Future gains in remaining life expectancy at age 80

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Abstract

Introduction: Projections of future mortality patterns among the elderly can inform about the general future mortality trend and about the future degree of population ageing. In projections in which past trends are extrapolated into the future, the influential choice of the projection base can be aided by recent insights in the past trends and its determinants.

Objective: To project future old-age mortality trends in seven European countries based on the extrapolation of different past mortality experiences, and to compare the effects.

Data en methods: We selected either all-cause mortality or non-smoking related mortality among either those aged 80-100+ from 1950 to 1999 or those aged 55-69 from 1975 to 1999. Alternative annual mortality changes were estimated by sex- and country specific age-period loglinear regression models and applied to smoothed national age-specific mortality rates among those aged 80 and over in 1999. Through life table techniques, the remaining life expectancy at age 80 (e80) in 2050 was obtained.

Results: Choosing a historical period of 25 years instead of 50 years resulted in higher gains among men and lower gains among women. The use of the recent mortality trends at ages 55-69 instead of at ages 80 and over led to higher gains, especially among men. Merely regarding recent trends in non-smoking related mortality led to larger gains in e80 among both sexes, and especially among women. Including the past mortality experience of France led to a almost similar gain in e80 for the different countries. The largest gains in e80 were observed among men when past trends in all-cause mortality for those aged 55-69 in the period 1975-1999 were used (average gain of 5.37 years), and among women when past trends in non-smoking related mortality for those aged 55-69 in the period 1975-1999 were used (average gain of 5.22 years). The smallest gains in e80 were observed when, among men, all-cause mortality among those aged 80 and over in 1950-1999 was projected into the future (average gain of 1.72 years), and when, among women, all-cause mortality among those aged 80 and over in 1975-1999 was used (average gain of 3.37 years).

Conclusion: The identification of the projection base should be preceded by a thorough study of past trends and its determinants, including the developments at younger ages, in other countries, and for the opposite sex. For the future, substantial increases in old-age mortality can be expected.

Key words: Mortality, Elderly, Projection, Life expectancy, Limit to life expectancy, Europe

Background

In low-mortality countries, the past has witnessed an enormous growth in the number, the proportion, and the mean age of elderly people. This ageing of populations has important consequences for future demands of health care services and old-age benefit systems. The future degree of ageing of populations is strongly influenced by future patterns of old-age mortality (1-3). Moreover, future old-age mortality patterns highly determine general mortality patterns in the future (4). Therefore, projections of future mortality patterns among the elderly are highly important for public health and society.

In most projections of future mortality patterns, past mortality trends are used as an input (5, 6). These past mortality trends are either being extrapolated or in other ways, e.g. by projecting life-table parameters or their constructs, or by the use of mortality models, used to determine the future trends (7-9). However, it has been shown difficult to make a selection of the past mortality trends to base the projections upon. The first question that immediately arises is the length of the historical period to include (10). Other questions, for example, involve whether to consider all-cause mortality versus cause-specific mortality or whether to correct for important determinants, whether to use period trends or cohort trends, and whether developments from other countries should be integrated (10). To make an informed selection of the projection base, insight in the past trends and its determinants is necessary.

Recent studies on trends in old-age mortality and its determinants among seven European countries over the period 1950 to 1999 showed enormous heterogeneity in the past mortality trend (11). The general tendency, however, was a decline and a convergence of old-age mortality levels between the countries (11). Smoking proved an important determinant of past mortality trends among the elderly (11). Also, cohort effects were important in determining the recent trends in mortality among the elderly in seven European countries (12), with positive correlations between all-cause mortality changes at ages 80-89 and all-cause mortality changes at ages 55-69 between 10-year overlapping birth cohorts centred around the birth years 1895, 1900, 1905 and 1910 (13). These results have implications for the choice of the projection-base.

Our objective is to use the information on the observed past trends and its determinants to select different baselines for the projection of future old-age mortality trends in Denmark, England&Wales, Finland, France, the Netherlands, Norway and Sweden. In addition, we compare the effects of the extrapolation of the different baselines to determine to what extent projections are sensitive. We apply extrapolation of age-specific mortality rates instead of life expectancy, as the latter has proven to be less insightful (5).

The high amount of heterogeneity indicates that a long historical period will lead to different results than a short historical period, and that a careful comparison of the two is needed. The importance of cohort effects, and the observed positive correlation between all-cause mortality trends among the elderly and those among the late middle aged of the same cohorts, could indicate that it is beneficial to include the mortality experiences of younger cohorts. The highly unstable trends in smoking make it impossible to extrapolate past trends in smoking-related mortality linearily into the future. A more stable projection base can be obtained by merely regarding non-smoking related mortality. The general tendency towards convergence of old-age mortality levels between the countries indicates that the use of the mortality experience of other countries might be valuable.

Data and methods

All-cause mortality data and population data were obtained from the Human Mortality Database (HMD), for Denmark, England&Wales, Finland, France, Netherlands, Norway, and Sweden, in the period 1950-1999, by sex and single year of age (up to age 100+)(http://www.mortality.org). For England&Wales, data from the HMD were not available for 1999, and for this year national data on all-cause mortality and population numbers for those aged 80 and over were included.

Levels of smoking-related mortality per sex, country, and calendar year were estimated using a simpler application of the indirect Peto-Lopez method (14, 15). In the first step, the prevalence of smoking (p) in the different populations was determined by comparing the lung cancer rates in the different populations (data obtained from national statistical offices and related institutes)(see Janssen et al., 2004)(11) with the smoothed lung cancer rates among the never smokers of the ACS CPS-II study (14, 15). In the second step, the etiologic fraction (EF), i.e. the proportion of all deaths attributable to smoking, was estimated as a function of the proportion of the population that is exposed (p) and the relative risk (RR), by using the formula $EF = p(RR-1)/(p(RR-1)+1)$. The relative risk for smoking of total mortality was set at 2 (14, 15). To take into account residual confounding and to obtain conservative estimates of the numbers of deaths attributable to smoking, the etiological fractions were adjusted by 30% (16). The level of smoking-related mortality was estimated by multiplying all-cause mortality by the adjusted etiological fractions.

Based on the four choices of the baseline data, we selected six different projection alternatives. As a first projection alternative, we based our extrapolation on past mortality trends among mortality among those aged 80 and over in the period 1950 to 1999. Second, we based our extrapolation on mortality trends among those aged 80 and over in the period 1975 to 1999. As a third projection alternative, we based our extrapolation on mortality trends among the younger cohorts, i.e. those aged 55-69 in the period 1975 to 1999. In projection alternative four and five, merely past trends in non-smoking related mortality were regarded for those aged 80 and over in the period 1975 to 1999 and those aged 55-69 in the period 1975 to 1999, respectively. The sixth projection alternative took as an input the mortality experience of the country with the most favourable past trends among those aged 80 and over in the period 1950 to 1999.

To estimate sex- and country- specific alternative overall annual mortality changes (%), Poisson regression model was applied to the different selections of the data. The dependent variable was the number of deaths, with the person-years at risk (measured as the midyear population) as offset variable. As independent variables, we used single year of age (categorical) and single calender year (discrete).

The alternative annual changes in mortality were applied to smoothed national age-specific mortality rates among those aged 80 and over in 1999, to project age-specific mortality rates up to 2050, again by sex. Because of very irregular patterns over time after the age of 100, we selected 100 as the maximum age. The smoothing over age of the age-specific mortality rates in 1999 was done by 5-year (=age) smoothing averages.

As a final step, a lifetable was applied to the projected age-specific mortality rates among men and women aged 80 and over in 2050. As a result, the remaining life expectancy at age 80 for the different alternatives and the different countries could be obtained.

Results

In general, the past mortality trends of the different projection alternatives showed a decline (Table 1). Among men, on average, the declines were highest for all-cause mortality for those

aged 55-69 from 1975 to 1999 (annual mortality change of -1.80 %), and lowest for all-cause mortality for those aged 80 and over from 1950 to 1999 (-0.68 %). Among women, the declines were highest among non-smoking related mortality for those aged 55-69 from 1975 to 1999 (-1.67 %) and lowest for all-cause mortality for those aged 80 and over from 1975 to 1999 (-1.16 %). The declines were higher among women than among men, except for all-cause mortality among the late middle aged (ages 55-69) from 1975 to 1999 (-1.80 % for men; -1.21 % for women). The trend in non-smoking related mortality among the late middle aged in 1975-1999 was fairly similar among men (-1.60 %) and women (-1.67 %). For both sexes, mortality decline was most pronounced in France, and less pronounced in Denmark. The differences between the annual changes for the different past trends were more pronounced among men than among women, except for Denmark.

Projected remaining life expectancy at age 80 (e80) in 2050 ranged among men from 7.01 years (Netherlands all-cause mortality 1975-99 80+) to 14.60 years (Finland all-cause mortality 1975-99 55-69) and among women from 7.69 years (Denmark all-cause mortality 1975-99 55-69) to 17.53 years (France non-smoking related mortality 1975-99 55-69) (Figure 1).

Choosing a historical period of 25 years instead of 50 years resulted in a larger gain in e80 among men (on average 2.13 years instead of 1.72 years), and a lower gain in e80 among women (on average 3.37 years instead of 3.76 years).The use of the mortality trends at ages 55-69 instead of using the mortality trends at ages 80 and over, in the period 1975 to 1999, led in general to a much higher gain in e80 among men (on average 5.37 years instead of 2.13 years), and a slightly higher average gain in e80 among women (3.74 years instead of 3.37 years). Under this projection alternative, the gains in e80 became larger for men than for women in all countries except France. Merely regarding trends in non-smoking related mortality among those aged 80 and over in the period 1975 to 1999 led to larger gains in e80 among both sexes, and especially among women (on average 2.40 years in stead of 2.13 years among men, and 4.38 years in stead of 3.37 years among women).The extrapolation of the recent trends in non-smoking related mortality among those aged 55-69 resulted among men in larger gains than the extrapolation of non-smoking related mortality among those aged 80 and over and in smaller gains than all-cause mortality among those aged 55-69 (on average 4.57 years in stead of 2.40 years and 5.37 years, respectively). The extrapolation based on the annual all-cause mortality change in France among those aged 80 and over in the period 1950-1999 led to an almost similar gain in e80 for the different countries, of approximately three years among men, and somewhat less than five years among women. (Table 2)

The largest gains in e80 were observed among men when past trends in all-cause mortality for those aged 55-69 in the period 1975-1999 were used (average gain of 5.37 years), and among women when past trends in non-smoking related mortality for those aged 55-69 in the period 1975-1999 were used (average gain of 5.22 years). The smallest gains in e80 were observed when, among men, all-cause mortality among those aged 80 and over in 1950-1999 was projected into the future (average gain of 1.72 years), and when, among women, all-cause mortality among those aged 80 and over in 1975-1999 was used (average gain of 3.37 years). On average, the gains in e80 between 1999 and 2050 were 3.21 years for men and 4.21 years for women (Table 2).

Both the extrapolation of the past trends in old-age mortality from either 1950 or 1975 onwards and the extrapolation of non-smoking related mortality among the elderly since 1975 led to future trends in e80 that were generally in line with the past. Extrapolation based on the past trends in France was in line with the past trend in e80 merely in Finland and among men in England and Wales. For women, furthermore, the extrapolation of the all-cause mortality trends among those aged 55-69 from 1975 onwards, was in line with the past trend in e80 for Norway, Sweden, and England and Wales. (Figure 1)

A clear divergence of the old-age mortality level between the countries showed, except when the annual change of France aged 80 and over from 1950 to 1999 was used. A general widening of the sex differences in remaining life expectancy at age 80 occured when past trends in all-cause mortality and non-smoking related mortality among those aged 80 and over were extrapolated, and when the past mortality experience in France was used. The extrapolation of non-smoking related mortality among those aged 55-69 in 1975-1999 resulted in an increase in the sex difference among France and Finland, a decrease in Sweden and Norway, and approximately no change in the remaining countries. The extrapolation of all-cause mortality among those aged 55-69 in 1975-1999 showed mainly divergence of the sex differences, with a reversal of the sex difference for Denmark, the Netherlands, England&Wales, and Sweden. (Figure 1)

Discussion

Independent of the projection-alternative, substantial increases in remaining life expectancy at age 80 can be expected for the future. If we consider the average over the different projection alternatives, then up to 2050, remaining life expectancy at age 80 is expected to increase further by on average 3.21 years among men, and 4.21 years among women. For some countries, even increases in remaining life expectancy at age 80 of 8 years can be expected. With unchanged mortality rates for those aged less than 80, the average expected increase in the life expectancy at age 80 can lead to an average increase of life expectancy at birth of 1.39 years among men, and 2.66 years among women (data not shown).

However, the different projection alternatives led to a large range in the gains in e80. Choosing a historical period of 25 years instead of 50 years resulted in higher gains among men and lower gains among women. The use of the recent mortality trends at ages 55-69 instead of those at ages 80 and over led to higher gains, especially among men. Merely regarding recent trends in non-smoking related mortality led to larger gains in e80 among both sexes, and especially among women. Including the past mortality experience of France led to a almost similar gain in e80 for the different countries. The differences between the different projection alternatives were larger for men than for women.

The largest gains in e80 were observed among men when past trends in all-cause mortality for those aged 55-69 in the period 1975-1999 were used, and among women when past trends in non-smoking related mortality for those aged 55-69 in the period 1975-1999 were used. The smallest gains in e80 were observed when, among men, all-cause mortality among those aged 80 and over in 1950-1999 was projected into the future, and when, among women, all-cause mortality among those aged 80 and over in 1975-1999 was used.

For all the alternatives, except the one which takes into account the past trend in France, a clear divergence of mortality levels between the countries showed. Although this is in line with what is recently being observed in industrialised countries (17) and even at the global level (18), this is not a likely outcome for the long run for countries that are quite similar in the composition of the determinants of mortality trends, like the seven countries under study.

With respect to the gap in e80 between the two sexes, a general widening occurred when past trends in mortality at ages above 80 were regarded, although less when more recent trends were regarded. Divergence of old-age mortality levels and even a reversal of the sex difference occurred when past mortality trends at ages 55-69 were extrapolated. This dependence of the projected sex difference in life expectancy on the choice of the projection base can be largely explained by the the less favourable recent trends in smoking-related mortality among women as compared to men, which was even more pronounced at ages 55-69 (data not shown). The most likely outcome is a reduction of the gap in life expectancy between the sexes (19, 20).

Recommendations on the choice of the projection base

Important in making projections based on past trends is to identify the basic long-term trend on which the projection should be based. The identification of this "projection base" involves making a number of important choices that will be discussed below.

Length of the historical period

Common rule for the length of the historical period is that it should be at least the period that you want to predict ( ). Others state that the historical period should be preferably two or three times the predicted period ( ). The length of the historical period, however, also depends on the quality of data (10). Moreover, the existence of an abrupt change in the trend can influence the choice of the baseline time period. On the one hand, it is being argued that in case of an abrupt change in the trend, the most recent years for which a new pattern, i.e. either a more even pace of mortality decline or a change in the role of determinants, is observed should be used (10). On the other hand, the historical interval should be long enough to avoid giving undue weight to atypical, short-term trends (21).

Important, thus, is to determine whether changes in the trend occurred and whether these periods of stagnation or accelaration are regarded as either demonstrating the emergence of new determinants or as merely demonstrating temporal effects of amenable factors. This asks for careful study of the underlying mechanisms. If the changes in the trend demonstrate the emergence of new determinants, a shorter historical period might be chosen. If the changes merely demonstrate temporal effects of modifiable factors, a longer historical period is to be preferred. For the seven countries under study, two periods of stagnation were observed, i.e. in the 1950s and 1960s in the Nordic countries and since the 1980s in the Netherlands, Denmark, and among Norwegian men. On the contrary, in the 1970s extreme mortality declines were observed, especially for Finland and the Netherlands (11). Including both periods of stagnation in the historical trend can easily lead to an underestimation of the long-term mortality decline, whereas including the 1970s might lead to an overestimation. The trend from 1975 onwards, thus, seems a likely basic long-term trend.

Excluding the effects of important determinants

Including epidemiological information in mortality projections, either through the use of an explanatory model or through mortality projections by cause, is often seen as unlikely to produce more accurate results (10, 21). Explanatory models only have information on partial effects of determinants of mortality at hand. Mortality projections by cause (a) face the problem of the interdependencies between causes of death (10, 22), (b) automatically lead to a deceleration in the rate of mortality decline over time, due to the increasing share of causes of death that decrease only slowly, and the declining share of causes of death with higher mortality declines (10), and (c) face difficulties in constructing time series of cause-specific mortality due to coding changes (10, 22). Some of these problems are even more apparent when dealing with old-age mortality, because of the lack of quantified information on the determinants and because coding problems are more numerous at older ages.

Although it might be difficult to take into account all the determinants of mortality trends, we argue that the long-term trend in mortality can be identified more accurately if the effects of important determinants with highly irregular patterns, like smoking, are excluded. In our analysis we did so by extrapolating the trend without the effects of smoking, assuming that future trends in smoking-related mortality run parallel with past trends in non-smoking related mortality. We observed that merely regarding recent trends in non-smoking related mortality led to larger gains in e80 among both sexes, and especially among women, which is a likely outcome. Including as well assumptions on the estimated time it will take to eliminate the

effect of smoking, which may be different for men and women, can further improve projections.

Including the mortality experience of the younger cohorts

Another choice that can be made regarding the projection of past mortality trends, is whether or not to take into account mortality trends over subsequent cohorts. With respect to predictions of all-cause mortality the extrapolation of cohort mortality trends is not done often, with the national projections of Australia and the United Kingdom as notable exceptions (22, 23). National agencies are reluctant in using this approach due to the data requirements, the importance of period effects, and the rather stable long-term trend over past periods (23). For the prediction of separate causes of death, for example lung cancer, ischeamic heart disease or stroke, age-period-cohort models or age-cohort models are much more frequently being used (24-27).

We argue that instead of applying a full cohort approach, which is only beneficial if trends are to a large extent determined by cohort effects, the study of trends in younger cohorts at younger ages can help in determining whether the identified long-term trend in old-age mortality is indeed likely to continue, or whether adjustments are necessary. Examining trends in younger cohorts at younger ages can provide insights into the emergence of new determinants that operate cohortwise and whose effects are unmodifiable. For the countries under study, the much higher pace of mortality decline among younger men than among older men could point to favourable trends in cohort-wise determinants among men. Furthermore, the strikingly similar pace of decline in non-smoking related mortality among men and women aged 55-69 suggests that future annual changes in mortality might be similar for men and women.

Including past mortality experiences in other countries

Target setting, in which mortality rates observed for a 'more advanced' subpopulation (region, other country) are viewed as mortality schedules that shall be achieved by another population at some time in the future (8), is frequently applied in forecasts from national statistical offices (8, 22, 28). Often the mortality levels in countries where mortality had declined earlier or faster are applied. In Europe, in the past, the mortality levels of the Nordic countries were frequently used, and nowadays the experience of especially Japan is used as an indication of the ultimate level which could be reached in the projection period (22, 28). More recently, Oeppen and Vaupel recommended the use of the gap between national performance and the best-practice level to forecast life expectancy (29).

Without doubt, projections based on past trends should include the mortality experience of other countries. Taking into account the mortality experience in other countries has as an important advantage that not inevitably a divergence of the mortality levels occurs, which is the case when separate projections for different countries based on the projection of past trends are made. Divergence of old-age mortality levels between countries is not a very likely development, because many of the known determinants of differences in mortality levels, i.e. smoking and other risk factors associated with cardiovascular diseases, socio-economic circumstances, and care for the elderly (30) are amendable.

We further recommend that the choice of the target country should be based on the existence of similar determinants, and not merely on a country with the lowest mortality level. Furthermore, we recommend using target trends instead of target levels, as the latter are much more difficult to reach, and are therefore less feasible. In practice, we purpose to let the national annual mortality changes gradually shift to the annual mortality change of the target country.

Including information on the opposite sex

We observed that not all projection alternatives projected a likely future difference in mortality level between the sexes, i.e. a reduction of the sex-difference in life expectancy . Projections, thus, can also benefit from carefully studying the trends for the two opposite sexes, in order to avoid the occurrence of a reversal of the sex difference in mortality when making projections. The use of equal % annual changes for men and women can help in doing so.

Implications

The identification of the basic long-term trend to be projected should be preceded by a thorough study of past trends and its determinants, including the developments at younger ages, in other countries, and for the opposite sex.

Careful examination of changes in the past trend can determine the length of the historical period. Furthermore, the basic long-term trend in mortality can be identified more accurately if the effects of important determinants with highly irregular patterns are excluded. The study of trends in younger cohorts at younger ages can help in determining whether the identified long-term trend in old-age mortality is indeed likely to continue, or whether adjustments are necessary. Furthermore, projections based on past trends should include the mortality experience of more advanced countries with similar determinants, and of the most advanced sex.

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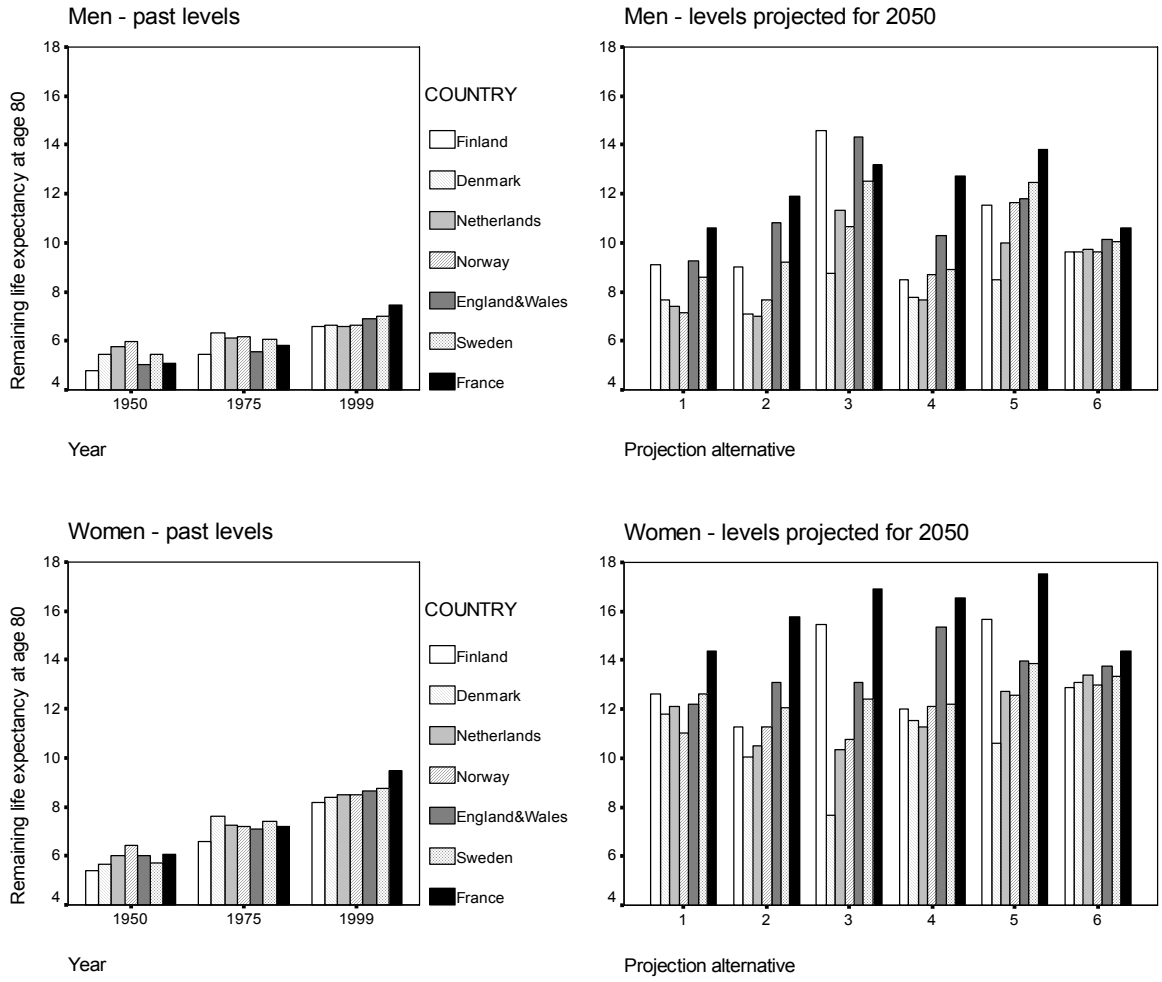
Table 1 - Annual mortality changes (%) for the different projection alternatives, by country and sex

	Total mortality			Non-smoking mortality		
	1950-1999 80+	1975-1999 80+	1975-1999 55-69	1975-1999 80+	1975-1999 55-69	Average
MEN						
Denmark	-0.46	-0.23	-0.86	-0.49	-0.77	*-0.56*
Netherlands	-0.36	-0.19	-1.66	-0.47	-1.26	*-0.79*
Norway	-0.25	-0.45	-1.48	-0.84	-1.76	*-0.95*
Sweden	-0.66	-0.88	-1.92	-0.78	-1.91	*-1.23*
Finland	-1.00	-0.96	-2.51	-0.78	-1.75	*-1.40*
England&Wales	-0.89	-1.36	-2.24	-1.20	-1.63	*-1.46*
France	-1.17	-1.57	-1.93	-1.80	-2.08	*-1.71*
Average	*-0.68*	*-0.81*	*-1.80*	*-0.91*	*-1.60*	*-1.16*
WOMEN						
Denmark	-1.21	-0.64	0.26	-1.13	-0.84	*-0.71*
Netherlands	-1.24	-0.74	-0.69	-0.99	-1.42	*-1.02*
Norway	-0.97	-1.06	-0.88	-1.32	-1.47	*-1.14*
Sweden	-1.37	-1.20	-1.32	-1.25	-1.73	*-1.37*
Finland	-1.53	-1.12	-2.24	-1.35	-2.29	*-1.71*
England&Wales	-1.18	-1.42	-1.42	-1.97	-1.64	*-1.53*
France	-1.59	-1.93	-2.18	-2.10	-2.31	*-2.02*
Average	*-1.30*	*-1.16*	*-1.21*	*-1.45*	*-1.67*	*-1.36*

Table 2 – Estimated gains in remaining life expectancy at age 80 1999- 2050, by country and projection alternative

	Total mortality			Non-smoking mortality		France Total
	1950-1999	1975-1999	1975-1999	1975-1999	1975-1999	1950-1999
	80+	80+	55-69	80+	55-69	80+
MEN						
Denmark	1.06	0.49	2.11	1.14	1.87	3.00
Netherlands	0.85	0.44	4.78	1.12	3.43	3.14
Norway	0.53	1.02	4.01	2.05	5.01	3.02
Sweden	1.59	2.20	5.50	1.92	5.48	3.03
Finland	2.51	2.41	8.00	1.92	4.94	3.03
England&Wales	2.40	3.94	7.44	3.41	4.92	3.30
France	3.13	4.44	5.73	5.24	6.31	3.12
Average	*1.72*	*2.13*	*5.37*	*2.40*	*4.57*	*3.09*
WOMEN						
Denmark	3.40	1.65	-0.70	3.14	2.24	4.68
Netherlands	3.64	2.03	1.86	2.81	4.27	4.91
Norway	2.51	2.79	2.27	3.60	4.09	4.50
Sweden	3.85	3.28	3.67	3.46	5.08	4.59
Finland	4.45	3.08	7.25	3.82	7.45	4.66
England&Wales	3.54	4.42	4.43	6.74	5.33	5.11
France	4.92	6.33	7.43	7.08	8.07	4.94
Average	*3.76*	*3.37*	*3.74*	*4.38*	*5.22*	*4.77*

Figure 1 – Observed and projected levels of remaining life expectancy at age 80, by sex, country and projection alternative



Projection alternative
1 = all-cause mortality among those aged 80 and over in 1950-1999
2 = all-cause mortality among those aged 80 and over in 1975-1999
3 = all-cause mortality among those aged 55-69 in 1975-1999
4 = non-smoking related mortality among those aged 80 and over in 1975-1999
5 = non-smoking related mortality among those aged 55-69 in 1975-1999
6 = all-cause mortality among those aged 80 and over in France in 1950-1999