Future mortality in the Netherlands: application of a new methodology

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Abstract

Objective of this paper is to obtain future levels of life expectancy (e0, e65, e80) for the Netherlands up to 2050 by separately projecting smoking-related and non-smoking related mortality, and taken into account the mortality experiences of the opposite sex and in 10 other European countries.
Data on all-cause mortality, lung cancer mortality and population by age, sex, and year for the Netherlands was obtained through Statistics Netherlands for the period 1970-2006. For the other European countries these data were obtained through the Human Mortality Database and WHOSIS. Non-smoking-related mortality is estimated using an adapted version of the indirect Peto-Lopez method. Both all-cause mortality and non-smoking-related mortality were projected into the future by means of the Lee-Carter and Lee-Li methodology. Smoking-related mortality is projected into the future by means of assumptions on the future course of the proportion of mortality caused by smoking.
Based on the proposed methodology, the life expectancy at birth in 2050 will raise to 88.1 years for Dutch women, and 83.8 years for Dutch men. These values are higher than the most recent forecast of Statistics Netherlands, especially for females.
The separate prediction of smoking-related mortality and non-smoking-related mortality led to lower life expectancy values in the short run and higher life expectancy values in the long run, especially for females, not so much for males, and especially at the higher ages.
The effect of including the experience of other populations, when already separately projecting non-smoking and smoking-related mortality, is not big, and leads to a higher life expectancy in the long run.
Clearly, different projection methods and choices lead to different projection outcomes. The use of coherent projections and separate projections for non-smoking-related mortality and smoking-related mortality gives rise to more stable results and for the Netherlands higher levels of life expectancy in 2050.

Background

Knowing the future mortality levels of a country is highly relevant. Mortality projections are highly valuable for social security programs and are often used to predict the sustainability of pension schemes. The level of future mortality levels, especially among the elderly, has important implications for social and health care policies.

In most projections of future mortality patterns, past mortality trends are used as an input (Wilmoth 2000; Bongaarts 2005). These past mortality trends are either extrapolated or used in other ways - e.g., by predicting life-table parameters or their constructs, or in mortality models - to determine future trends (Pollard 1987; Olshansky 1988; Murphy 1990).

In projecting mortality, many choices have to be made which affect the outcome. Important considerations are whether to extrapolate trends in life expectancy or rates and whether to apply a stochastic vs deterministic approach. In addition, it has proved difficult to assess which past mortality trends are the most suitable as the basis for projections. Important questions include (i) whether to consider cause-specific mortality or all-cause mortality; (ii) whether to take specific determinants explicitly into account; and (iii) the length of the historical period that should be used (Wilmoth 2005). These different methods, and different additional choices to be made, affect the projection outcome (e.g. Janssen & Kunst 2007).

Recent recommendations include the use of coherent projections, e.g. to take into account the development of the opposite sex and/or the development in other countries.

A further widening of the sex difference in life expectancy or in some cases a reversal of the sex difference in life expectancy is a probable result when separate mortality predictions for men and women are made. However, the general expectation for the sex difference in life expectancy at birth (e0) is a reduction in the short term (Mesle´ 2004; Gjonca et al. 2005). This expectation is based on the observed narrowing of the difference in e0 between men and women in many low-mortality countries since the 1980s (Waldron 1993; Trovato and Lalu 1996), which is related to the narrowing of the gap in cigarette smoking between men and women (Pampel 2002).

Also, when projections for separate countries are based on past mortality trends in each individual country, an almost inevitable result is divergence in future mortality levels, even though there may have been convergence in the past (Lundström 2003; Giannakouris 2004; Li and Lee 2005). Although the divergence in mortality levels between countries is in line with what has recently been observed for industrialized countries (Vallin and Meslé 2004) and also at the global level (Wilson 2001; Moser et al. 2005), this is not a likely outcome in the long run for a group of countries for which trends in most determinants of mortality are likely to be similar, thanks to common socio-economic policies, similar progress in medical technology, and similar developments in more specific factors, such as the smoking epidemic. Therefore, the use of the mortality experience of other countries in making national projections might be valuable.

The authors recommend as well to systematically take into account epidemiologic information. The longterm trend to be used as the projection basis can be identified more accurately if the effects of important determinants with irregular trends, such as smoking, are isolated. We suggest to separately project non-smoking-related mortality and smoking-related mortality.

The need for separate projections of non-smoking-related mortality and smoking-related mortality lies in the profound influence smoking has on mortality trends in all European countries, non-linear pattern, and highly predictable because of time lag.
Smoking has a very profound influence on mortality trends in all European countries. The smoking epidemic has increased mortality levels over a long period of time. In the pattern of this smoking effect on mortality a strong cohort effect is discernable. Therefore it does not fit

naturally in the age-period framework of the LC or LL model. Moreover, future trends in mortality will to a substantial degree be influenced by smoking, and this influence is not a straightforward extrapolation of past trends.

We combine abovementioned issues in a new methodology consisting of a coherent projection of non-smoking-mortality, taking into account the experiences of the opposite sex and the experiences in other low-mortality countries, combined with a projection of smoking-related mortality.

Objective

In this paper, we apply this new methodology to mortality in the Netherlands and look at the effects of a coherent projection over a separate projection and the effects of separately projecting non-smoking-related mortality and smoking-related mortality over the projection of all-cause mortality.

Research questions

- What is, based on the proposed methodology, the life expectancy for the Netherlands and the two sexes in 2040/2050?
- What is the effect of separately projecting smoking-related and non-smoking-related mortality?
- What is the effect of taking into account the mortality experiences of other populations?

Data

Data on all-cause mortality and population numbers by age (0, 1-4, 5-9, …, 110+), sex, and year (1970-2006) for the Netherlands was obtained through Statistics Netherlands. For the other European countries, e.g. West Germany, England & Wales, France, Denmark, Norway, Finland, Switzerland, Spain, and Sweden, these data were obtained through the Human Mortality Database.

To estimate smoking-related mortality and non-smoking-related mortality we used lung cancer mortality data for the period 1950-2006. Lung cancer deaths by sex, age (0-4, 5-9, …, 80+), and year were largely obtained through WHOSIS. For the Netherlands (2005-2006), West Germany (191-2004), Denmark (2002-2006), and Italy, additional recent data was obtained through Statistics Netherlands, Gesundheitsberichterstattung (GBE) des Bundes, NORDCAN en ISTAT.

Methodology

Levels of smoking-related mortality by age, sex, country, and calendar year were estimated using an adapted version of the indirect Peto-Lopez method (Peto et al. 1992; Ezzati and Lopez 2003; Bonneux et al., 2003). See Appendix I. Non-smoking-related mortality was calculated as total mortality minus smoking-related mortality.

To the all-cause mortality data and the non-smoking-related mortality data, we apply both the Lee-Carter methodology and the Li&Lee methodology, and compare the results. (See Appendix II for a full description of the Lee-Carter and Li&Lee methodology.) For this purpose, we will use the programme LCFIT by Webb Sprague from UC Berkeley (http://lcfit.demog.berkeley.edu). Note that the programme is still under development, and that the results need to be interpreted with caution.

To arrive at the projection of all-cause mortality (T), based on the projection of non-smoking-related mortality (N), we can apply the formula $m(x,t)^T = m(x,t)^N \cdot \left(\frac{1}{1-EF} \right)$. In this

formula, EF stands for the etiologic fraction, i.e. the proportion of all deaths attributable to smoking. We therefore need to obtain future levels of EF for the Netherlands (by age and sex). These are obtained by applying the general ideas from the descriptive model of the smoking epidemic (Lopez et al. 1994), by examining historical trends in etiologic fractions by age and sex for the Netherlands, Denmark and England & Wales and by studying trends in smoking prevalence. See appendix III.

To obtain future values of life expectancy (up to 2050), life tables were applied to the predicted age-specific mortality rates, by sex and country.

Results

According to the baseline variant of our projection, which consists of the separate projection of smoking-related and non-smoking-related mortality taking into account the mortality experience of the opposite sex and ten other West European countries (see Figure 1 and Table 1), the life expectancy at birth in 2050 will be 88.1 years for Dutch women and 83.8 years for Dutch men. The values for remaining life expectancy at age 65 are 24.6 and 21.1 respectively. Dutch women and men aged 80 in 2050 can expect to live another 11.4 years and 9.5 years respectively.

Compared to the life expectancy values in 2006, the increase is substantial. At birth, the expected gain is 6.2 years for both women and men. For those aged 65, the gain amounts to about 4 years, and for those aged 80 the gain is 2.4 years.

The increase in life expectancy is quite linear. In 2025, the life expectancy at birth is estimated to be 84.1 for women and 80.4 years for men. At age 65, this amounts to 21.5 and 18.6 years respectively and at age 80 these numbers are 9.7 and 8.1 years.

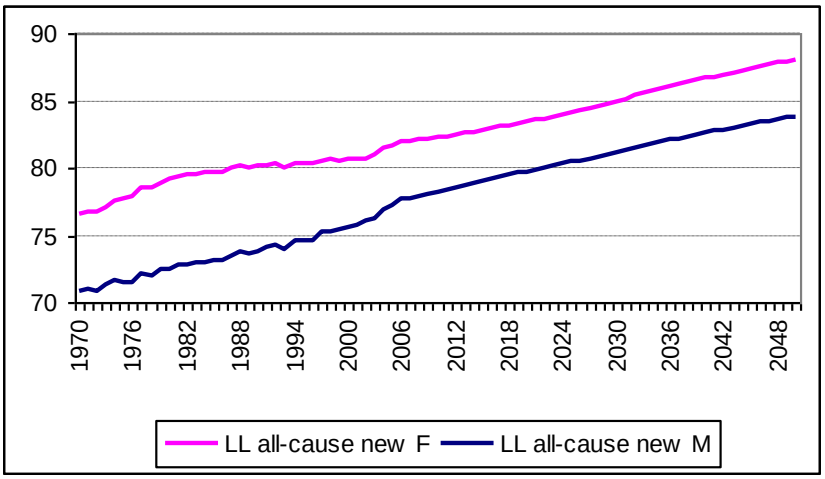
The sex difference in life expectancy at birth will decrease up to 2022. From 6.7 years in the early 1980s to 4.3 years in 2006, and to 3.7 years in 2022. From 2022 onwards, the levels for men and women will slightly diverge, to an expected sex difference in 2050of 4.2 years. At higher ages, we see the same pattern of convergence followed by divergence. At all ages, the difference in life expectancy between men and women in 2050 is close to the current difference between men and women.

Table 1: Results separate projection smoking-related and non-smoking-related mortality for the Netherlands, taking into account the mortality experience of the opposite sex and the 10 other West European countries, 2006, 2025, 2050.

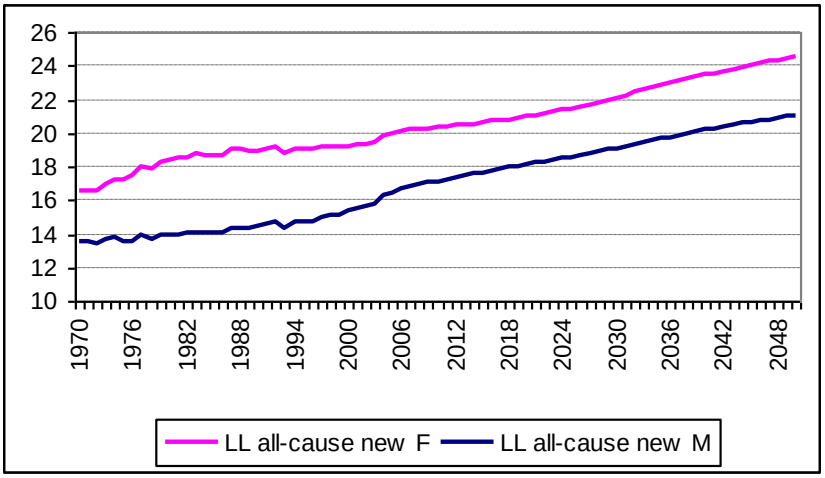
	2006	2025	2050
Life expectancy at birth (e0)			
Females	81.9	84.1	88.1
Males	77.6	80.4	83.8
Difference between females and males	4.3	3.7	4.2
Life expectancy at age 65 (e65)			
Females	20.1	21.5	24.6
Males	16.7	18.6	21.1
Difference between females and males	3.4	2.9	3.5
Life expectancy at age 80 (e80)			
Females	8.9	9.7	11.4
Males	7.1	8.1	9.5
Difference between females and males	1.8	1.6	1.8
Median age at dying			
Females	84.9	86.7	90.4
Males	80.3	83.0	86.1
Difference between females and males	4.6	3.7	4.3

Figure 1 Observed and future life expectancy values for the Netherlands based on the separate projection of smoking-related mortality and non-smoking-related mortality, taking into account the trend in the opposite sex and ten other Western European countries

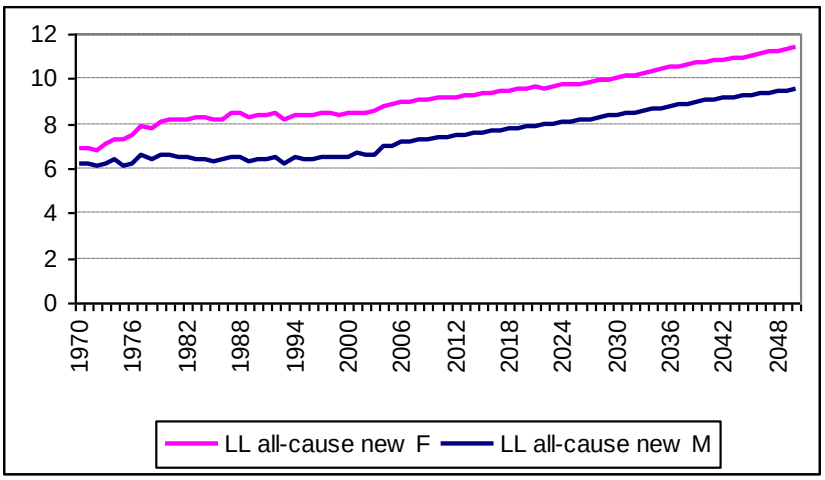
Life expectancy at birth (e0)



Remaining life expectancy at age 65 (e65)



Remaining life expectancy at age 80 (e80)

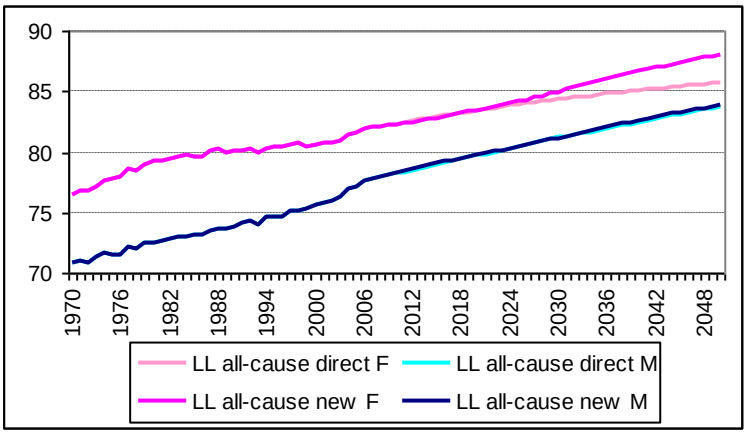


The effect of separately projecting smoking-related mortality and non-smoking related mortality

For men, the estimated future levels of life expectancy are almost equal when smoking-related mortality and non-smoking related mortality is projected either separately or combined (Figure 2).
For women, the separate projection of smoking and non-smoking-related mortality leads to a much higher life expectancy in the long run than the projection of all-cause mortality.
These two results combined lead to less convergence in the sex difference in life expectancy when smoking and non-smoking-related mortality are projected separately.

The effects of separately projecting smoking-related mortality and non-smoking-related mortality are higher at older ages.
For women at older ages it results in a lower life expectancy in the short run. Only in the long run, the life expectancy values become more positive than those for all-cause mortality.
For men, with increasing age, the remaining life expectancy values become more and more positive when smoking-related mortality and non-smoking-related are projected separately instead of combined.

Figure 2 Comparison of the life expectancy at birth when either separately projecting smoking-related mortality and non-smoking-related mortality or not, taken into account the mortality experiences in the opposite sex and ten other Western European countries, the Netherlands, by sex, 1970-2050



LL new = separately projecting smoking-related mortality and non-smoking-related mortality, taken into account the mortality experiences in the opposite sex and 10 other European countries.
LL direct = projection all-cause mortality, taken into account the mortality experiences in the opposite sex and 10 other European countries.

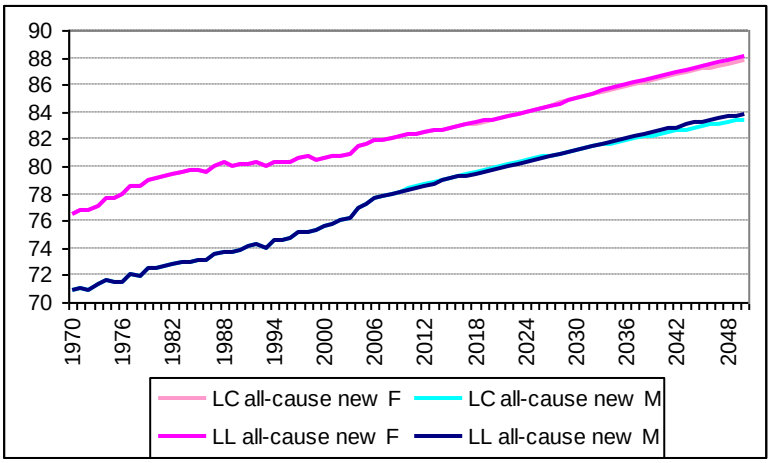
The effect of taking into account the mortality experiences in the opposite sex and 10 other European countries

Figure 3 shows that the effect of taking into account the mortality experiences in the opposite sex and 10 other European countries is small when smoking-related mortality and non-smoking-related mortality are separately projected. Taking into account the mortality experiences in other populations only results into a slightly higher value of life expectancy for both men and women. The difference in life expectancy at birth in 2050 is 0.3 years for women and 0.4 years for men.

For the higher ages, the effect of taking into account the mortality experiences in the opposite sex and 10 other European countries is slightly higher, but does not lead to substantial differences either.

The effect of including the trends in other populations seemed bigger when smoking-related mortality and non-smoking-related mortality were not projected separately.

Figure 3 Comparison of the life expectancy at birth when separately projecting smoking-related mortality and non-smoking-related mortality, taken into account the mortality experiences in the opposite sex and ten other Western European countries, or not, the Netherlands, by sex, 1970-2050



LL new = separately projecting smoking-related mortality and non-smoking-related mortality, taken into account the mortality experiences in the opposite sex and 10 other European countries.
LC new = separately projecting smoking-related mortality and non-smoking-related mortality, not taken into account the mortality experiences in the opposite sex and 10 other European countries.

Conclusion and discussion

Applying our new methodology which consists of a coherent projection of non-smoking-mortality, taking into account the experiences of the opposite sex and the experiences in other low-mortality countries, combined with a projection of smoking-related mortality, led to a life expectancy at birth in 2050 for the Netherlands of 88.1 years among women, and 83.8 years among men. The values for age 65 are 24.6 and 21.1 respectively, and for age 80, 11.4 and 9.5 respectively.
The separate prediction of smoking-related mortality and non-smoking-related mortality led to lower life expectancy values in the short run and higher life expectancy values in the long run, especially for females, not so much for males, and especially at the higher ages. This shows the relevance of separately projecting smoking and non-smoking-related mortality.
The effect of including the experience of other populations, when already separately projecting non-smoking and smoking-related mortality, is not big, and leads to a higher life expectancy in the long run. This shows the robustness of the underlying non-smoking-related mortality trend. By including the experience of other populations, divergence of the long-term mortality trend is avoided.

Our life expectancy values are higher than those predicted by the most recent forecast of Statistics Netherlands (see Table 2).

Table 2: Life expectancy in 2050 (e0, e65, e80) for the different variants and compared with the Statistics Netherlands' forecasts, by sex.

	Females			Males		
	e0	e65	e80	e0	E65	e80
Baseline	88,1	24,6	11,4	83,8	21,1	9,5
Variant 1	85,7	23,1	10,8	83,7	20,6	8,8
Variant 2	87,7	24,2	11,0	83,4	20,7	9,1
SN 2006 forecast	84,2	21,5	10,0	81,5	19,2	8,7
SN 2008 forecast	85,5	22,7	10,8	83,2	20,6	9,5

Baseline => separate projection smoking and non-smoking related mortality, taking into account mortality experiences in other populations
Variant 1 => all-cause mortality, taking into account mortality experiences in other populations
Variant 2 => separate projection smoking and non-smoking related mortality

Most likely this is largely due to the fact that Statistics Netherlands assume for the short run a levelling off of the mortality decline. We, however, merely extrapolate the historical trends in non-smoking-related mortality and combine this with estimated future levels of smoking-related mortality. Our method thus seems less subjective and leaves less room for adaptations to the results based on a priori ideas about the possible future level of life expectancy in the Netherlands.

Our aim was to project future mortality levels, not to predict them. But also in projections we have to deal with insecurity. Up to now we purely showed the point estimates. We plan to show the confidence intervals as well. But it is good to realise that insecurity does not only depend on the used projection model. Presenting merely confidence intervals might therefore be misleading. Insecurity also results from the different choices that need to be made, such as the choice for the length of the historical period to be included in the mortality projection. Especially for the Netherlands, which experienced different periods of stagnation of mortality decline and more rapid mortality decline in the past, this latter element could be crucial, as was shown previously for old-age mortality (Janssen & Kunst, 2007). By using the Li-Lee methodology and performing separate projections for non-smoking-related mortality and smoking-related mortality the arbitrariness around the length of the historical period will diminish. We also expect that the selection of the in-the-group and out-of-group populations will have less effect on the results when non-smoking-related mortality trends are used instead of all-cause mortality trends.

All in all, different projection methods and choices lead to different projection outcomes. The use of coherent projections and separate projections for non-smoking-related mortality and smoking-related mortality gives rise to more stable results and for the Netherlands higher levels of life expectancy in 2050.

Appendices

Appendix I: Method to assess levels of smoking-related and non-smoking-related mortality

Levels of smoking-related mortality by age, sex, country, and calendar year were estimated using an adapted version of the indirect Peto-Lopez method (Peto et al. 1992; Ezzati and Lopez 2003; Bonneux et al., 2003). The Peto-Lopez method takes into account the fact that not all mortality from lung cancer is due to smoking and it includes deaths from other causes that could be attributed to smoking.

In the first step, the proportion of the population exposed to smoking in the different populations ("synthetic smoking prevalence") (p) was determined by comparing the mortality rates for lung cancer in these populations with the mortality rates for lung cancer of smokers and never-smokers from the ACS CPS-II study (Peto et al. 1992; Mackenbach et al. 2004). Following Ezzati & Lopez (2003) values for p higher than 1 were set to 1 to avoid any potential overestimation of risk.
In the second step, the etiologic fraction (EF), that is, the proportion of all deaths attributable to smoking, was estimated as a function of the proportion of the population exposed to smoking (p) and the relative risk of dying of smoking (RR), using the formula EF=p(RR-1)/(p(RR-1)-1)). Age and sex specific relative risks were obtained by dividing the all-cause mortality rates for the smokers in the ACS CPS-II study with the all-cause mortality rates for never-smokers from the same study (Peto et al. 1992; Bonneux et al., 2003). To these relative risks we applied smoothing, by using regression analysis with age plus age squared (Bonneux et al., 2003). To take into account residual confounding and to obtain conservative estimates of the numbers of deaths attributable to smoking, the excess risks (RR-1) were reduced by 30 per cent (Ezzati and Lopez 2003).
In the third step, the level of smoking-related mortality by age, sex, country, and calendar year was estimated by multiplying all-cause mortality by age, sex, country, and calendar year by the adjusted etiological fractions. Subsequently, non-smoking-related mortality was calculated as total mortality minus smoking-related mortality.

The Peto-Lopez method is a comprehensive way of estimating smoking-related mortality. It takes into account the fact that not all mortality from lung cancer is due to smoking and it includes deaths from other causes that could be attributed to smoking (Peto et al. 1992).

However, an important restriction of the method remains, which leads to an underestimation of the onset of the increase in the age-specific etiologic fractions, and also in age-specific smoking-related mortality. The indirect Peto-Lopez method uses the lung cancer mortality rate as its starting point for the estimation of smoking-related mortality. The time lag between the uptake of smoking and lung cancer is however larger than the time lag between smoking and cardiovascular diseases. Thus, before smoking resulted in lung cancer mortality, smoking could have resulted in mortality from cardiovascular diseases. This smoking-related mortality is not included in the method. However, as soon as smoking leads to lung cancer, then the EF also includes the cardiovascular disease mortality as a result of smoking. Thus, only the onset of the increase in the EF for the different age groups is influenced, not the trend in the EF for the different age groups. However, when the overall trend in EF for all age groups combined is calculated based on the etiologic fractions for the different age groups, the increase in the EF for all age groups combined will be underestimated. This should be taken into account when interpreting the trends. Only when the trend in EF for all age groups combined is used for the prediction, this will have an effect on the prediction of smoking-related mortality for the future.

Appendix II: The Li&Lee method

The Li&Lee method (LL) is an extension of the LC method. The Lee-Carter model (LC) forecasts mortality by age and period. It therefore decomposes the log of the mortality rate, $\log[m(x,t)]$, into a time-invariant age component $a(x)$, an overall time trend $k(t)$, and a vector $b(x)$ denoting the magnitude of the age-specific change over time, which is not captured by the overall time trend $k(t)$. The basic model is:

$$\log[m(x,t)] = a(x) + b(x)k(t)+\varepsilon(x,t)$$

The $a(x)$ are the means of the $\log[m(x,t)]$ over the observation period. The $b(x)$ and $k(t)$ are found by singular value decomposition of the matrix $\{\log[m(x,t)]-a(x,t)\}$.

The Li-Lee method basically amounts to applying the LC model twice. In the first round, the LC model is applied to the aggregate mortality of all countries, which results in a common time trend, which we

denote by *K(t),* and a common age-specific trend factor *B(x)*. The age-pattern *a(x)* is found separately for each subpopulation as the average of the log rates.

In the second round, a country-specific LC model is applied to the residuals from the first round. For each subpopulation these residuals take the form of an age-vector of mortality that changes over time. This second round LC model results in a subpopulation-specific time trend *k(t,i)* and age-specific trend factor *b(t,i),* which is added to the common-factor model from the first round. This so called augmented common factor model is:

$$\log \bar{m}(x,t,i) = a(x,i) + B(x)K(t) + b(x,i)k(t,i) + \varepsilon(x,t,i) \qquad 0 \le t \le T$$

The *b(x,i)* and *k(t,i)* describe the difference between the rate of change of age *x* of country *i* at time *t* with the rate of change implied by the common factor *B(x)* and *K(t)*.

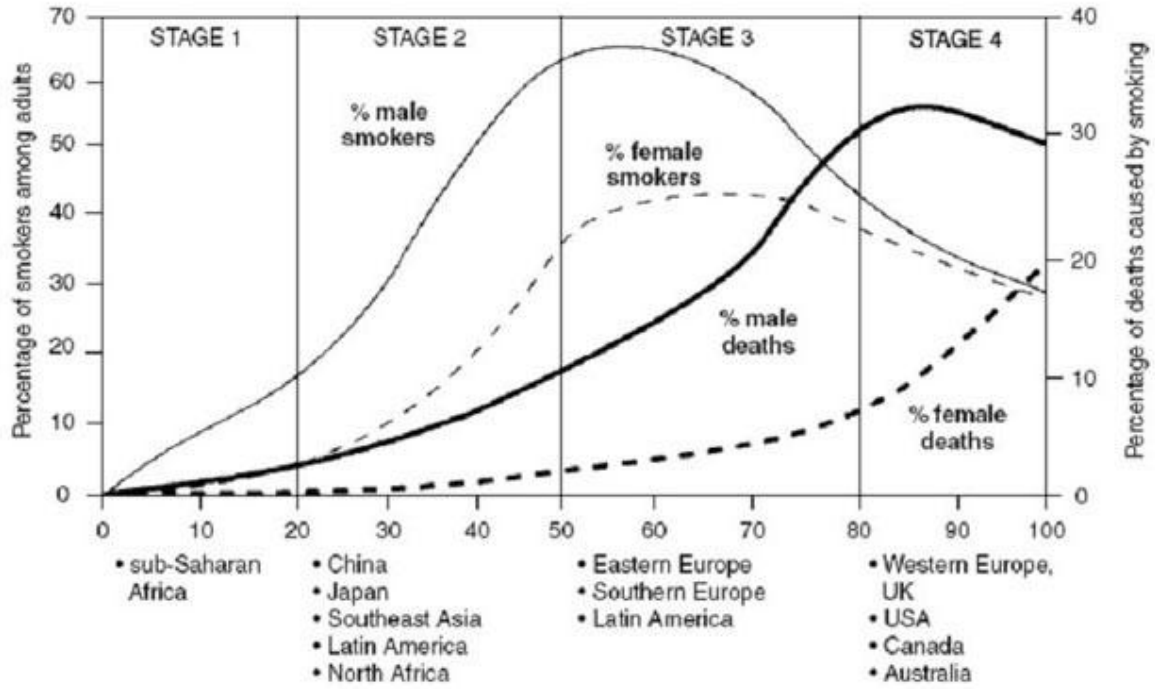
We assessed the goodness of fit of the LC model, the common factor model and the augmented common factor models by means of the explanation ratio *R*, which is the 'explained' sums of squares as a ratio of the total sums of squares in the rates. (Li and Lee 2005)

Appendix III: Projection of smoking-related mortality

Future levels of the etiological fractions (the proportion of mortality attributable to smoking), by age and sex, are obtained by applying the general ideas from the descriptive model of the smoking epidemic (Lopez et al. 1994), by examining historical trends in etiologic fractions by age and sex for the Netherlands, Denmark and England & Wales, and by studying trends in smoking prevalence.

General principles descriptive model smoking epidemic

The descriptive model of the smoking epidemic shows the common pattern of an increase and thereafter a decrease in smoking prevalence followed by similar patterns in smoking attributable mortality three to four decades later. See the figure below. For women, the increase in both smoking prevalence and smoking attributable mortality started later than for men and is more modest. All countries follow more or less the same patterns, but with a different timing of onset, saturation, etc. (Lopez et al., 1994)



For the Netherlands, the peak in smoking-attributable mortality has been reached for men, whereas for women the peak will occur somewhere in the future. For Dutch women, in addition, there has not yet been a peak in the etiological fraction for any of the age groups. We therefore need to estimate the year and level of the peak, as well as the trend up until the peak and the trend since the peak. For men, it is only necessary to estimate the future decline.

Women in Denmark and in England & Wales are among the few who showed already a peak in smoking-attributable mortality. Studying the trends in these two countries revealed that the smoking-attributable mortality trends by age for men show a clear cohort pattern up until the peak, followed by a period pattern after the peak. For women, the cohort pattern is much less clear. An important observation is that for each age group the time span between the peak for men and the peak for women is almost similar. This time span furthermore approximately equals the number of years between the peak in smoking-attributable mortality for men and women for all ages combined.

The data on the smoking prevalence proved to be quite sparse, and not of high enough quality to assess a peak year in smoking prevalence which could resemble a peak in smoking attributable mortality three to four decades later. The recent data however revealed that both the age-specific smoking prevalence and the trend therein are almost equal for men and women. A similar pattern can thus be assumed for smoking attributable mortality by age.

Based on the above findings we formulated some assumptions to estimate the etiological fractions for the future. Very essential proved to be the estimation of the year and level of the peaks in the etiological fraction for females. For all ages combined, we firstly determined the cohort with the highest lung cancer mortality (= highest smoking intensity) by means of an age-period-cohort regression model on lung cancer mortality data from 1950-2004 by 5 year age groups and 5 year periods. Then, we added the average age of dying from lung cancer to this cohort (NL => 1953 + 68 = 2021). The peak years for the etiological fractions for the separate age groups were subsequently estimated by applying the difference in timing of the peak between men and women for the etiologic fraction for all ages combined (NL => 38) to the peak years for the separate age groups for men. These peak years for the etiological fractions by age for men were assessed through fitting a fourth degree polynomial and obtaining the maximum.
For females, the trend in the age-specific etiological fraction up until the peak was based on the age-specific growth rate observed over the past 10 years. In addition, a deceleration of the growth rate to 1 was applied.
The age-specific long-term decline after the peak for both men and women has been set equal to the trend in smoking-attributable mortality after the peak for males. This latter trend proved to approximately reflect the recent trend in smoking prevalence. We thus assume convergence on the long run.
For women, the trends are smoothed by means of a fourth-level polynomial.