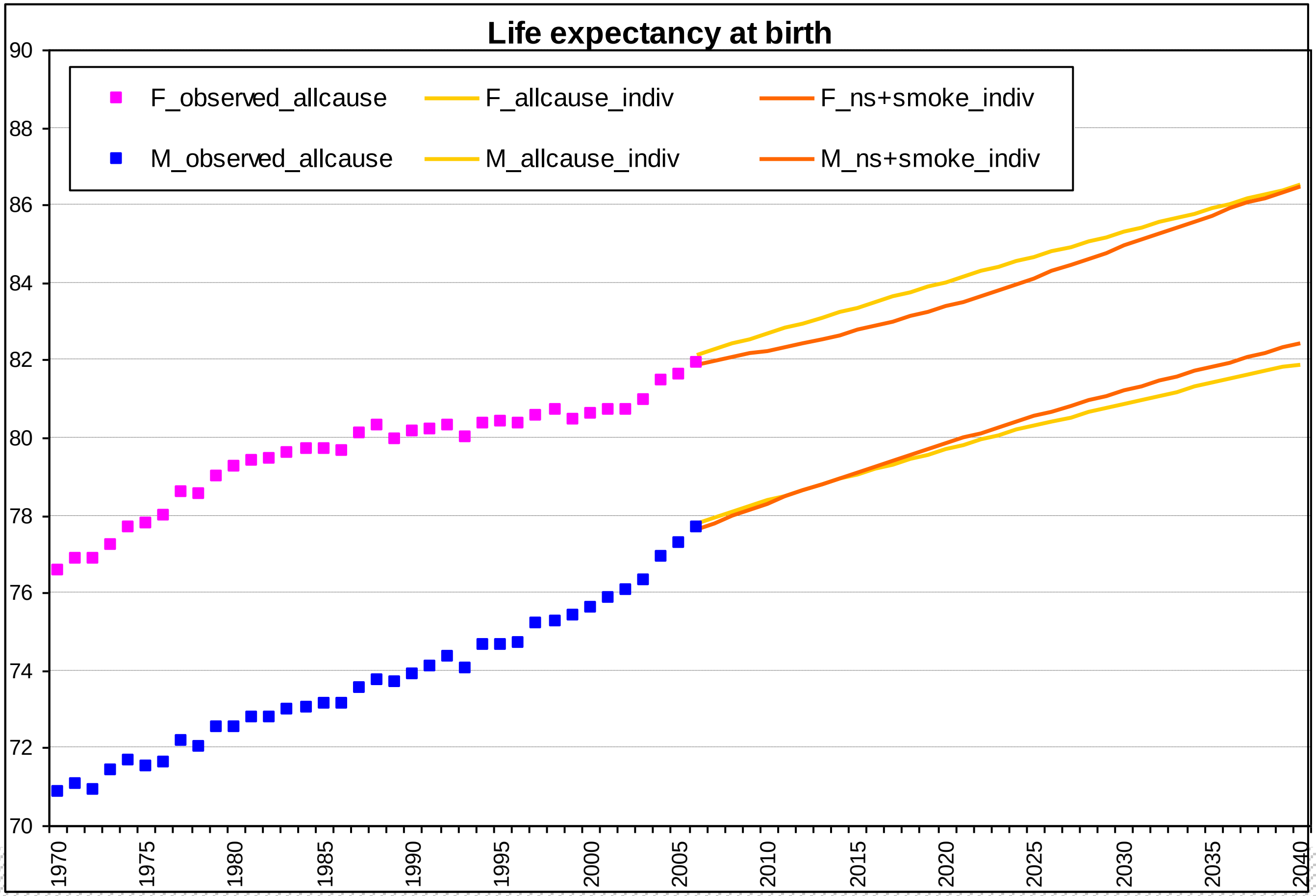
Stoeldraijer, van Duin and Janssen (2013)

Important role of smoking – future trends

- Increased interest in the potential of including smoking in mortality forecasting (Pampel 2005, Bongaarts 2006, Wang & Preston 2009, King & Soneij 2011, Preston et al. 2012) – mainly USA; micro
- 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

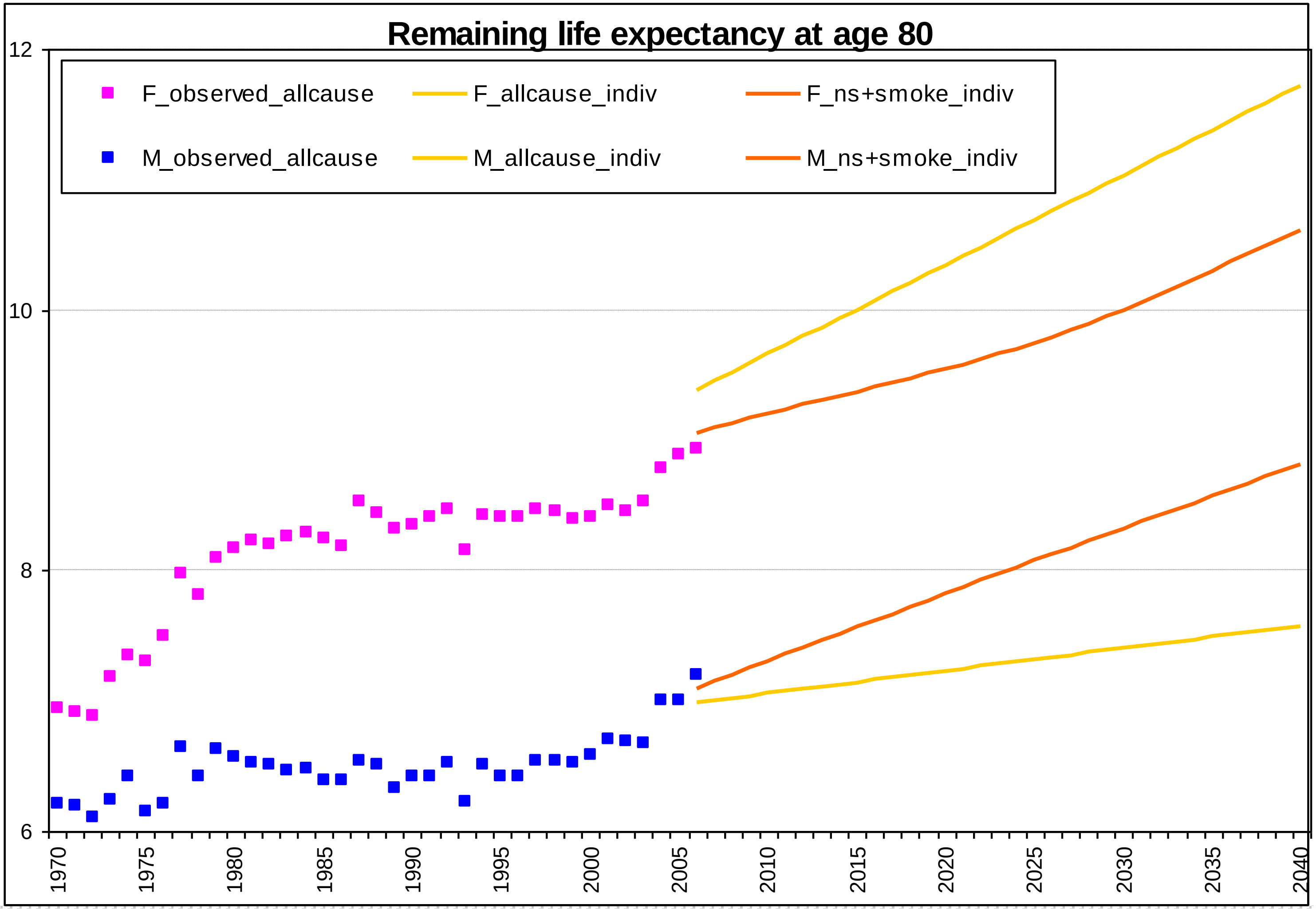
university of groningen

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



Janssen et al. 2013

university of groningen



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)

See: Janssen et al. 2013, Including the smoking epidemic in internationally coherent mortality projections. *Demography* 50(4), 1341-1362.

Recent mortality research

- Large impact of smoking
- Age at death distribution => mortality compression & mortality delay

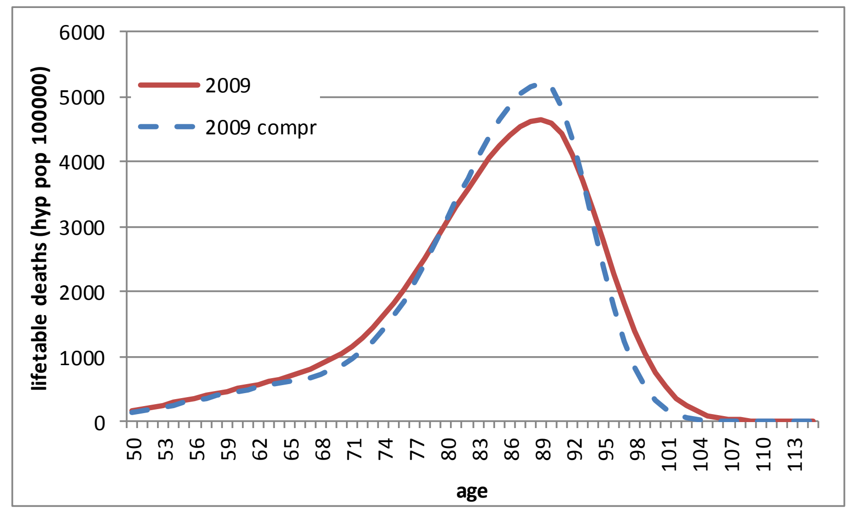
university of groningen

Changes in age at death distribution

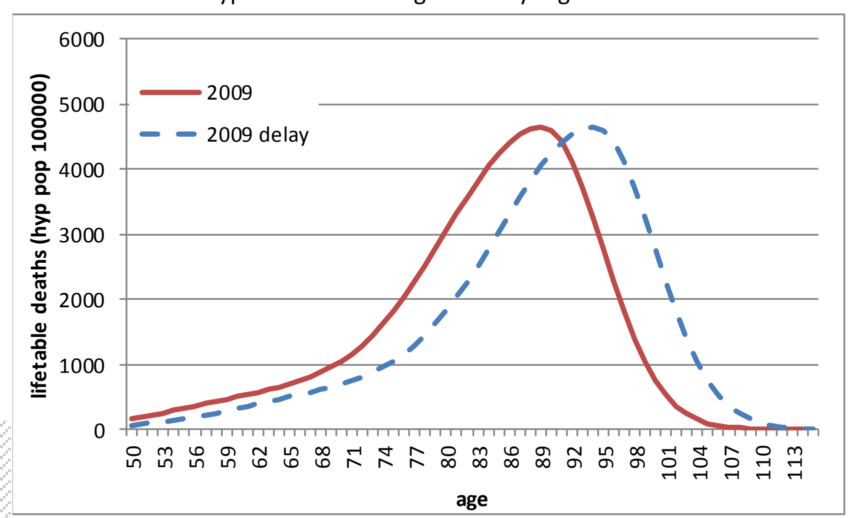
Compression of mortality scenario (Fries 1980)

- Rectangularization
- declining variability in the age of dying

NLF 2009 & hypothetical compression of mortality scenario



NLF 2009 & hypothetical shifting mortality regime



Shifting mortality regime / **mortality delay** (e.g. Vaupel 2010)

- Increase in modal age at dying
- No changes in shape

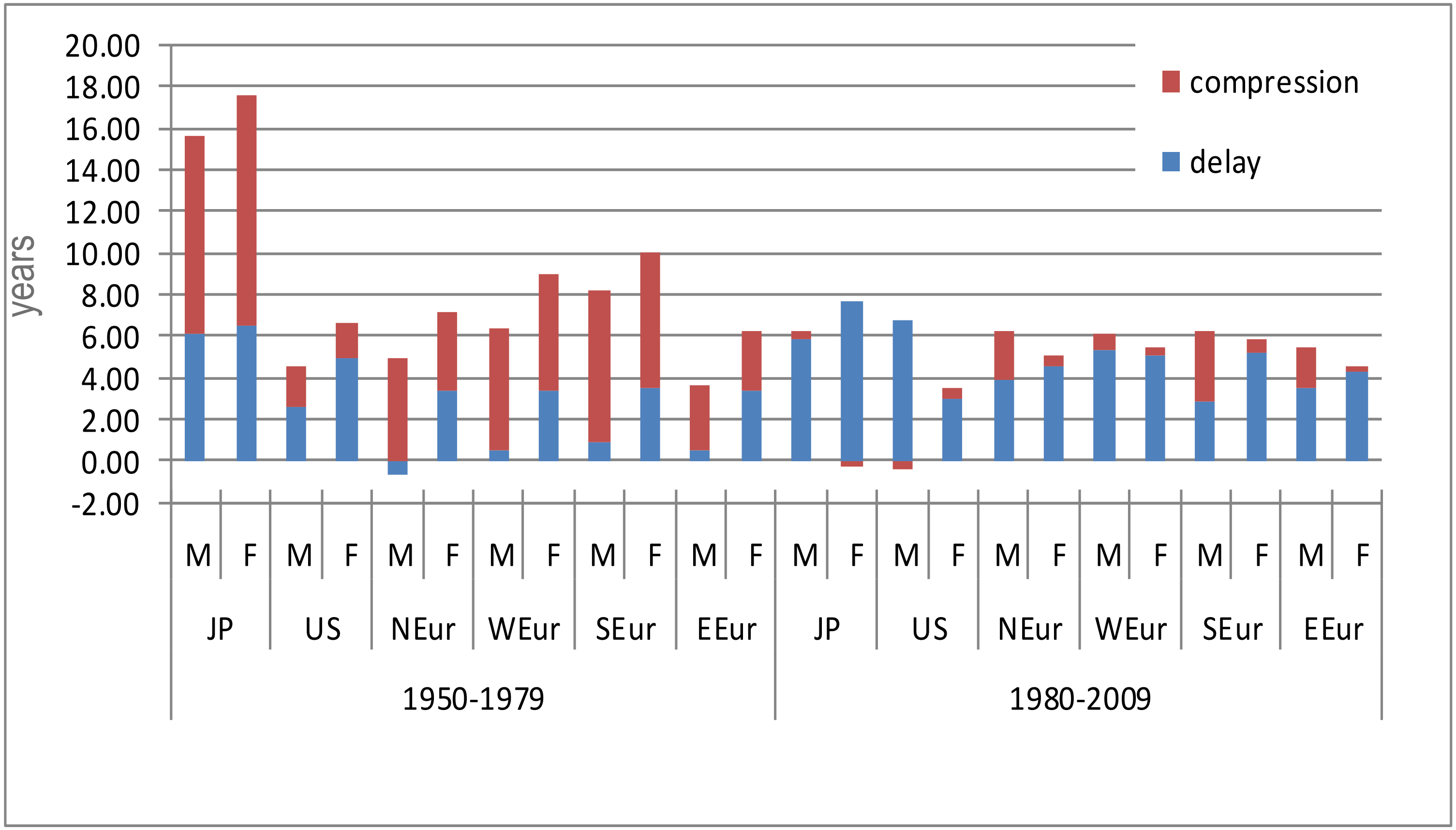
Importance of delay vs compression

- 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 eo

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

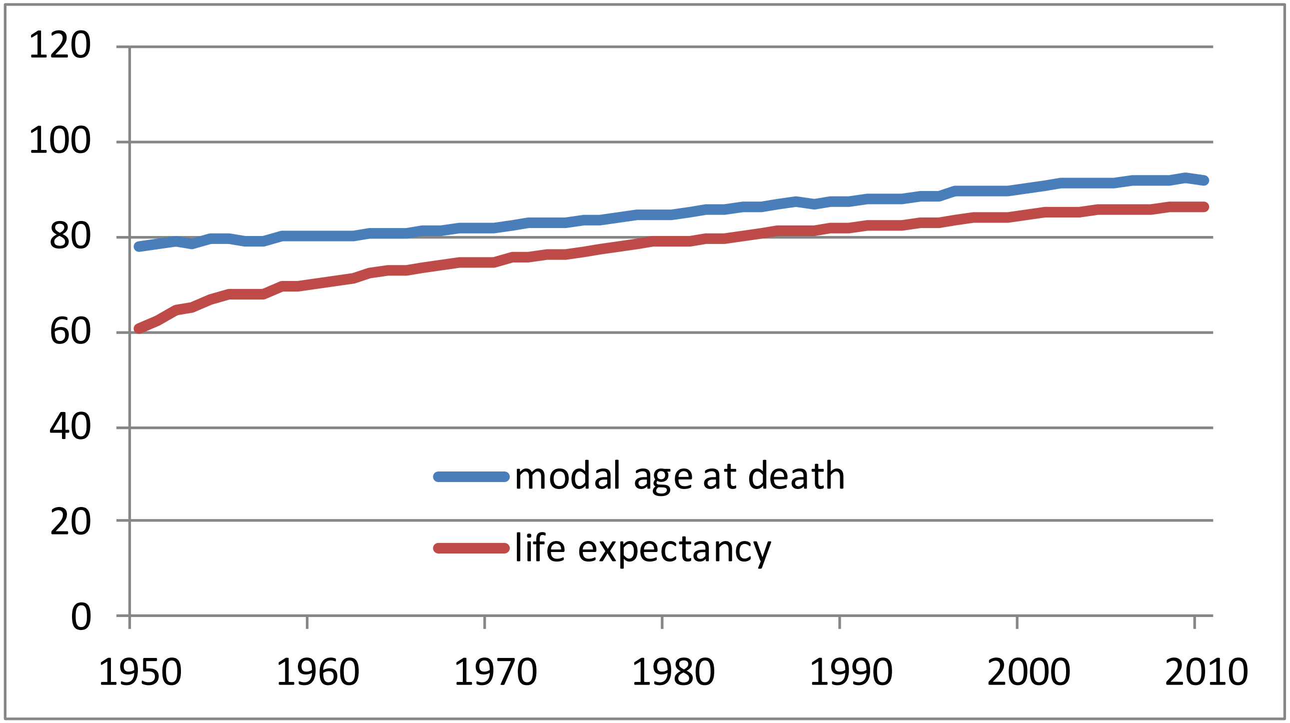
university of groningen

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

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 e0

- 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

Delay of ageing

Use of epidemiologic evidence

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-atttributable 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

$$q(x) = a + I(x \le x_1)\left[\frac{b_1 e^{b_1(x-M)}}{1+\frac{b_1}{g}e^{b_1(x-M)}}\right] + I(x_1 < x \le x_2)\left[\frac{b_2 e^{b_2(x-M)}}{1+\frac{b_2}{g}e^{b_2(x-M)}} + c_1\right]$$
$$+ I(x > x_2)\left[\frac{b_3 e^{b_3(x-M)}}{1+\frac{b_3}{g}e^{b_3(x-M)}} + c_2\right]$$

background + adult age + middle age + old age

$x_2 = M$; $x_1 = M - h$

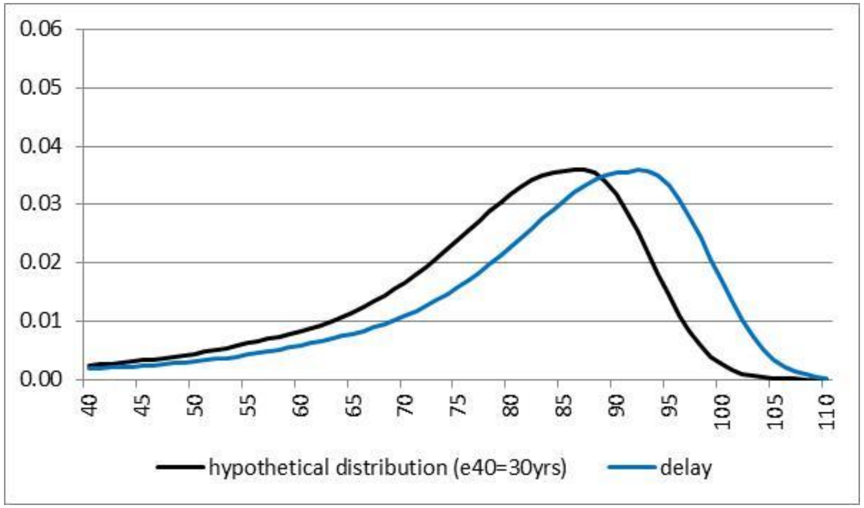
g (0.7) and h (30) time invariant

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

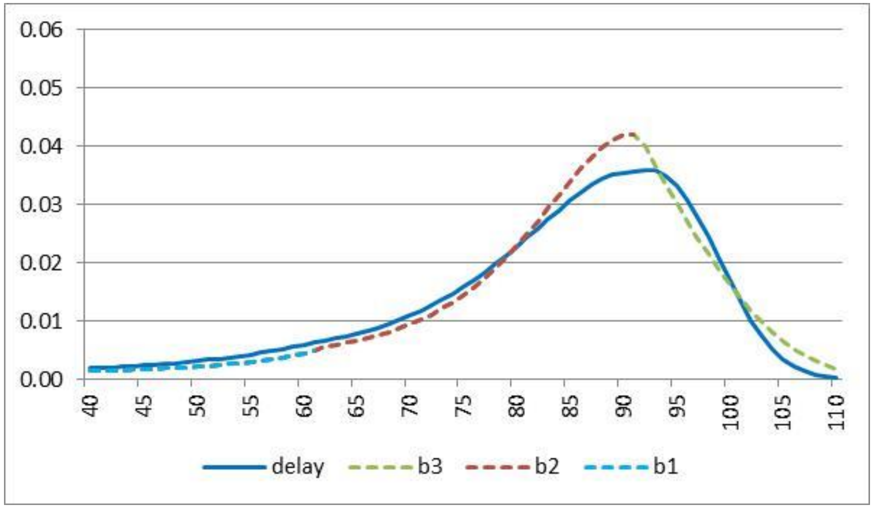
See: Janssen & de Beer (2016)

Effects of the parameters of the model

Increase in M that corresponds with 5 yrs increase in e40



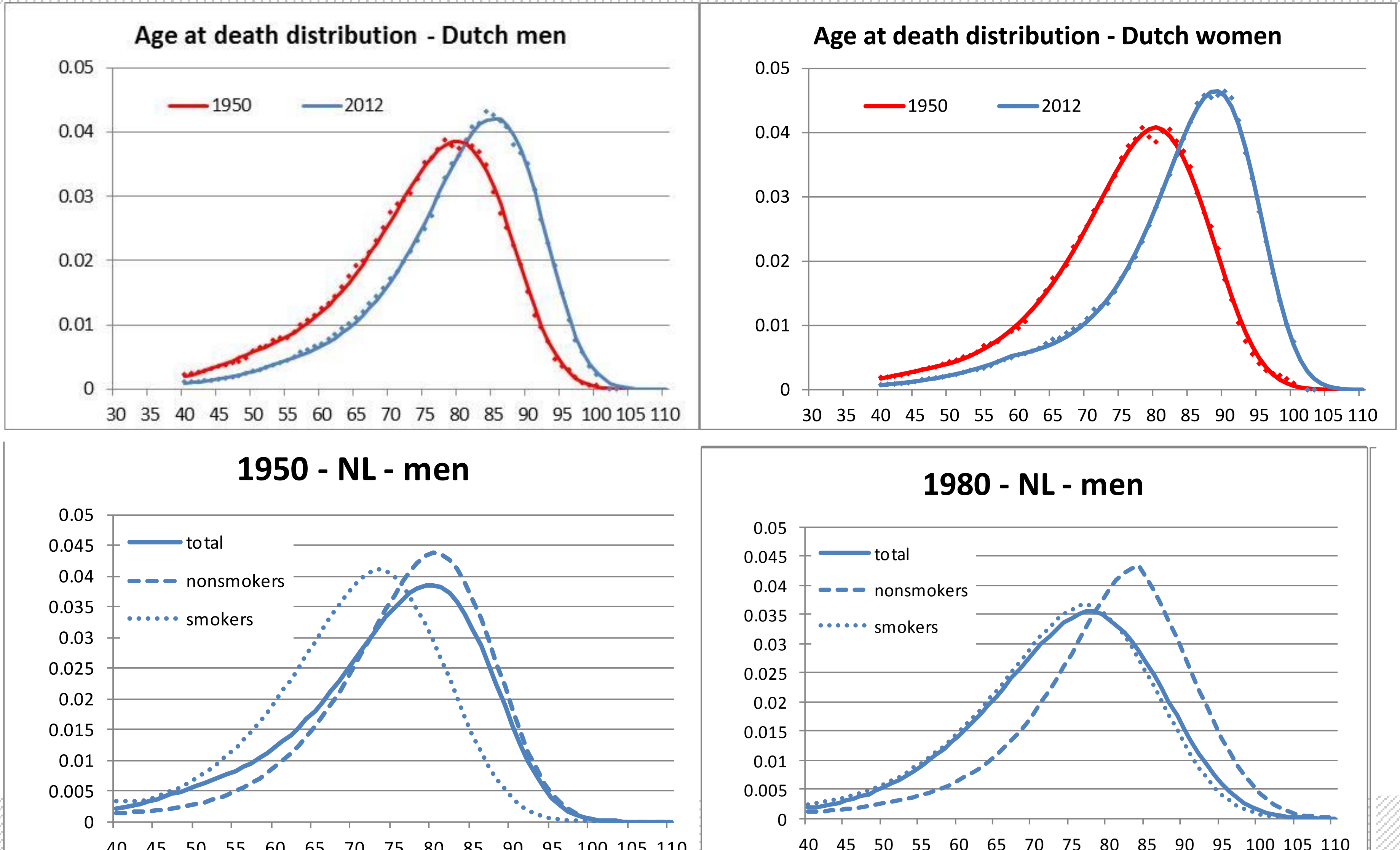
Increase in b1 and b2, and decrease in b3 that all three correspond with a 0.5 yrs increase in e40



Janssen & de Beer (2016)

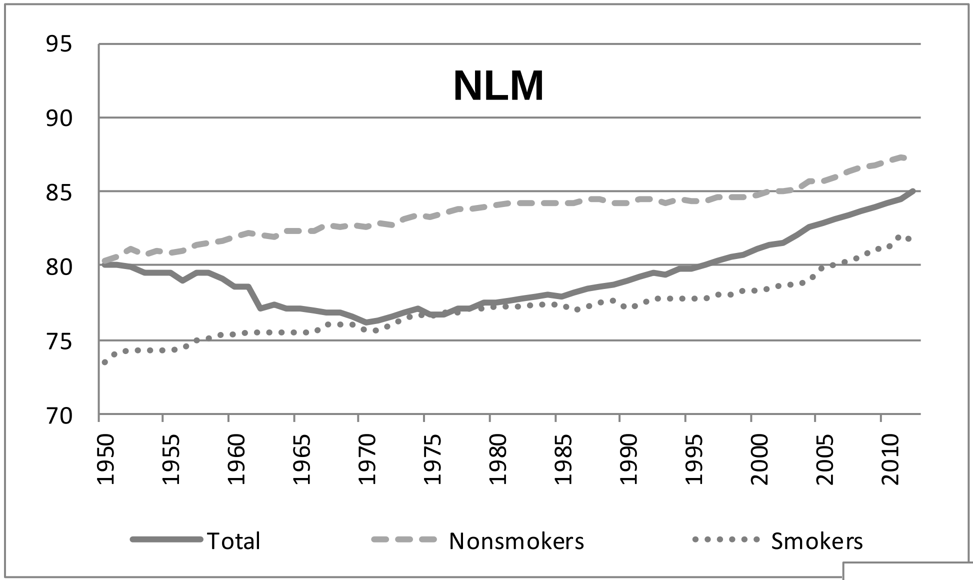
Results

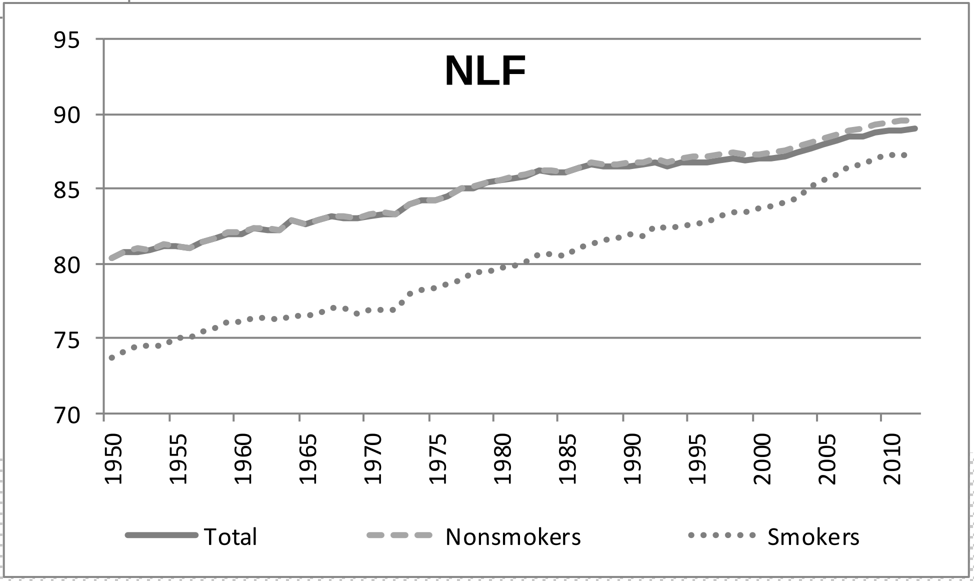
Age at death distributions



Janssen & de Beer (2016)

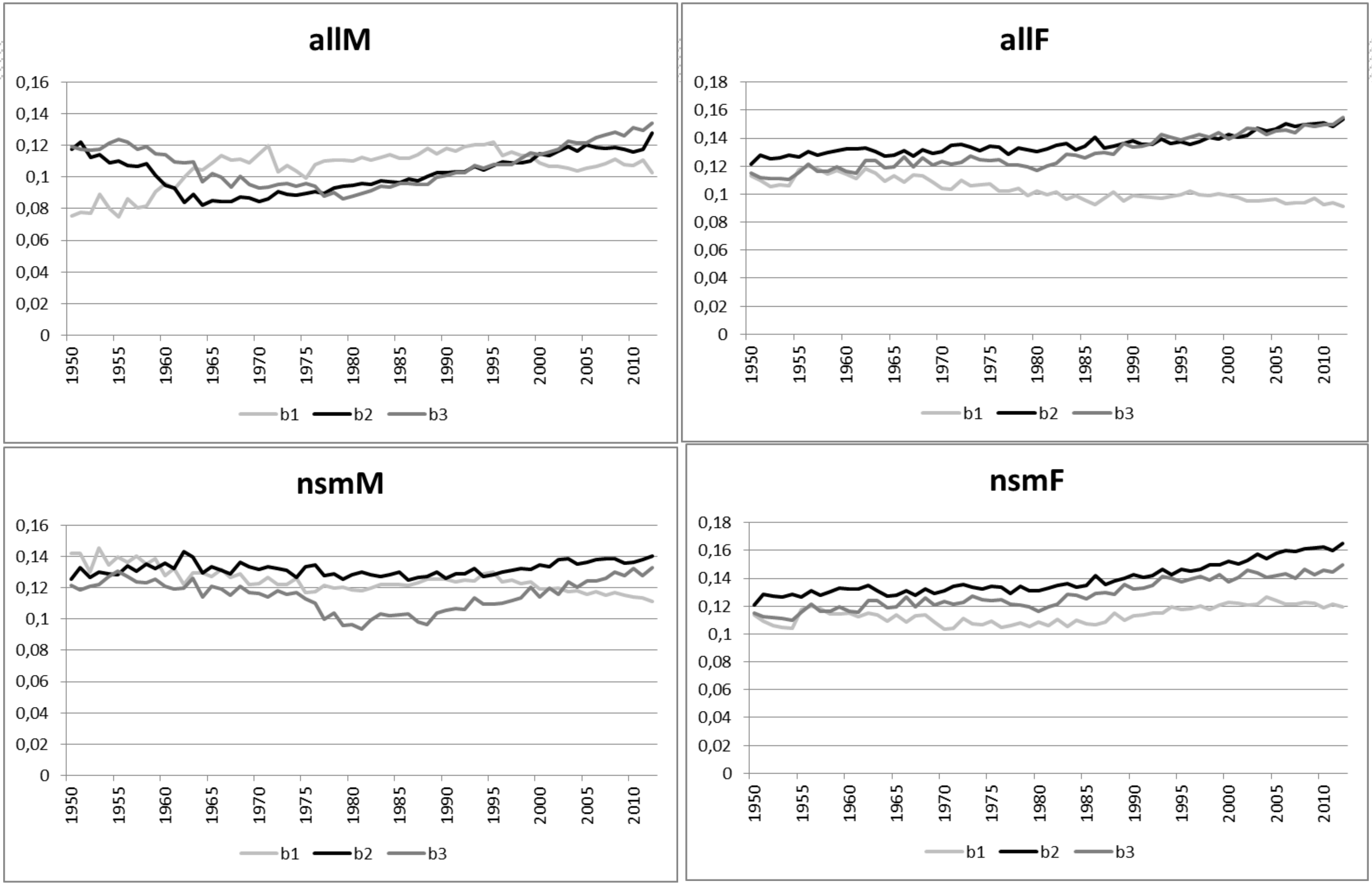
Model age of death





Janssen & de Beer (2016)

Additional parameters



Janssen & de Beer (2016)

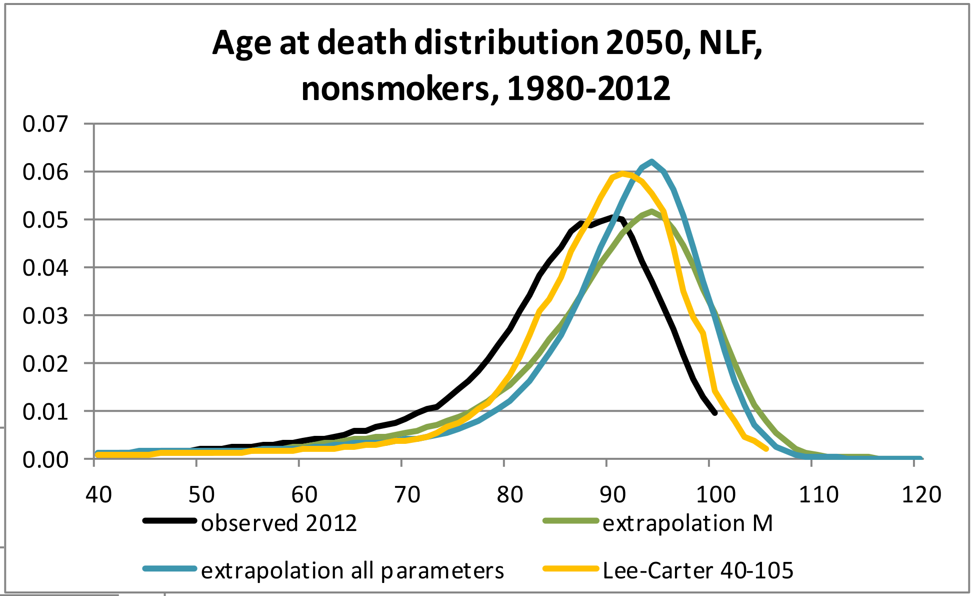
university of groningen

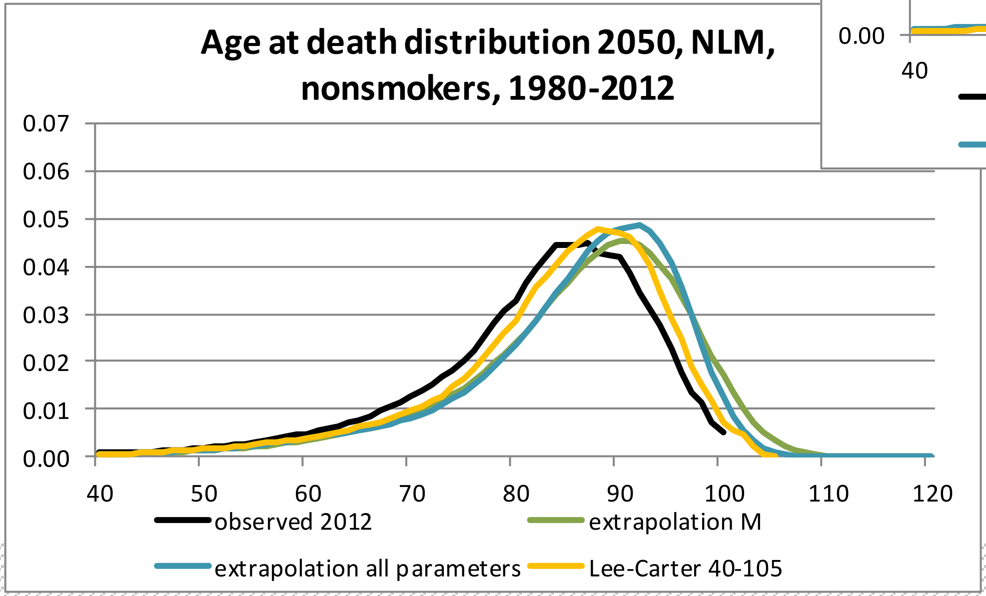
e40 2050, the Netherlands

	1950-2012		1980-2012	
	men	women	men	women
nonsmokers (e40 2012 = 42.76 (M), 45.15 (F))				
extrapolation M; rest similar to 2012 ns	46.80	50.51	46.37	49.62
extrapolation a, b1, b2, b3, M	46.47	50.58	46.00	50.02
LC 40-100	45.94	49.23	45.07	48.68

Janssen & de Beer (2016)

Difference with Lee-Carter





Janssen & de Beer (2016)

university of groningen

e40 2050, the Netherlands

	1950-2012		1980-2012	
	men	women	men	women
nonsmokers (e40 2012 = 42.76 (M), 45.15 (F))				
extrapolation M; rest similar to 2012 ns	46.80	50.51	46.37	49.62
extrapolation a, b1, b2, b3, M	46.47	50.58	46.00	50.02
LC 40-100	45.94	49.23	45.07	48.68
total (e40 2012 = 40.22 (M), 43.57 (F))				
extrapolation nonsmokers (M) + SAM (APC)	45.63	48.79	45.20	47.92
extrapolation nonsmokers (all parameters) + SAM (APC)	45.21	48.94	44.87	48.51
LC 40-100	42.69	47.54	44.89	46.39
SAM = smoking-attributable mortality				
APC = age-period-cohort analyses				

Janssen & de Beer (2016)

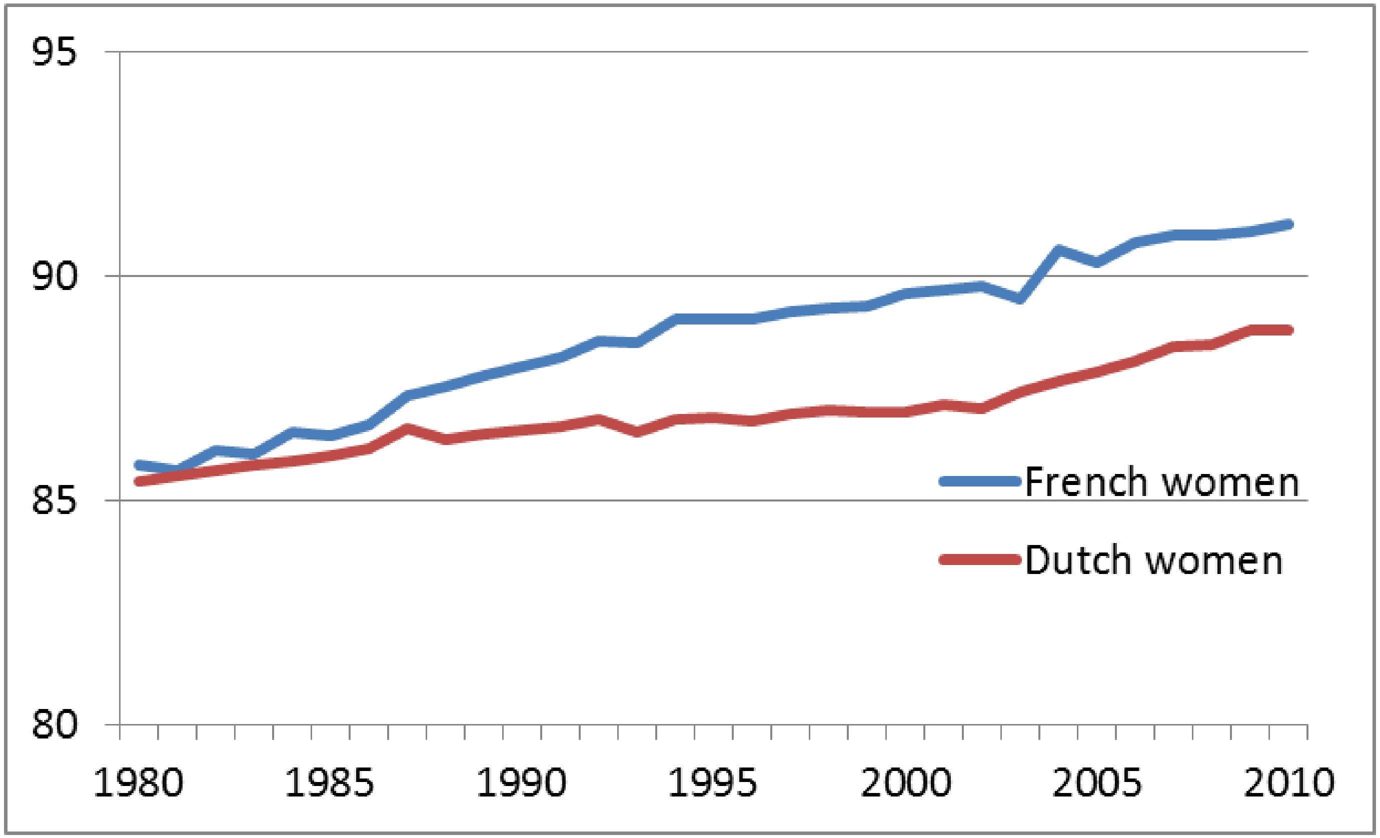
For age-period-cohort projection of smoking-attributable mortality see Stoeldraijer et al (2014)

e40 2050, the Netherlands, coherent forecast

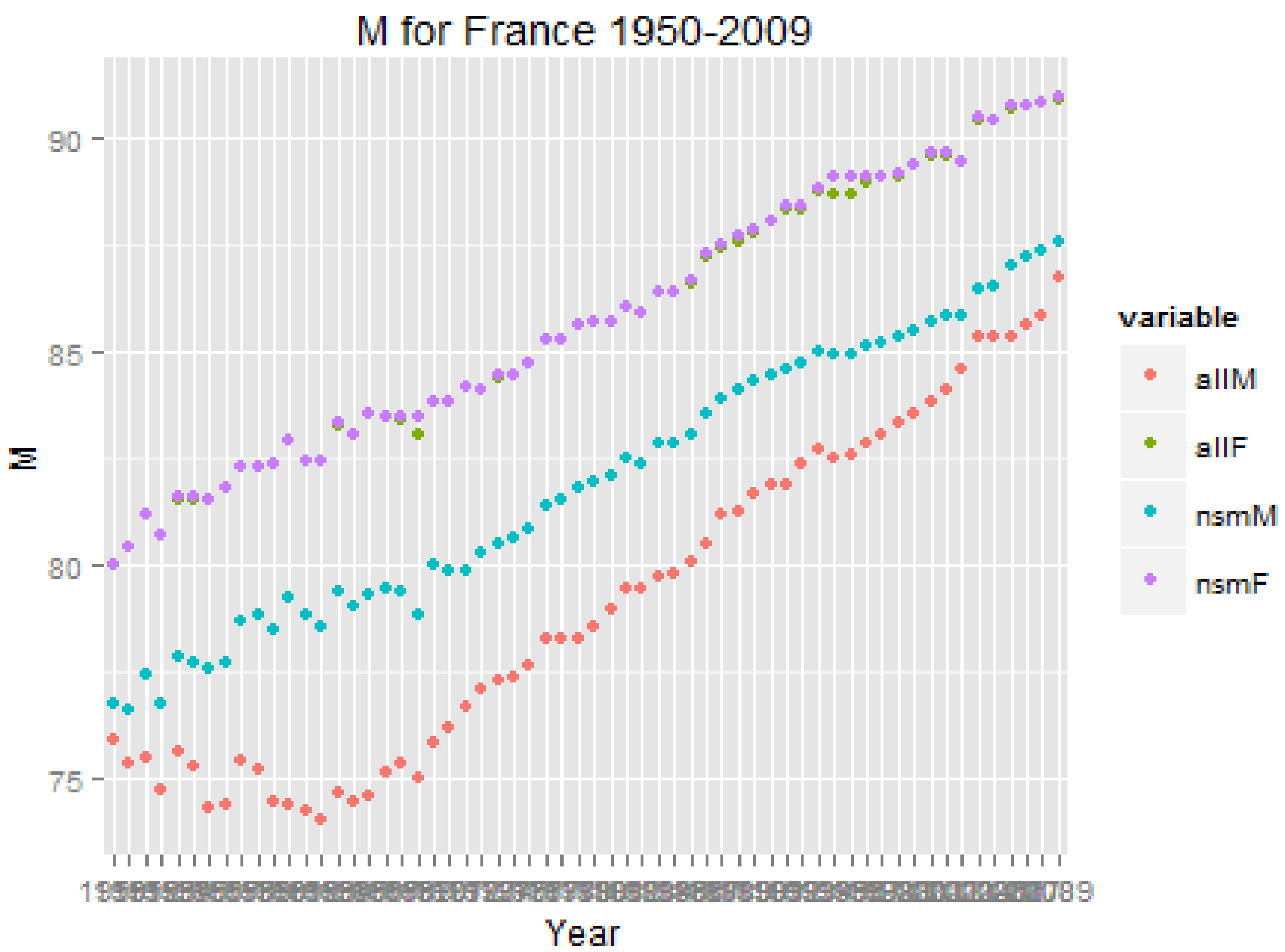
- Use of development M nsm among France women
- 1.9 years per decade (M)(equal for 1950-2009, 1980-2009, equal for M & F)

university of groningen

Modal age at death - Dutch and French women



preliminary results



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

university of groningen

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 slighly 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

university of groningen

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)

NWO
Netherlands Organisation
for Scientific Research

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

university of groningen

References (1)

- De Beer, J. & F. Janssen (submitted), A new model to describe the full age pattern of mortality and to assess delay and compression of mortality.
- Fries, J. F. (1980), Aging, natural death, and the compression of morbidity. *New England Journal of Medicine*, 303(3): 130-5.
- Janssen, F. & J. De Beer (2016) Projecting future mortality in the Netherlands taking into account mortality delay and smoking. Working paper 18. Joint Eurostat/UNECE Work Session on Demographic Projections.
- 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
- Janssen, F., van Wissen, L.J.G. and A.E. Kunst (2013), Including the smoking epidemic in internationally coherent mortality projections. *Demography* 50(4), 1341-1362.
- Lopez, A. D., Collishaw, N. E., and T. Piha (1994). A descriptive model of the cigarette epidemic in developed countries. *Tobacco Control* 3: 242–247.

References (2)

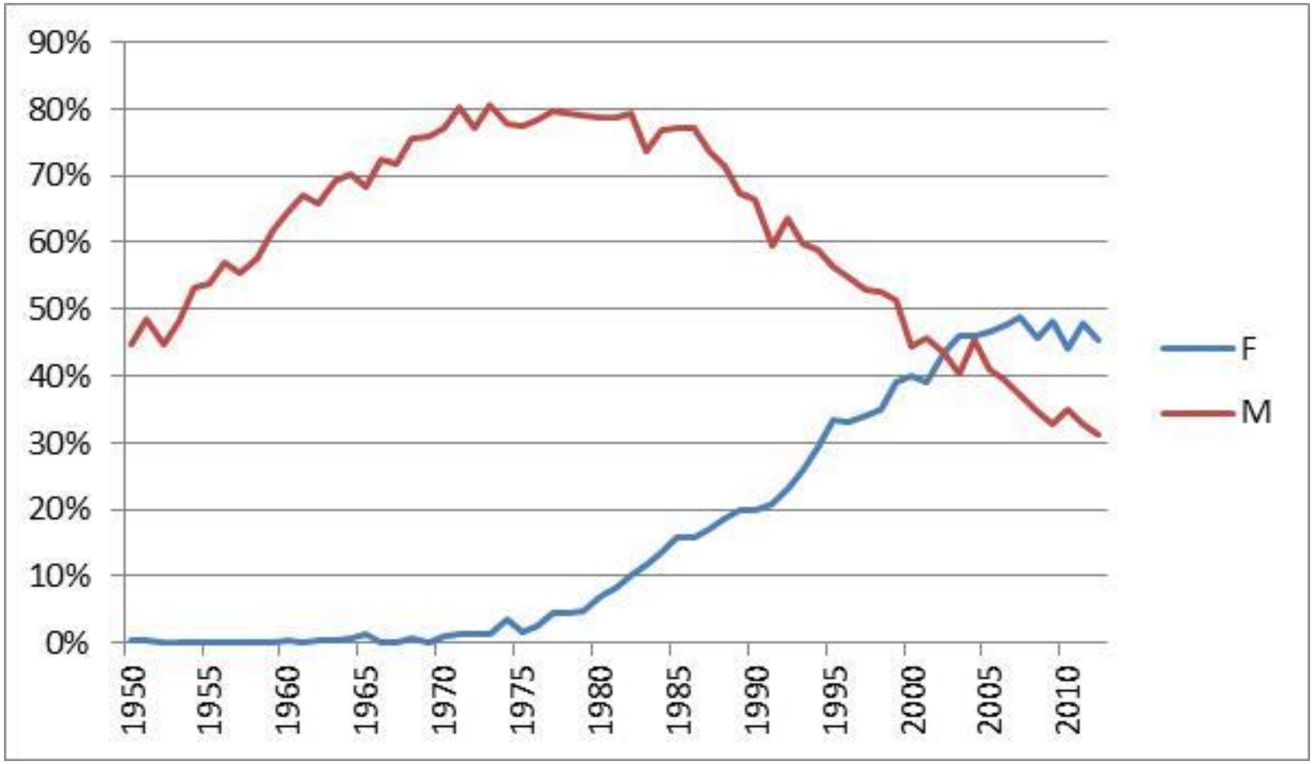
- Oeppen, J. and J.W. Vaupel (2002). Broken limits to life expectancy. *Science* 296(5570): 1029-1031.
- Stoeldraijer, L., C. van Duin, L.J.G. van Wissen, F. Janssen (2013), Impact of different mortality forecasting methods and explicit assumptions on projected future life expectancy: The case of the Netherlands. *Demographic Research 29(13): 323-354*.
- Stoeldraijer, L., van Duin, C. and F. Janssen (2013). Bevolkingsprognose 2012-2060: Model en veronderstellingen betreffende de sterfte. [Population forecast 2012-2060: Model and assumptions on mortality] *Bevolkingstrends*: 1-27.
- Stoeldraijer, L., Bonneux, L., van Duin, C., van Wissen, L.J.G. and F. Janssen (2015) The future of smoking-attributable mortality: the case of England & Wales, Denmark and The Netherlands. *Addiction* 110(2), 336-45.
- Terblanche, W. (2016) Retrospective Testing of Mortality Forecasting Methods for the Projection of Very Elderly Populations in Australia. *Journal of Forecasting*, doi: 10.1002/for.2404.
- Vaupel, J.W. (2010), Biodemography of human ageing. *Nature* 464(7288): 536-542.

university of groningen

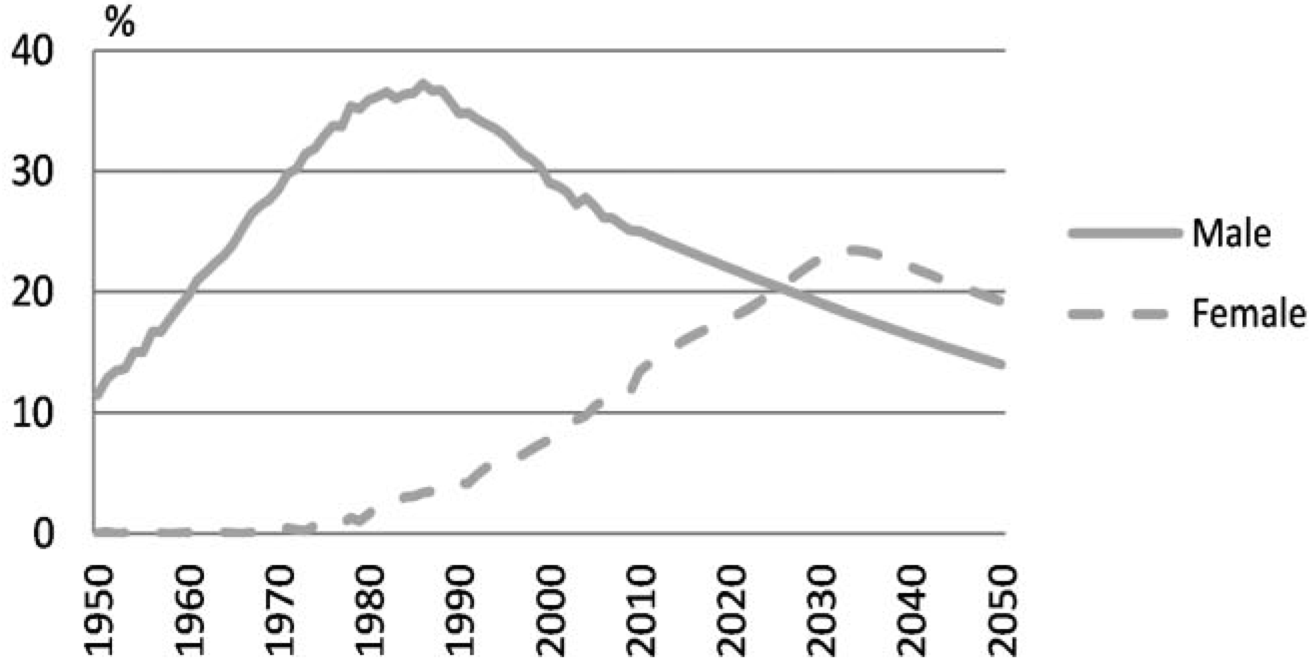
Parameters of the CoDe model (for ages 40+)

	total population			nonsmokers			smokers		
	1950	1980	2012	1950	1980	2012	1950	1980	2012
Men									
a	-0.0017	0.0000	0.0000	0.0009	0.0005	0.0002	0.0031	0.0009	0.0000
b1	0.0755	0.1103	0.1029	0.1419	0.1188	0.1115	0.2137	0.1152	0.0948
b2	0.1177	0.0948	0.1277	0.1258	0.1285	0.1402	0.1157	0.1017	0.1044
b3	0.1193	0.0880	0.1341	0.1215	0.0963	0.1329	0.1057	0.0933	0.1215
M	79.9984	77.5729	85.0469	80.4220	84.0962	87.2444	73.5540	77.2369	81.4735
Women									
a	0.0007	0.0002	-0.0003	0.0007	0.0004	0.0005	0.0002	-0.0010	-0.0011
b1	0.1133	0.1020	0.0916	0.1136	0.1084	0.1193	0.1303	0.0983	0.0809
b2	0.1211	0.1305	0.1535	0.1211	0.1313	0.1649	0.1087	0.0939	0.1301
b3	0.1150	0.1168	0.1548	0.1150	0.1166	0.1496	0.0873	0.0938	0.1531
M	80.3754	85.5382	89.0655	80.3748	85.6003	89.5696	73.7691	79.7570	87.5596

Past smoking intensities (40+)



Smoking-attributable mortality fractions, NL, past and future



Stoeldraijer et al. (2014)