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The Impact of Demographic Uncertainty on Liabilities for Public Old Age Pensions in Norway

NICO KEILMAN*

Abstract

The paper analyses the importance of demographic uncertainty for the net present value (NPV) of public old age pension obligations in Norway. A probabilistic population forecast is combined with a deterministic macro model for future pension expenditures. The model is applied to Norwegian data for the period 2003-2100. Under the current pension system, the liabilities are likely to grow by a factor of ten towards the end of the century. The demographic driving force is an assumed increase in the life expectancies of men and women by some 13-16 years over the next 95 years.

The results show also that long-run relative uncertainty is larger for total population than for the NPV, due to the enormous uncertainty in the number of births in the long run. In 2100, the 80 per cent prediction interval of population size is 1.5 times as wide as the median value. For the NPV, this relative uncertainty ratio is 80 per cent. Also for earlier years, the relative uncertainty in the NPV is approximately half that in population size. There is no single broad age group, in which relative uncertainty is similar to that in the NPV during the entire period.

After the Second World War, many Western countries developed general systems for the provision of public old age pensions. At that time, life expectancies for men and women were about ten years lower than nowadays. Falling mortality has led to longer periods over which retirees received their pension benefits. At the same time, early retirement and increased disability among older workers resulted in a fall in the actual age at which workers left the labour market. Shorter periods of active life in the labour market and longer periods of life spent as retiree resulted in problems connected to the sustainability of the public old age pension systems. As a result, a number of countries, including all OECD

* Dept. of Economics, University of Oslo, Norway. Email: nico.keilman@econ.uio.no

countries, have revised their pension systems, or are currently considering such a reform.

The performance of the public old age pension system depends strongly on the size and the age composition of the elderly population. Thus, any analysis of the future performance of such a system requires a reliable forecast of the elderly. The precise number of elderly in the future cannot be known in practice, but certain numbers are more probable than others. In other words, a probabilistic approach is required, and the population forecast to be used in the pension analysis should be given in the form of prediction intervals.

The purpose of this paper is to analyse how important demographic uncertainty is for the net present value (NPV) of public old age pension obligations of the Norwegian state. The NPV is a major variable in fiscal policy planning. When its value systematically exceeds the expected tax contributions targeted for public pensions, the pension system is not sustainable. In that case, contributions have to be raised, benefits have to be reduced, or both. If such changes in pension parameters are not sufficient or not feasible, the pension system has to be reformed. Whether a reform is necessary or not, an important question is for how long demographically induced uncertainty can be neglected. To put it differently, how long in advance can one discover early signals that warn us that a pension reform is required, or that pension parameters have to be adjusted?

When one assumes fixed benefits under the current pension system in Norway, the average contribution rate of employees has to increase from 10 per cent of current wages to 23 per cent in 2050 and 30 per cent in 2100. Relative to the Mainland GDP (MGDP), old age pension expenditures will grow from currently 6 per cent to 15 per cent in 2050. Other age-related expenditures are also expected to increase -- for instance, an estimated three percentage point increase to 2050 due to health care. It is unrealistic to assume that a stronger tax burden, neither for individual taxpayers nor for the private sector, can be used to avoid a deficit. Thus, in January 2004, the Norwegian Pension Commission proposed a major pension reform (see Pension Commission:2004).[1] In their analysis of the current obligations of the Norwegian state concerning old age pensions, the commission published deterministic projections of the NPV up to 2100. We will take a stochastic perspective, and present the predictive distribution of the future NPV in selected years, resulting from the predictive distribution of the population in those years. Pension variables are deterministic, including the remaining life expectancy at each age (the period over which pension rights are discounted). Only the age pyramid is stochastic.

Under the current system, Norwegian public old age pensions have a strong PAYG-component, and pension rights depend on two factors: work history, and labour income. Contributions come from employers, employees (through general taxes), and directly from the state budget. The legal retirement age is 67. In practice, many workers leave the labour market before that age, due to disability pensions or early retirement.

Stochastic Demographic Forecast to 2100

Point Predictions

Expected values for key parameters to 2100 were borrowed from Statistics Norway's long-term demographic projections (see Brunborg and Texmon: 2003). These projections are of the cohort-component type. TFR, life expectancy and net immigration to 2100 are in principal straight-line extrapolations of assumed values in Statistics Norway's official forecast for the period 2002-2050, published in 2002 (http://www.ssb.no/emner/02/03/ folkfram/). Table 1 summarizes these key parameters. Inger Texmon kindly provided us with unpublished data.

Table 1: Assumptions in Statistics Norway's long-term population projection

	Registered	Low	Medium	High
1. Total Fertility Rate				
2001	1.78			
2002	1.75	1.74	1.75	1.77
2050		1.40	1.80	2.20
2100		1.07	1.80	2.53
2. Life expectancy at birth, men				
2001	76.2			
2002	76.5	76.0	76.3	76.6
2050		81.6	84.2	86.7
2100		87.6	92.1	96.0
3. Life expectancy at birth, women				
2001	81.5			
2002	81.5	81.4	81.6	81.9
2050		86.0	88.1	90.0
2100		90.9	94.8	97.4
4. Net immigration				
2001	7,955			
2002	17,200	16,000	18,000	19,000
2003	11,300	9,000	15,000	20,000
2004-2100		6,000	13,000	20,000

Specification of Demographic Uncertainty

We used uncertainty parameters from the UPE-project "Uncertain Population of Europe" (see http://www.stat.fi/tup/euupe/) in which annual stochastic population forecasts were computed starting on 1 January 2003 (assumed to be known) to the year 2050 for 18 European countries, including Norway. For the purpose of the current paper we extrapolated Norwegian uncertainty parameters until 2100.

UPE obtains quantified uncertainty of a demographic forecast by applying the cohort-component book-keeping model a large number of times, typically 3,000 or 5,000 times, with a deterministic jump-off population, and stochastically varying values for age-specific mortality, age-specific fertility, and net migration. The method is based on the so-called scaled model for error (Alho and Spencer 1997). The main characteristics of the model in the current application are qualitatively as follows:

- Uncertainty in age-specific mortality and age-specific fertility was treated in the relative (logarithmic) scale; for net-migration uncertainty was treated in the additive scale.
- Uncertainty was assumed to increase with forecast year based on empirical analyses. Error increments were scaled such that they represented increasing patterns of error variances.
- Error increments of each age and sex group have a constant non-negative autocorrelation estimated from the data. Similarly, cross-correlation of errors across age were represented by an AR(1) process with empirically estimated correlations between neighbouring ages.
- Correlation between error increments in male and female mortality, in each age, was included.
- Correlation between errors in male and female net migration was included.
- Uncertainty in fertility, mortality, and migration were assumed to be independent of each other.
- A normal distribution was used to represent error increments for each age- and sex-group.

The UPE-forecast assumptions were based on three separate sources.

1. Time series analyses of age-specific (and total) fertility; age- and sex-specific mortality and life expectancy at birth; net migration by age and sex, relative to total population size.
2. Analyses of historical forecast errors for total fertility, life expectancies, and net migration.
3. Interviews with experts for fertility, mortality, and migration.

(See Alders *et al.* (forthcoming) for details on the UPE assumptions).
For Norway, the following specification was chosen in the UPE project.

Mortality
Scales for error increments were specified so they depended both on age and forecast year. The scales were estimated from long-term data series from Austria, Denmark, Finland, France, West Germany, Italy, the Netherlands, Norway, Sweden, Switzerland, and the U.K. The estimates were based on the median level of uncertainty in the past, averaged across countries. Autocorrelation of error increments was 0.05. Cross-correlation across age was 0.95. Cross-correlation across sexes was 0.85.

Fertility
Scales for error increments were specified so they depended on forecast year but not on age. Total fertility rate was used to obtain the estimates. Initial values for the scales were estimated from the data for 1990-2000, by calculating the standard deviation of first differences (log-scale). Eventual value for the scales was obtained from long-term data series for Denmark, Finland, Iceland, the Netherlands, and Sweden. The initial value was limited to the eventual value linearly. Autocorrelation of error increments was zero, ie. log(TFR) was assumed to be a Random Walk. The cross-correlation across age was 0.95.

Net Migration
Uncertainty in net-migration was specified in terms of total net migration. Scales were determined by connecting an estimate of past variability to a judgmentally chosen ultimate value. Norway relies on population registers as the source of population data, and thus the uncertainty of net migration was set to zero for year t = 2003. Autocorrelation of error increments for Norway was 0.56. Cross-correlation in net migration error between males and females, each year, was assumed to be 0.9. A schedule of empirically estimated gross migration levels by age and sex was estimated based on

data from Denmark (1998-2002), Norway (2000, 2002) and Sweden (1998-2002). It was used as a multiplier to derive the proportional level of uncertainty by age and sex. Thus, the cross-correlation across age was 1.0.

Demographic Results to 2100

We used Juha Alho's macro simulation program PEP ("Program for Error Propagation", see http://joyx.joensuu.fi/~ek/pep/pepstart.htm) to compute 5000 simulations of the population of Norway broken down by sex and one-year age groups. Populations as of 1 January 2004 to 1 January 2100 were forecasted. The population as of 1 January 2003 was the latest considered known.

Throughout the paper, we will present uncertainty for a certain forecast variable in terms of the width of the 80 per cent prediction interval for that variable. We prefer to use 80 per cent instead of the usual 95 per cent (at least in many econometric applications), since a 95 per cent prediction interval would reflect all possible values except for outliers, i.e. values that have a predictive value less than 2.5, or more than 97.5 per cent. The 80 per cent interval gives a better impression of where the major part of the probability distribution is located.

Table 2 presents selected results for the years 2050 and 2100. 80% L and 80 % H represent the lower and upper bounds of the 80 per cent prediction intervals. For reasons of comparison, the last column gives corresponding values from Statistics Norway's deterministic forecast to 2050, and the extrapolations by Brunborg and Texmon to 2100 (Medium Variant in both cases).

The central tendency of the predictive distributions for life expectancy is generally in agreement with the values for the medium variant of Statistics Norway's long term forecast, although the long-range life expectancy for men tends to be a bit low. The median population sizes in 2050 and 2100 are very close to the values predicted by Statistics Norway, and also the numbers of elderly agree very well.

Population size in 2100 shows huge uncertainty, with an 80 per cent prediction interval between 3.7 and 14.2 million. The most important factor here is the uncertainty in the number of live births, as reflected in the population aged 0. Young children contribute to the uncertainty, too. Further results are given in the "Results" Section.

Table 2: Results of stochastic population projections

	Mean	Median	Standard deviation	80% L	80% H	Stat Norway (medium)
Life expectancy, men (yrs)						
2050	84.0	84.0	3.38	79.6	88.3	84.2
2100	91.8	91.8	5.06	85.5	97.7	92.1
Life expectancy, women (yrs)						
2050	88.0	88.0	3.20	83.9	92.0	88.1
2100	95.0	94.8	4.96	89.5	100.3	94.8
Population size (mln)						
2050	5.75	5.63	0.87	4.75	6.87	5.6
2100	8.20	6.59	5.53	3.73	14.2	6.5
Population aged 0 (1000s)						
2050	69.5	60.6	38.9	31.7	118.9	59.5
2100	135.8	67.8	214.1	17.2	303.9	N/A
Population aged 67+ (1000s)						
2050	1.24	1.25	0.16	1.02	1.45	1.25
2100	1.76	1.73	0.43	1.24	2.32	1.8

N/A: Not available

Modelling Liabilities

The Pension Commission published the following projections of the Net Present Value of old age pensions.

Table 3: Projections of Net Present Value of old age pension obligations, billion NOK (2003 value)

2003	2004	2005	2010	2020	2030	2040	2050
2948	3074	3204	3917	5520	7295	9235	11554

Source: Pension Commission Table 10.3

The projections were obtained by means of a micro simulation model, which simulates the demographic, labour market, income, and pension histories of individuals. The NPV is based on an assumed discount rate of four per cent per year, and an annual wage increase equal to 1.5 per cent. Note that both the results of the Commission and our results reported below relate to the *current* pension system, not the proposed reform.

Instead of a micro simulation model, we will use a macro model to trace the consequences of population uncertainty for the NPV. We assume that expenses for old age pensions each year are equal to the average pension times the number of pensioners. The net present value of the current pension *obligations*, however, equals this year's pension expenses plus the net present value of all currently known future expenses, arising from the currently earned rights. The NPV is computed specifically for one-year age groups, both for current and for future pensioners.

One important assumption in this calculation concerns the number of years over which expenses are likely to accrue. We have assumed the following.

1. For all current pensioners, we use the 2004-value of the remaining life expectancy at each age. For future pensioners we use an estimate of the future remaining life expectancy for a 67-year old, from the date they reach 67. Because we assume falling mortality, this will be a higher number than today's remaining life expectancy for the 67 years old.
2. Pension rights are earned linearly from the year a person becomes 16, until his 56th year (or up to 70 years for a person earning income later than age 16). This is in accordance with current rules for pension earning time ("trygdetid"), according to which full pension rights are earned after a period of 40 years. We assume that the pension he receives when reaching 67 years of age is based on the average pension that future year. Data on future average pension are taken from table 3.9 of the Pension Commission's report. In case a person has had income over a period shorter than 40 years, the pension is reduced proportionally according to the number of years he has earned pension rights.

The net present value of the obligations is computed as the sum of all age-specific obligations. Let P_t be the average pension in terms of basic pension units in year t, and let G_t be the size in Norwegian Crowns (NOK) of that unit. Let e_x^t be the remaining life expectancy in year t for a person aged x, averaged across sexes, and rounded to the nearest integer. Let N_x^t represent the population aged x in year t, and let NPV_x^t be the net present value of pension obligations for the cohort that is x years old at 1 January of year t. Finally, r is the annual discount rate. Then for current pensioners we have that

$$NPV_x^t = G_t N_x^t P_t \sum_{i=0}^{e_x^t} \frac{1}{(1+r)^i}, \quad 67 \le x \le 99, \qquad (1)$$

where $x = 99$ indicates the open ended age group 99 and over.

For younger persons, we write k for the number of years until retirement (age 67) for the cohort currently aged x. Let v_x be the fraction of full pension earned, i.e. for a 25-year old $v_{25} = (25\text{-}15)/40$. Then

$$NPV_x^t = G_t N_x^t v_x P_{t+k} \sum_{i=0}^{e_{67}^{t+k}} \frac{1}{(1+r)^{i+k}}, \quad 16 \le x < 67. \qquad (2)$$

The net present value of current obligations is then

$$NPV^t = \sum_{x=16}^{99} NPV_x^t. \qquad (3)$$

With t =2004, r = 0.04, G_{2004} = 56861 NOK, an annual growth in G_t of 1.5 per cent, P_t from Table 3.9 of the Commission's report (interpolated where necessary), and N_x^t as observed for 1 January 2004, we obtained an NPV-value of 3074 billion NOK, which is the same as predicted by the Commission (see Table 3 above).

Results

Table 4 shows main results: median values, with the relative width of 80 per cent intervals in parentheses. The relative width is defined as the width of the interval divided by the median value. First we will discuss uncertainty, and compare the relative width of prediction intervals across variables and over time.

Of the five variables shown here, uncertainty in 2100 is largest for total population -- its 80 per cent prediction interval that year has a width that is 1.5 times as large as the median forecast. As indicated in Section 2, this is due to the enormous uncertainty in births and young children. Figure 1 shows how quickly the relative width of the 80 per cent prediction interval for age group zero accelerates during this century. This age group concerns the grand-grandchildren of children born today. Such a "multiple generation effect" is clearly less relevant for age groups 67+ and 80+. The relative width of the 80 per cent interval for these two groups is roughly between two-thirds and three-fourths. Yet the uncertainty for the 67+ accelerates somewhat around 2075, when the survivors of children born today disappear from that age group, and uncertainty caused by future fertility adds to that caused by future mortality and migration. The uncertainty connected to the Old Age Dependency Ratio, ie. the number of persons aged 67+ as a ratio of those aged 20-66, increases regularly over time to a level that is somewhat higher than that for the number of elderly. This is because the OADR is much more strongly influenced by immigration than the number of elderly is. Yet uncertainty in the OADR is much lower than that in total population, because the impact of fertility is less.

Table 4: Median values and relative width of 80 per cent prediction intervals (in parentheses) for selected population variables and pension liabilities

	2010	2025	2050	2075	2100
Population size (in millions)	4.73	5.13	5.63	6.10	6.59
	(0.023)	(0.117)	(0.377)	(0.839)	(1.586)
Elderly 67+ (in millions)	0.62	0.90	1.25	1.48	1.73
	(0.045)	(0.142)	(0.341)	(0.408)	(0.627)
Elderly 80+ (100 000)	215	254	522	672	858
	(0.097)	(0.337)	(0.646)	(0.698)	(0.750)
Old Age Dependency Ratio	0.212	0.296	0.395	0.448	0.498
	(0.049)	(0.160)	(0.385)	(0.709)	(0.992)
NPV (in billions NOK)	3 846	6 194	11 486	20 448	35 776
	(0.015)	(0.064)	(0.191)	(0.391)	(0.829)

The uncertainty in the NPV is of a similar magnitude as that in the number of elderly, although it accelerates strongly around 2075. It shares this phenomenon with the number of persons aged 67+, but the acceleration is stronger for the NPV. Figure 2 shows the predictive distributions of the NPV in 2050, 2075 and 2100.

Figure 1: Relative width of 80 per cent prediction interval for population variables

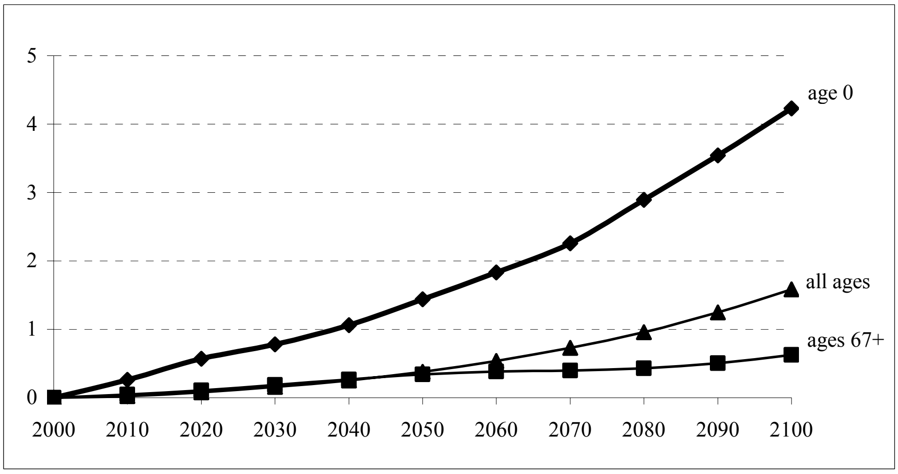
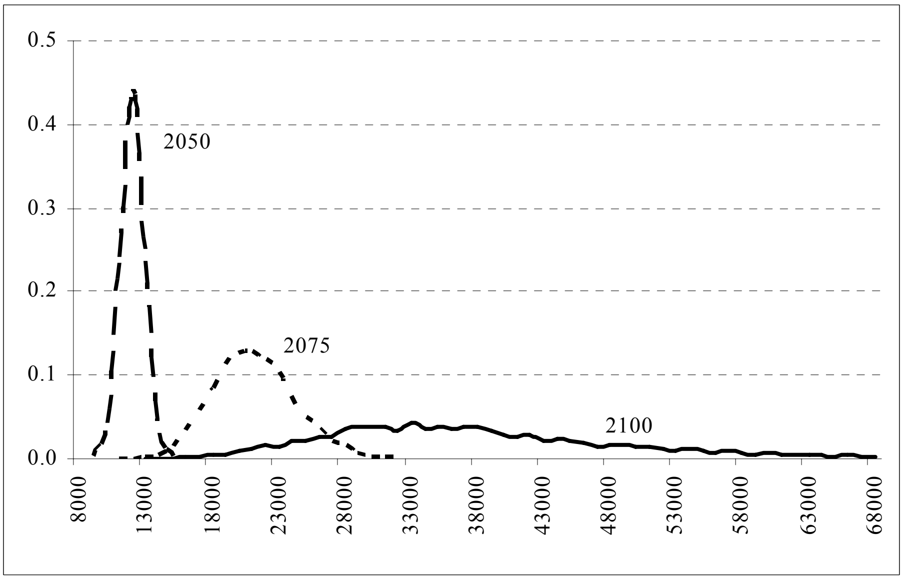


Figure 2: NPV (bln NOK) Predictive distribution



The expected value of the NPV increases regularly over time, from its current 3,074 billion NOK to 11,459 billion NOK in 2050 and 37,740 billion NOK in 2100. Our value for 2050 is very close to the one predicted by the Pension Commission: 11,554 billion NOK (see Table 3). The expected values for 2010 and 2025 are slightly lower than those of the commission. (The Pension Commission did not give predictions beyond 2050.) The predictive distribution for the year 2100 is so flat that it is hardly informative. One should be aware of the horizontal scale, of course – by compressing that scale, one could make the curve for 2100 as peaked as one wishes. But compared to the curves for 2050 and 2075, it is clear that the predictive distribution for the year 2100 reflects enormous uncertainty. Expressed as a ratio of the median forecast, the 80 per cent prediction interval of the NPV-distribution in 2100 is 0.83 -- four times that of the distribution in 2050 (see also Table 4).

How does uncertainty in the NPV compare with uncertainty in the age structure? In the current analysis the uncertainty in the NPV in any year in the future is fully determined by that in the population age structure N_x^t -- in other words, by the variance in each age group and the covariances across ages. Equations (1) to (3) show that the NPV is a weighted sum of the stochastic population sizes of subsequent age groups, with deterministic weights equal to the age-specific pension liabilities per capita. Through the reduction factor v_x, young workers get relatively little weight because they have rather short work histories. Pensioners over 67 contribute little to the overall NPV because they have rather short remaining life spans. Can the relative width of the 80 per cent prediction interval of the *NPV* be approximated by the relative width of that interval for a *certain age group*? If this were the case, a detailed pension model would be unnecessary since we could obtain a first impression of how fast the uncertainty in the NPV increases as a result of growing population uncertainty, by only inspecting population uncertainty.

The question of which age group, if any, might give a reasonable approximation is an empirical one. We have investigated a few selected age groups, and the results are given in Table 5.

In 2004, half the total liabilities were concentrated in ages 47-67. Table 5 gives the relative width of the 80 per cent prediction interval for the NPV and that of the population aged 47-67 in selected years. Comparing rows 1 and 2, we note that the relative uncertainty in the NPV can be approximated quite well by that in the population aged 47-67 during the first half of the century. In the second half of the century, however, this is no longer the case, since the NPV is less uncertain, in relative terms, than the population aged 47-67. Uncertainty in the latter grows rapidly after, because the children and grandchildren of currently unborn generations enter the age group 47-67.

Neither the retirees (row 3) nor the population of labour force age (row 4) give an accurate description of uncertainty in the NPV. The uncertainty in population aged 17-66 increases much faster than that in the NPV, as a result of the accelerating uncertainty attached to subsequent generations. For the population aged 67 and over, the increase is much slower than that in the NPV.

After some experimentation (not all results are reported here) we concluded that it is unlikely that one single age group is able to display the same relative uncertainty as the NPV for the entire 21st century. The changes in the age structure, in mortality, and in the pension rights per capita, result in a complex propagation of the forecast error in the NPV, as a result of the error in the population forecast. The population aged 47 to 67 can be used for the first half of the century only. In fact, the relative prediction interval in total population (row 6) shows a development over time that is closely parallel to that in the NPV – but this may be a mere coincidence.

Table 5. Relative uncertainty (width of 80 per cent prediction interval as a ratio of the median value) in NPV (all ages) and in population of selected age groups

	2010	2025	2050	2075	2100
NPV	0.015	0.064	0.191	0.391	0.829
POP 47-67	0.010	0.052	0.185	0.471	1.018
POP 67+	0.045	0.142	0.341	0.408	0.627
POP 16-66	0.022	0.086	0.309	0.803	1.577
POP 16+	0.018	0.071	0.237	0.612	1.216
POP all ages	0.023	0.117	0.377	0.839	1.586

The results in this paper are based on a number of assumptions. General assumptions for demographic variables for the underlying pension calculations and for uncertainty parameters were presented earlier. But two important assumptions for the remaining life expectancy at each age (the variable e_x^t) have not yet been made explicit. First, these life expectancies are based on period life tables instead of cohort life tables. Second, they are deterministic, not stochastic.

1. For the present calculations, we took the values for e_x^t from the period life tables that correspond to future age-specific mortality as assumed by Brunborg and Texmon in their long-range demographic projections. For instance, the assumed remaining life expectancy for a person aged 67 in the year 2010 is 16.8 years. This value is based on a period life table, i.e. the death rates assumed for the year 2010. However, mortality is assumed to fall after 2010. For instance, in the year 2050, when none of the persons who were aged 67 in 2010 are alive any longer, the remaining life expectancy at age 67 is assumed to be 22.3 years. When, however we inspect the remaining life expectancy at age 67 in 2010 based on a *cohort* life table (in other words for persons born in 1942) we find 18.1 years. In general, because mortality is falling at all ages, the use of period life tables implies underestimating the remaining life expectancy at all ages and thus also the NPV.
2. Remaining life expectancies for future years are stochastic, with uncertainty increasing with forecast horizon. For instance, the relative width of the 80 per cent prediction interval for remaining life expectancy of persons born in 1942 is 0.21, or one-fifth of the median value of 18.1 years. For birth cohort 1982 the corresponding number is 0.36, i.e. one-third the median value of 22.5 years. Remaining life expectancy is positively correlated with population numbers, and thus the NPV-intervals given above are too narrow.

Conclusion

In this paper we have analysed the uncertainty in the Net Present Value (NPV) of future public old age pension liabilities in Norway, as a result of growing uncertainty about the future Norwegian population. Under the current pension system, the liabilities are likely to grow by a factor ten towards the end of the century. A demographic driving force, life expectancy, is assumed to increase by some 13-16 years over the next 95 years, which is in accordance with long-term demographic projections of Statistics Norway, carried out by Brunborg and Texmon. Total fertility and net migration are assumed to remain constant in these projections. Demographic uncertainty is in accordance with that in the probabilistic population forecast for Norway computed in the framework of the UPE ("Uncertain Population of Europe") project. The UPE-calculations apply to the period 2003-2050, and we have extrapolated uncertainty parameters to 2100. The results show an increase not only in the expected value of the NPV, but also in the uncertainty surrounding central values. For instance, the 80 per cent prediction interval for the NPV is less than two per cent of its median value in 2010, but it grows rapidly to six per cent of the median in 2025, 19 per cent in 2050, 39 per cent in 2075 and to over 80 per cent of the median NPV-value in 2100. Thus, although our best guess for the NPV in 2050 is in the order of 11 500 billion Norwegian Crowns, the odds are one against four that the NPV that year will be higher than 12 600 billion, or lower than 10 400 billion crowns. Although the uncertainty in the NPV-prediction for 2050 is certainly non-negligible, it is much less than that in the population in 2050. Population size is expected to be 5.75 million in 2050, with a median equal to 5.63 million. The 80 per cent prediction interval stretches from 4.75 to 6.87 million – in other words, its width is 38 per cent of the median value. Thus the relative uncertainty in population size in 2050 is twice that of the NPV. We found that also in other years in the period to 2100 relative uncertainty in population size is approximately twice as large as relative uncertainty in NPV.

Although the results in this paper give a realistic impression of the prediction intervals around future public old age pension liabilities, they are no more than a first impression. In future work we need to take account of cohort mortality, instead of the period-based mortality parameters used in this paper. This will result in somewhat higher estimates for the NPV. A further point is that the prediction intervals for the NPV in this paper are somewhat too narrow, because we considered remaining life expectancies in the discount formula as deterministic, not stochastic.

Notes

1 For an English summary of the Pension Commission's proposal, see http://www.pensjonsreform.no/english.asp

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