

## **2016-based national population projections**

### **Update note – Scotland mortality assumptions**

Papers regarding the proposed fertility, mortality and migration assumptions for the 2016-based national population projections were issued in June 2017 to key stakeholders. Consultation meetings were held during June by ONS, the National Records for Scotland (NRS) and Northern Ireland Statistics and Research Agency (NISRA) to discuss the proposals. In addition, the Welsh Government (WG) invited key stakeholders within Wales to comment on the proposed assumptions by correspondence.

Further to the consultation exercise, ONS provided NRS with the following additional paper providing further detail on the proposals for setting mortality assumptions for Scotland.

# **Comparison of the differentials in mortality rates between Scotland and the United Kingdom and Proposals for mortality assumptions for use in the 2016-based population projections for Scotland**

## **1. Background**

The current methodology (termed the ONS method in this paper) for projecting mortality in the official national population projections for the United Kingdom and constituent countries requires firstly deriving assumed mortality rates and rates of mortality improvement for the UK as a whole for the base year of the projection period. This is based on an analysis of past trends of mortality rates and improvements carried out on UK data. These are then adjusted for each constituent country after comparing the mortality experience for each country against that for the UK as a whole.

For the 2016-based projections, smoothed mortality rates for the UK for calendar years 1961 to 2015 have been derived using p-splines on deaths data and mid-year population estimates for those years (age specific population estimates are not available to carry out this analysis for the UK before 1961 for most years of age). The past trends in mortality are then projected forward to provide base mortality rates for the first year of the projections (2016) and to calculate the mortality improvements between 2015 and 2016, as described in section 2 of NPP paper 17(3) 'Mortality assumptions for the 2016-based national population projections'. Assumptions of future mortality improvements beyond the base year are then made by age, sex and year and these are applied successively to the base mortality rates derived for 2016 to obtain projected future mortality rates.

Country specific base mortality rates for 2016 are then derived by calculating the ratios of the age specific mortality rates for each constituent country to the corresponding mortality rate for the UK as a whole, in each case taken from the latest available National Life Tables (covering the period 2013-15). The resulting ratios are then smoothed and applied to the age-specific base year mortality rates derived for the UK for 2016, to obtain base year mortality rates for each country.

The comparison of past trends for each country and for the UK is also used to assess whether different mortality improvement rates for the base year and for future years should be used for each country compared to those derived for the UK as a whole. In past projections, whilst different base mortality rates were used for each country, the same age and sex-specific base rates of improvement were assumed for England, Wales and Northern Ireland, with different improvement rates assumed for Scotland at some ages.

The NPP paper 17(3) also discussed the possibility of adopting a new method for projecting mortality rates based on an approach developed by the

University of Southampton (termed 'the UoS method' in this paper). It has been decided that further testing is required of the UoS method before considering it for adoption in the population projections. Hence the ONS method will be retained for the 2016-based projections.

This paper provides a comparison of historical trends in mortality in Scotland with those for the UK. It also outlines the mortality assumptions proposed to be adopted for Scotland in the forthcoming 2016-based projections under the ONS method, based on the methodology used in past projections to derive assumptions for Scotland by adjusting those derived for the UK as a whole.

The results of the UoS method in its current form applied directly to Scottish historical data to derive projected mortality rates and improvement rates for Scotland data are given in the Annex, together with a comparison with the results obtained using the current method.

## 2. Comparison of trends

The following comparisons between Scottish and UK data have been considered:

- Period expectations of life at birth and at ages 20, 40, 60 and 80;
- Age-specific death rates ( $m_x$  values); and
- The ratios of improvements in mortality rates derived from National Life Tables.

These comparisons have been carried out on aggregate mortality data only and are discussed in the following sections.

Where comparisons of mortality rates are made these are based on central death rates ( $m_x$ ) calculated by dividing numbers of deaths aged  $x$  last birthday in a calendar year by the mid-year population aged  $x$  last birthday for that year.

### 2.1 Comparisons of period expectations of life

Figures 1 and 2, show the differences between the period expectations of life (eols) for the UK and Scotland, for ages 0, 20, 40 60 and 80, for each year between 1961 and 2015. A negative value indicates that the value for Scotland is lower than the corresponding value for the UK.

Figure 1 shows the comparison for males. As can be seen, during the 1960s and early 1970s the trend in the differences was relatively constant for each age shown, albeit with some year to year fluctuation. Since the mid-1980s the overall trend has been a gradual widening in the difference in period expectations of life between the UK and Scotland. However, from 2007 differentials appear to be reducing, except for age 80; although the last two years have seen increasing divergence again.

Figure 2 shows the comparison for females. The trends in the differences show signs of convergence in the late 1960s and early 1970s before remaining relatively stable during the mid-1970s. This was followed by a gradual divergence during the late 1970s and early 1980s. Differentials remained relatively stable again from the mid 1980s until the end of the 20<sup>th</sup> century, apart from two sharp increases in divergence in 1989 and in 1993, which in both cases were subsequently reversed in the following year. Since 2000 the trends show an increasing divergence compared to the figures for the UK with the largest differentials have been observed in 2012. As for males, there was a reversal in these trends in 2013, after which the differentials stayed relatively constant in 2014 and 2015.

Figure 1 Difference between period expectation of life in the UK and Scotland, Males, selected ages, 1961 – 2015

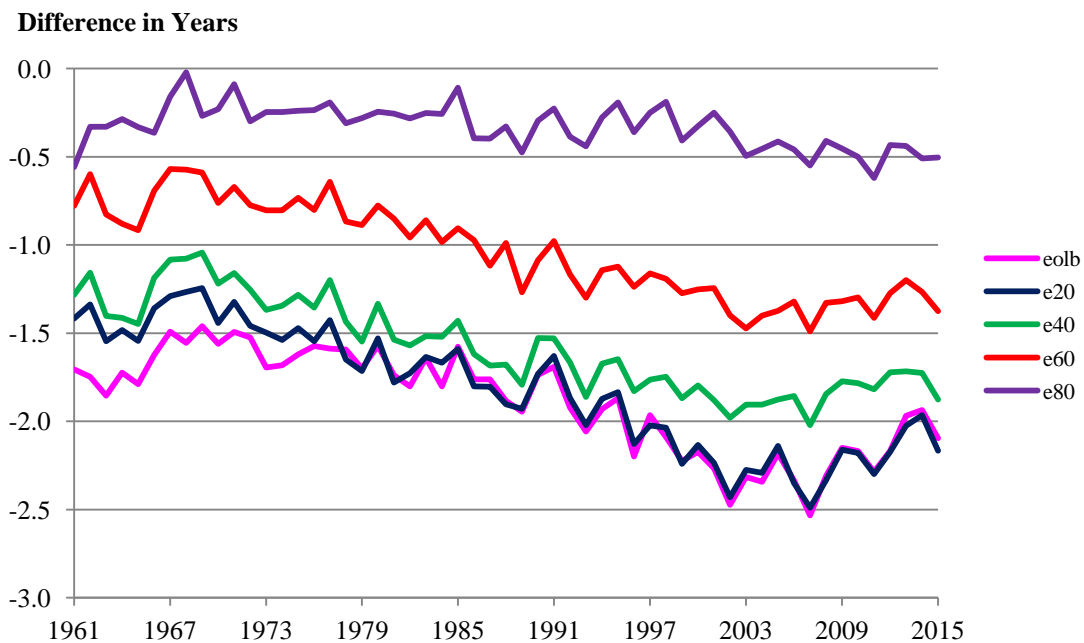
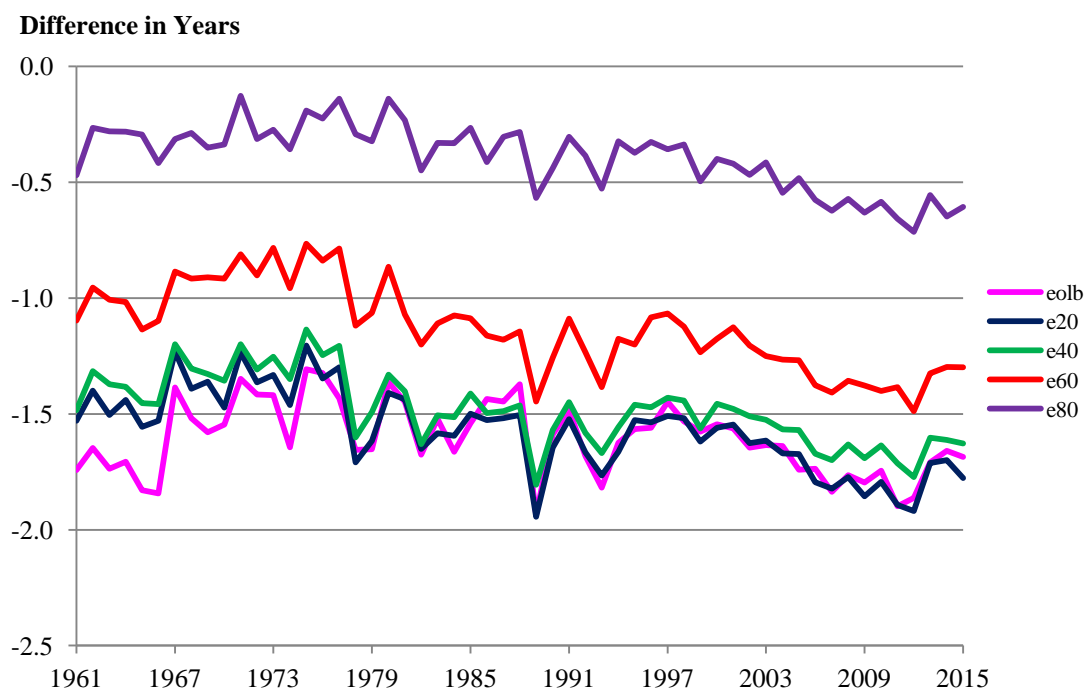


Figure 2 Difference between period expectation of life in the UK and Scotland, Females, selected ages. 1961 – 2015



The diverging trends in the absolute differences in the expectation of life values between Scotland and the UK in the past for males and females for ages up to 80 illustrated by Figures 1 and 2 have led to lower rates of mortality improvement being assumed in recent past projections at some ages for Scottish males and females over the first 25 years of the projection period (together with higher rates at some other ages for Scottish males).

## 2.2 Comparison of death rates (mx)

Figures 3 and 4 show the annual improvements in the derived smoothed values of death rates by sex, age and year for 1961 to 2015. As can be seen there is evidence that, as for the UK as a whole, both males and females born in the late 1920s to late 1930s experienced higher mortality improvements than those born either side, at least until recent years. For males in their 30s and 40s there appears to have been little improvement in mortality over recent years, whilst for females at those ages the trends suggest worsening mortality.

Figures 5 and 6 show the ratio of death rates for Scotland to the equivalent death rate for the UK for a given age, sex and year. The ratios shown are calculated using mortality rates for Scotland and for the UK which have been smoothed using a p-spline methodology.

In Figures 5 and 6, the ratios of Scottish death rates to UK death rates, analysed by sex, age and year, are indicated by bands of different colours. The general colour scheme used shows ratios of less than one (i.e. where

Scottish rates are lower than UK rates for the same age and period) as differing shades of blue. Ratios of more than one are shown as green then yellow, orange and finally dark red as the value of the ratio increases. The ratio bands depicted by each colour are given to the right of the chart.

Figure 5 suggests that the ratio of the smoothed death rates for Scotland to those for the UK appear to be gradually increasing over recent years for a given age for males aged between 20 and 45. Conversely, mortality rates at ages 55 to 70 appear to be improving more rapidly in Scotland than in the UK.

In the 2016-based projections, rates of mortality improvement will be projected by age for ages below 57 and by year of birth for those aged 57 and over in 2016. Considering cohorts, males currently aged around 70 to 80 appear to have experienced wider differentials to UK mortality rates (for the same cohorts) over the past 30 years than those born immediately before or after. However, the chart provides some evidence that this divergence has been decreasing in recent years as these people have aged. If lower initial rates of improvement are assumed at these ages, they will be projected forward by cohort to the same target rate as for the UK in 2041, so the differentials with the UK would be projected to reduce over time. This is supported to some extent by the figures which indicate that there is convergence in the rates of mortality improvement at the oldest ages.

Figure 6 suggests that female mortality rates at ages 20 to 50 and at ages 70 and over are improving less rapidly in Scotland than in the UK. As for males, there is evidence that the cohorts currently aged 70 to 80 appear to have experienced wider differentials to UK mortality rates (for the same cohorts) over the past 30 years than those born immediately before or after but that this divergence has been decreasing in recent years as these people have aged.

Figure 3: Improvements in smoothed mx rates for Scotland, Males, 1962-2015

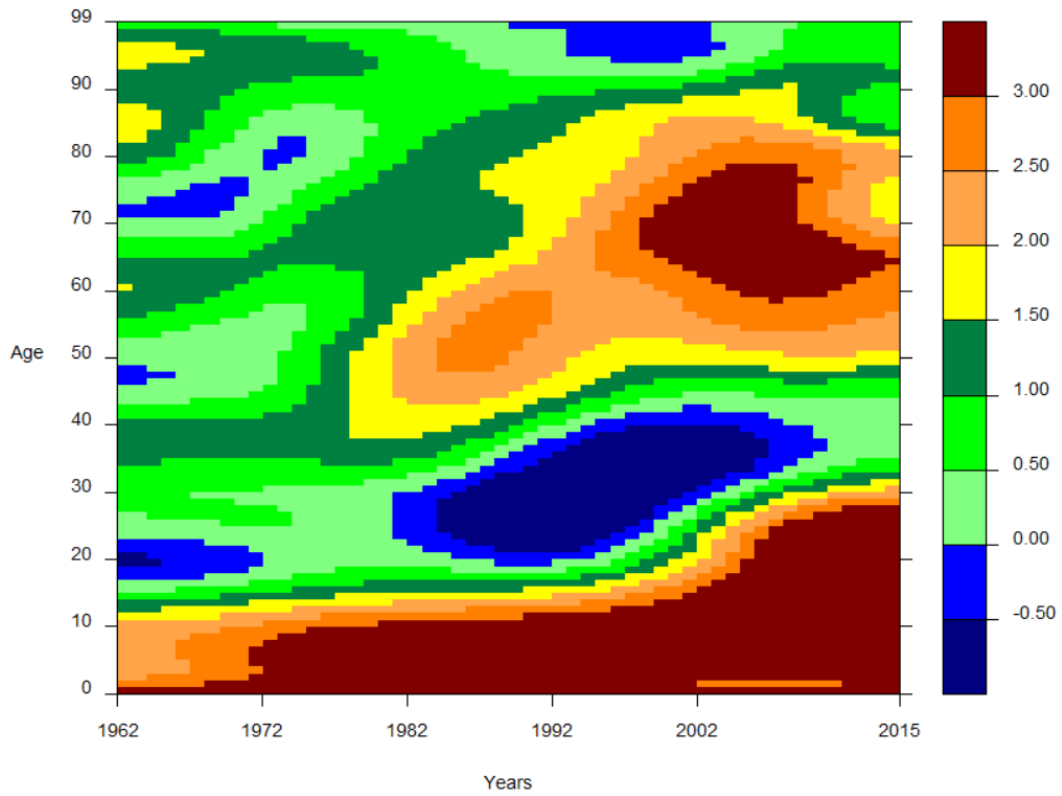


Figure 4: Improvements in smoothed mx rates for Scotland, Females, 1962-2015

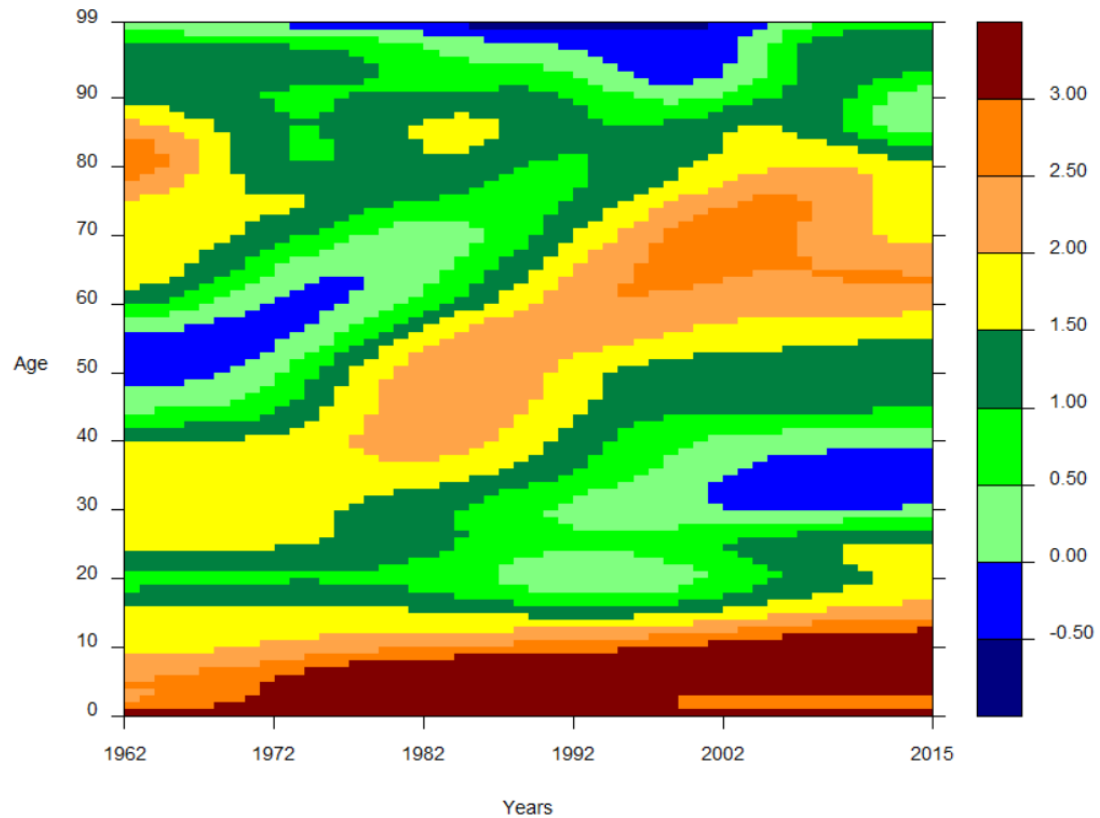


Figure 5: Comparison of Scottish and UK death rates – Scottish  $m_x$ /UK  $m_x$  Males, 1961-2015

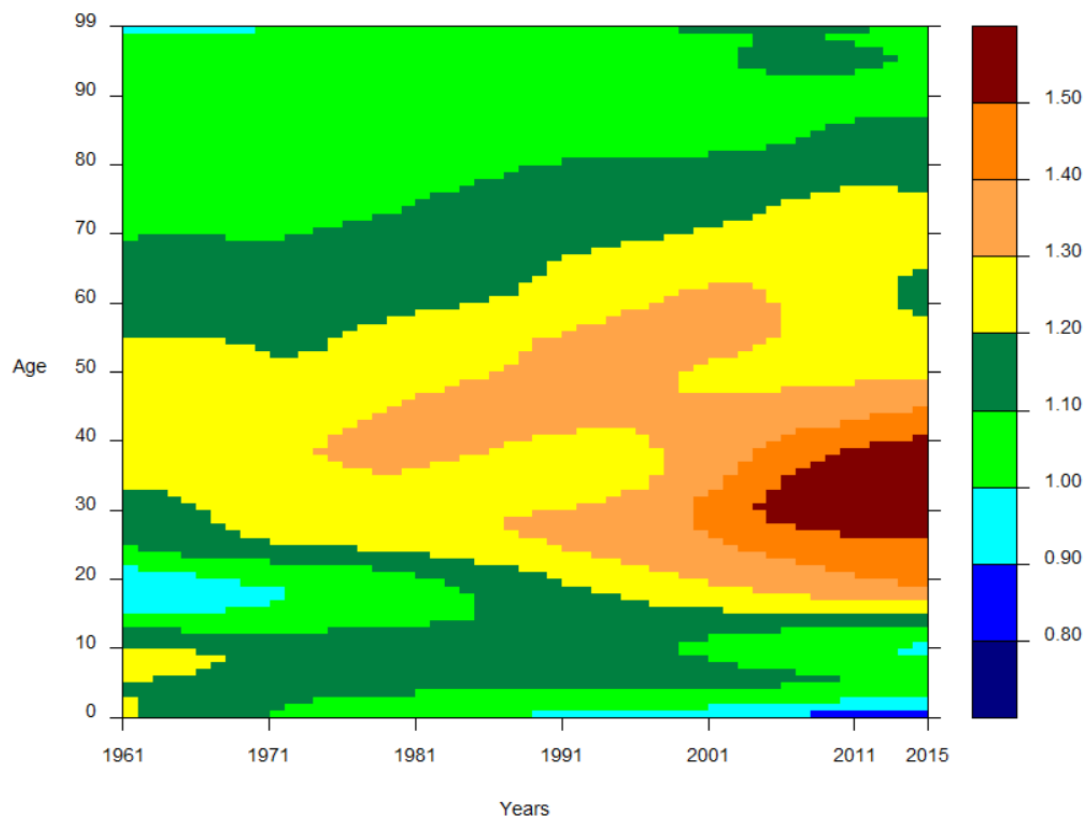
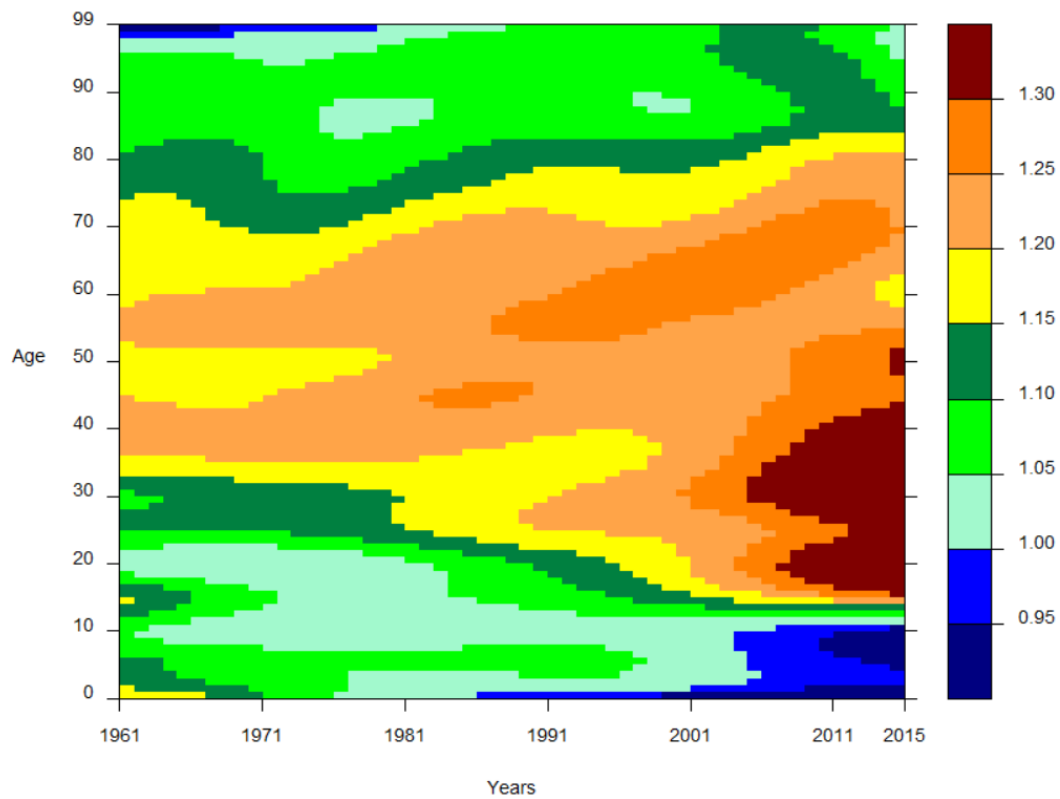


Figure 6: Comparison of Scottish and UK death rates – Scottish  $m_x$ /UK  $m_x$  Females, 1961-2015





## 2.3 Ratios of improvements in death rates derived from National Life Tables data

Figure 7a shows the differences in the average annualised rate of mortality improvements for Scotland and the UK by age and sex over the past 10 years. These have been calculated as the difference in the annualised rate of mortality improvement obtained by comparing mortality rates from the National Life Tables (NLT) for the years 2013-15 to those in the NLT for years 2003-05 for Scotland and for the UK.

Figure 7b shows the differences after smoothing by taking the average over 5 years of age.

The results are dependent on the starting and end points of the period used for analysing the improvements. A period of 10 years was chosen to lessen the effects from this whilst still providing results over a recent period.

Positive values in Figure 7 indicate a relatively greater rate of improvement in Scotland to that in the UK and vice versa. Excluding the values below age 25, which can be influenced by random fluctuations given the low numbers of deaths at the youngest ages, it can be seen for males that the relative improvement in Scotland were lower than for the UK for ages in the late 20s to the early 50s. For males aged in their mid 50s and 60s, mortality improvements are generally higher in Scotland than the UK before falling below those for the UK again for most ages from around age 70 to age 90, although generally not as low as for ages in the 30s. Fluctuations beyond age 90 are likely to be due to low numbers of deaths. Scottish females also appear to be experiencing lower rates of improvement over the age range 25 to 55 and also at ages over 68 up to age 90 and higher rates of improvement for ages 56 to 68.

In order to obtain proposals for initial improvement rates for Scotland for 2016, the resulting smoothed differences in mortality improvement by age were added to the rates of improvement estimated for the UK for the base year of the projections. This gives a set of improvement factors for Scotland for the base year of the projections.

The resulting rates of improvement for Scottish males are shown in Figure 8, together with those proposed for the UK. This suggests that improvement factors which are lower than those proposed for the UK should be adopted for males in their 30s and 40s and also for ages in the 70s and 80s. Higher rates might be assumed for males in their late 50s and early 60s.

Proposed smoothed rates of improvement for Scotland males are shown in Figure 9; these use the proposed UK rates until age 28, after which the improvement factors derived for Scotland are proposed until age 89 (after some additional smoothing, and also including higher assumed rates of improvement in Scotland for males age 53 to 67) when the UK factors are again used. Figure 9 also shows the proposed base rates of improvement for males in the UK.

Figure 7a: Difference in average annualised improvement in mortality for Scotland compared with UK, based on NLT data for periods 2003-05 to 2013-15

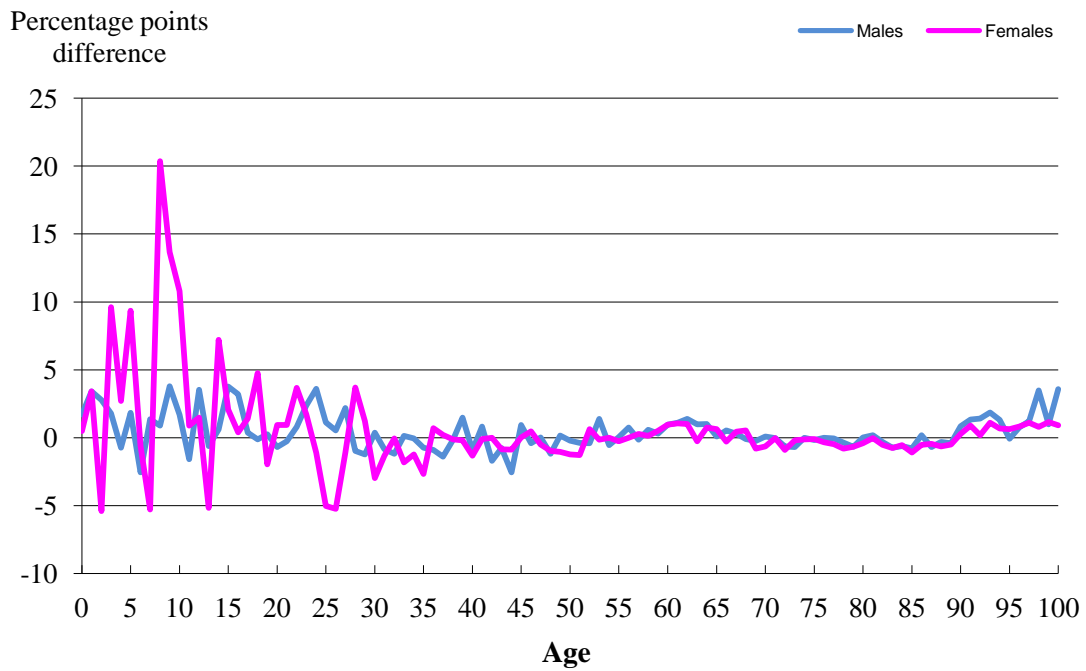


Figure 7b: Difference in average annualised improvement in mortality for Scotland compared with UK, based on NLT data for periods 2003-05 to 2013-15 (smoothed)

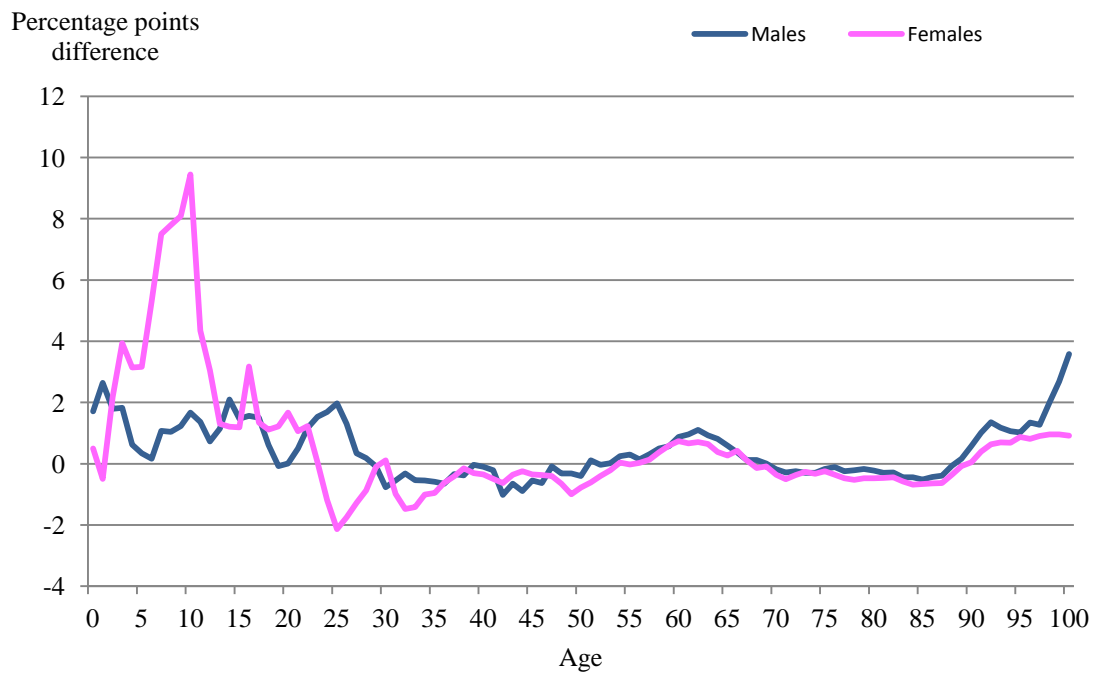


Figure 8: Comparison of improvement factors in base year of projections for UK and those derived from Scotland - Males

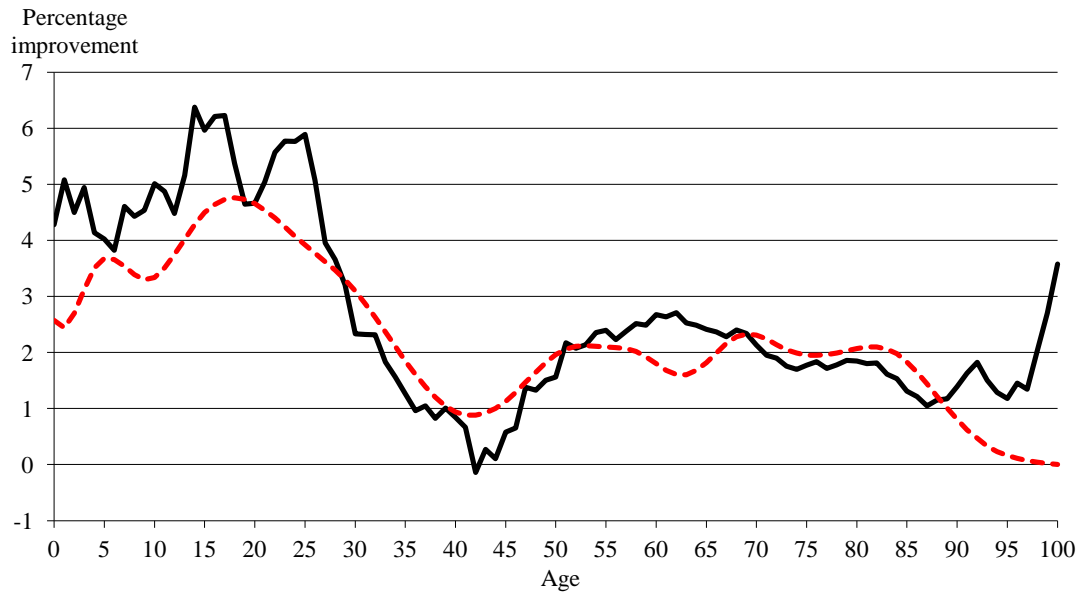
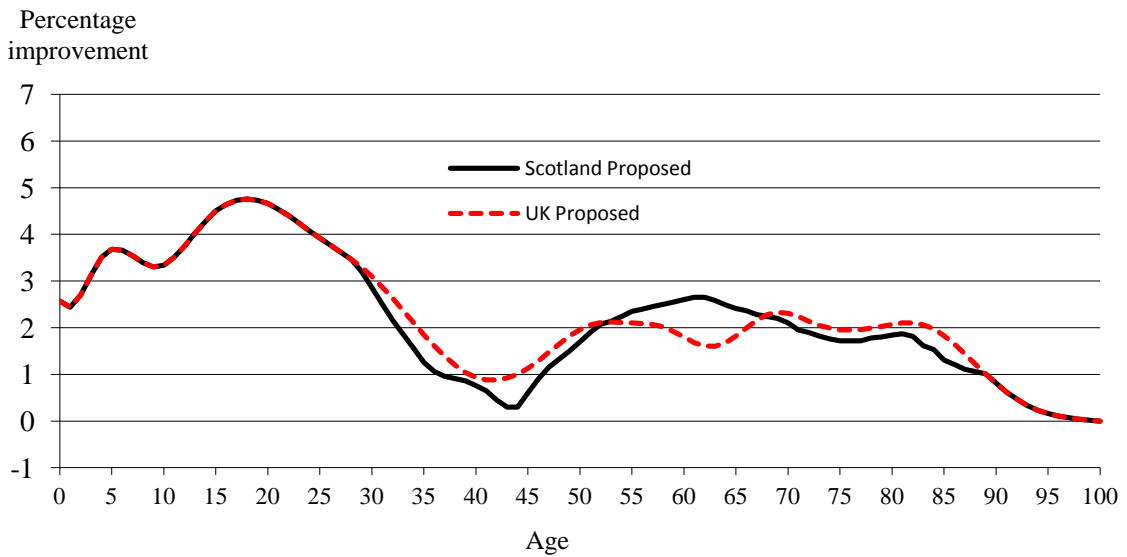


Figure 9: Comparison of proposed UK and Scotland mortality improvements for base year of projections – Males



The rates of improvement initially derived for Scottish females are shown in Figure 10, together with those proposed for the UK. This suggests that improvement factors which are lower than those proposed for the UK should be adopted for females for ages in the mid-20s to the mid-50s and also from the late-60s to the late-80s.

Suggested rates of improvement for Scotland females are shown in Figure 11; these use the proposed UK rates until age 24; lower rates of improvement are proposed for ages 24 to 53, then higher improvement rates than for the UK for ages 54 to 66 and lower rates of improvement for ages 67 until 89. Figure 11 also shows the proposed base rates of improvement for females in the UK.

Figure 10: Comparison of improvement factors in base year of projections for UK and those derived from Scotland – Females

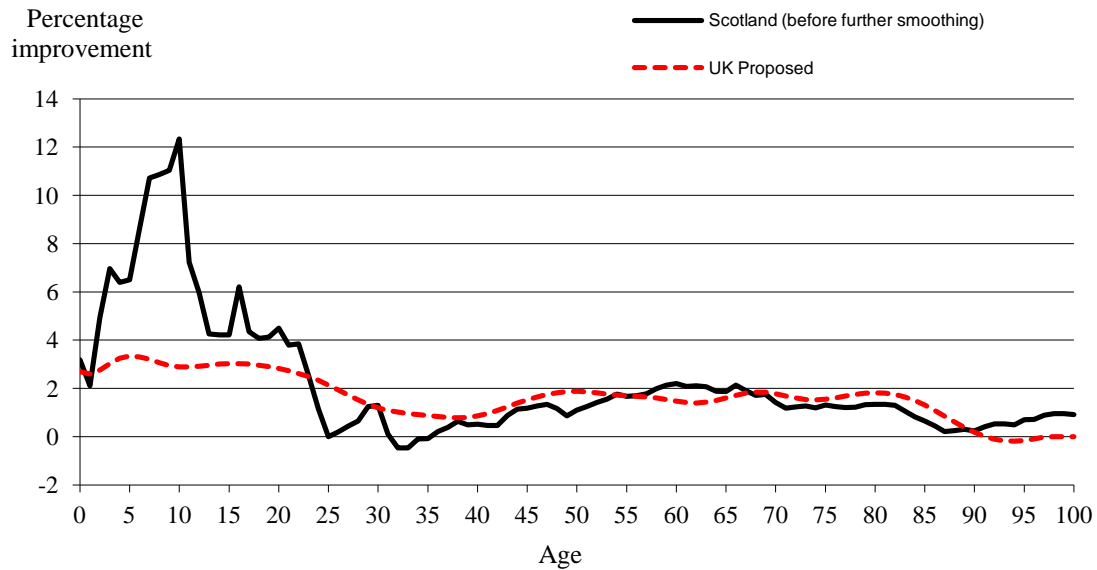
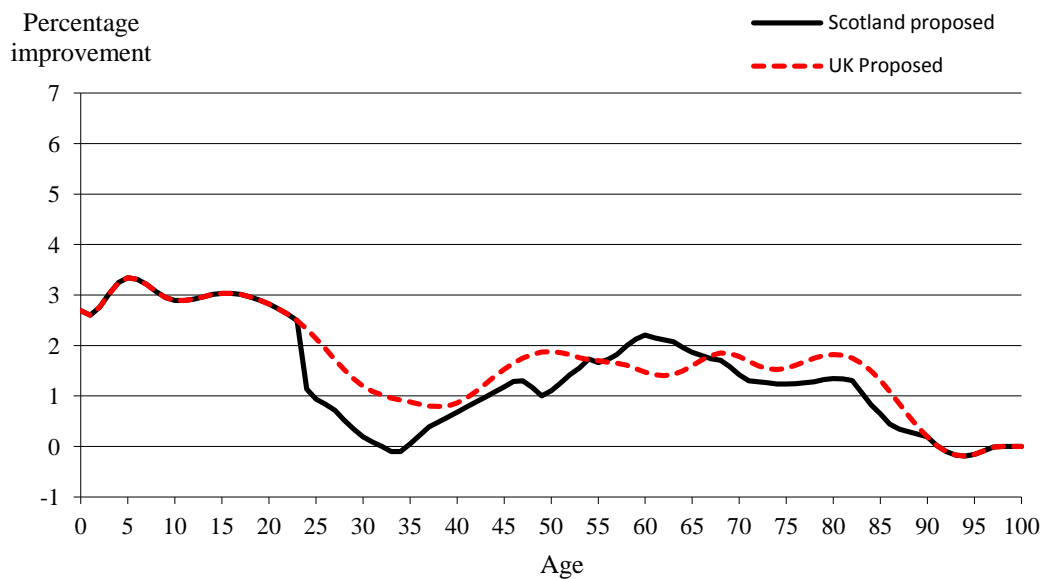


Figure 11: Comparison of proposed UK and Scotland mortality improvements for base year of projections – Females



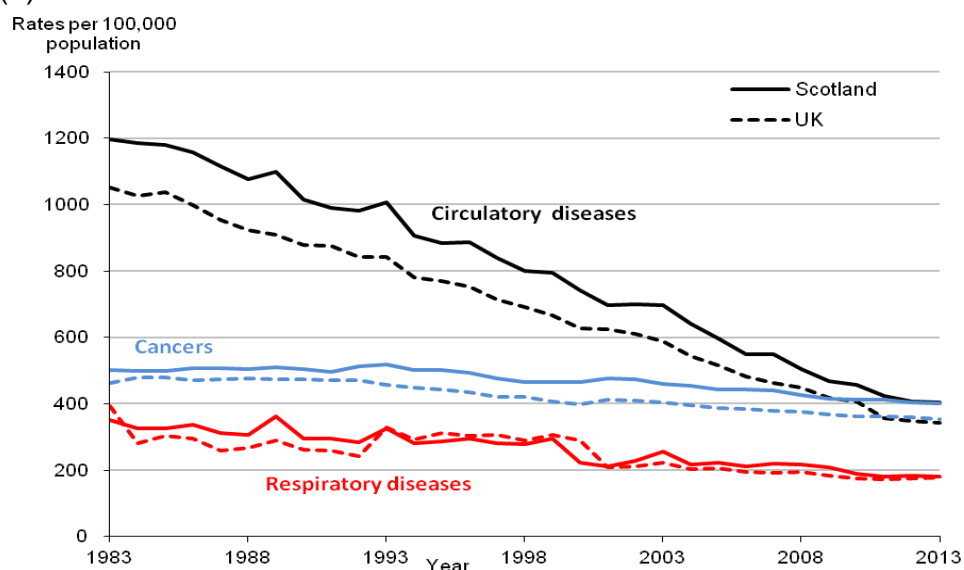
For projections before the 2014-based projections, smaller differentials than those suggested by the analysis were proposed for females as the extent of the lower rates of improvement in past years at the ages proposed to be adjusted was not clear. In general, adjusted improvement rates for females were taken as the values equal to those midway between those derived for Scotland and those derived for the UK as a whole. For the 2014-based projections the full differential was assumed. As the proposed lower rates of improvement for females at some ages appears to be continuing it is proposed to take the full differentials as outlined above again, subject to some smoothing.

### 3. Data by cause of death

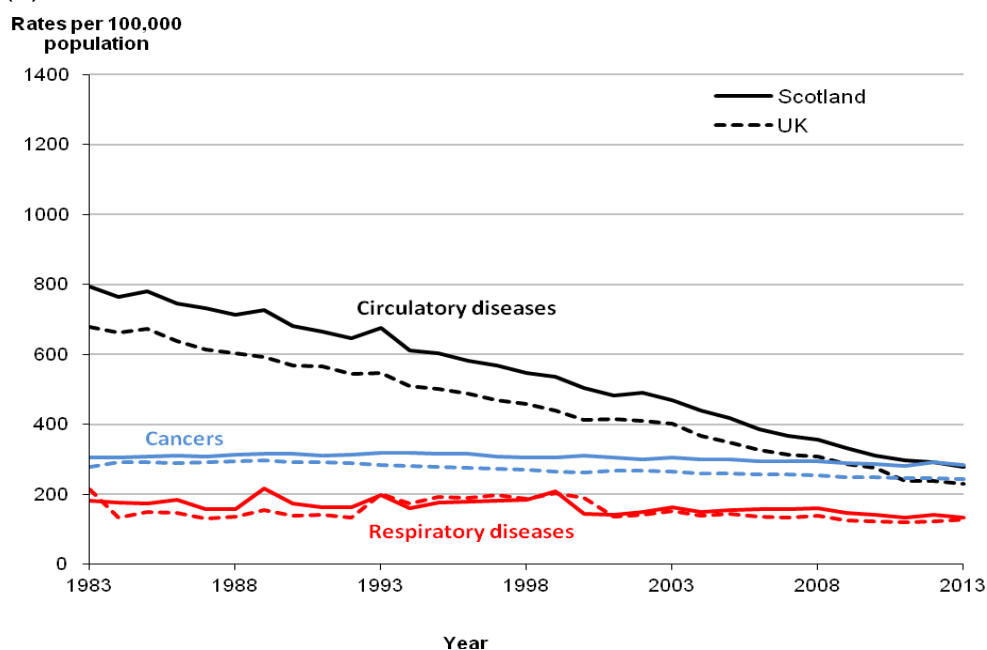
Figures 12(a) and (b) show the age standardised mortality rates by selected major cause of death over the period 1983 to 2013 for both Scotland and the UK for males and females separately. The age-specific death rates have been standardised to the 2013 European Standard Population using 5 year age groups up to 95+.

Figure 12 Age standardised mortality rates by selected major cause group, Scotland and UK 1983–2013

#### (a) Males



#### (b) Females



Sources: NRS, ONS

The overall trends for Scotland for both males and females follow those for the UK. The age standardised death rates from respiratory diseases since 1993 are at similar levels (there are some fluctuations with these latter data following the various changes in coding deaths where pneumonia is involved). Standardised death rates from cancers and circulatory diseases for Scotland broadly follow the same trends as for UK, but death rates have been higher for Scotland than for UK over the period. The graphs also suggest that the gap for circulatory diseases has been narrowing over recent years, whilst that for cancers has been relatively stable for both males and females.

The trends shown by the graphs do not suggest that aggregate mortality rates for Scotland are likely to converge to those for UK over the short term at least. However, they do indicate the potential for there to be more rapid improvements in mortality rates in Scotland than for UK at some time in the future.

The age-standardised mortality rates for circulatory diseases have now fallen below those for cancer for females in the UK and in Scotland, and are very similar for males. This suggests that future improvements in mortality from cancer will become a major influence on the course of future changes in mortality.

#### 4. Comparison of past and projected annualised rates of improvement in aggregate age-standardised mortality

Table 1 shows the annualised rate of improvement in age standardised aggregate mortality rates for ages 0 to 99 inclusive over the last 23, 33, 53 and 83 years for Scotland and the UK. The calculations for both use the  $m_x$  values derived from the decennial life tables for Scotland and for England and Wales (used as a proxy for the UK as a whole) for 1930-32, 1960-62, 1980-82, 1990-92 and the National Life Tables for 2013-15. The standard populations used were the mid-2011 population estimates for the UK.

Table 1 Estimated past annual rate of improvement in age standardised aggregate mortality rates for Scotland and England and Wales, for ages 0-99

Period ending in 2013-15 (years)	Annualised rate of improvement in aggregate age- standardised mortality rate for ages 0 to 99			
	Males		Females	
	Scotland	E&W	Scotland	E&W
23	1.98%	2.21%	1.29%	1.38%
33	1.82%	2.08%	1.26%	1.46%
53	1.38%	1.61%	1.21%	1.34%
83	1.10%	1.29%	1.14%	1.28%

The figures show that the pattern of annualised rates of mortality improvement over the last 22, 33, 53 and 83 years are similar for both Scotland and

England and Wales. For both males and females, the rate of improvement has been lower in Scotland than in England and Wales. Mortality rates for males in Scotland increased by around 0.23% per year less than in England and Wales over the last 23 years, compared to a differential of around 0.19% per year less over the last 83 years. For females the differentials are 0.09% per year less and 0.14% per year less over the same periods.

Table 2 shows the projected rates of improvement over the next 23, 33, 53 and 83 years using the proposed assumptions for the UK and those proposed for Scotland.

Table 2: Projected annual rate of improvement in age standardised aggregate mortality rates for Scotland and the UK for ages 0-99

Period beginning in 2016 (years)	Annualised rate of improvement in aggregate age-standardised mortality rate for ages 0 to 99			
	Males		Females	
	Scotland ONS	UK ONS	Scotland ONS	UK ONS
23	1.57%	1.55%	1.23%	1.32%
33	1.46%	1.44%	1.22%	1.28%
53	1.36%	1.35%	1.21%	1.25%
83	1.30%	1.30%	1.21%	1.23%

For males, for a given period similar annualised improvements are projected for Scotland as for the UK. For females, lower annualised improvement rates are projected for Scotland than for the UK over the short term. However, for males and females, the differential is narrower for a given future period than for the equivalent period in the past. Thus, the proposed adjustments to rates of improvement in Scottish mortality relative to that for the UK will produce smaller differentials over a given future period than was exhibited over the past period of the same length.

## 5. Comparisons

This section provides various comparisons of the proposed assumptions for Scotland for the 2016-based projections with those proposed for the UK, with projections derived using Scottish base mortality rates for 2016 and assuming the proposed mortality improvement factors for Scotland were those for the UK, and with the 2014-based projections for Scotland.

### 5.1 Comparison of proposed assumptions for 2016-based mortality projections for Scotland and for the UK

Table 3 shows the proposed reductions in death rates for the UK for various ages in selected future years and the total reduction over twenty-five years from 2016 to 2041. In this table the first column shows the reductions not from the actual mortality rates in 2016, but from the base mortality rates for 2016

estimated from the trends in the preceding years. The figures shown in italics in the final column are the corresponding reductions over the twenty-five year period 2016 to 2041 assumed in the 2014-based projections.

A significant feature is that those UK cohorts born in the early 1930s consistently show greater mortality improvements as compared with their predecessors or successors. There is some evidence of similar effects for other cohorts. Therefore, as in previous projections, changes in mortality will be projected on a cohort basis for those born before 1960. These cohorts were aged 57 and over in 2016 and are indicated by the figures below those underlined in Tables 3 and 4.

Table 4 shows the proposed percentage reductions in death rates for males and females in Scotland for the same ages and years as given in Table 3, for comparison purposes.

Table 3: Proposed percentage reduction in death rates, mx, between consecutive calendar years in the projection period and the total reduction over 25 years, United Kingdom

Age	2016 to 2017	2020 to 2021	2030 to 2031	2040 to 2041	Reduction over 25 yrs	Equivalent annual reduction	Reduction 2016-2041 (2014 projns)
<b>Males</b>							
0	2.50	2.25	1.66	1.20	36.4	1.80	<i>34.0</i>
2	2.63	2.35	1.70	1.20	37.3	1.85	<i>34.8</i>
12	3.63	3.15	2.05	1.20	44.3	2.31	<i>41.8</i>
22	4.25	3.65	2.27	1.20	48.2	2.60	<i>44.1</i>
32	2.56	2.29	1.68	1.20	36.9	1.82	<i>34.0</i>
42	0.90	0.96	1.09	1.20	23.4	1.06	<i>24.7</i>
52	2.07	1.90	1.50	1.20	33.1	1.60	<i>34.0</i>
62	1.66	1.87	1.49	1.20	32.3	1.55	<i>33.2</i>
72	2.19	1.93	1.49	1.20	32.4	1.56	<i>34.8</i>
82	2.06	1.78	1.52	1.20	32.6	1.57	<i>37.1</i>
92	0.65	1.38	1.45	1.20	29.2	1.37	<i>38.4</i>
<b>Females</b>							
0	2.62	2.34	1.70	1.20	37.3	1.85	<i>37.4</i>
2	2.69	2.39	1.72	1.20	37.8	1.88	<i>37.2</i>
12	2.84	2.52	1.77	1.20	38.9	1.95	<i>40.3</i>
22	2.55	2.29	1.67	1.20	36.8	1.82	<i>37.3</i>
32	1.03	1.06	1.14	1.20	24.6	1.12	<i>29.5</i>
42	1.10	1.12	1.16	1.20	25.2	1.15	<i>31.7</i>
52	1.79	1.67	1.41	1.20	30.9	1.47	<i>34.2</i>
62	1.41	1.54	1.35	1.20	29.3	1.38	<i>33.1</i>
72	1.67	1.66	1.35	1.20	29.6	1.40	<i>34.1</i>
82	1.78	1.57	1.40	1.20	29.9	1.41	<i>35.9</i>
92	0.08	0.93	1.36	1.20	25.3	1.16	<i>30.7</i>



Table 4: Proposed percentage reduction in death rates, mx, between consecutive calendar years in the projection period and the total reduction over 25 years, Scotland

Age	2016 to 2017	2020 to 2021	2030 to 2031	2040 to 2041	Reduction in mx over 25 yrs	Equivalent annual reduction	Reduction 2016-2041 (2014 projns)
<b>Males</b>							
0	2.50	2.25	1.66	1.20	36.4	1.80	34.0
2	2.63	2.35	1.70	1.20	37.3	1.85	34.8
12	3.63	3.15	2.05	1.20	44.3	2.31	41.8
22	4.25	3.65	2.27	1.20	48.2	2.60	44.1
32	2.11	1.93	1.52	1.20	33.5	1.62	21.8
42	0.49	0.63	0.95	1.20	19.7	0.87	21.9
52	2.04	1.87	1.49	1.20	32.9	1.58	36.4
62	2.58	2.16	1.62	1.20	35.9	1.76	37.4
72	1.91	2.03	1.62	1.20	35.0	1.71	38.0
82	1.84	1.59	1.56	1.20	31.9	1.52	36.3
92	0.65	1.13	1.37	1.20	27.3	1.27	36.4
<b>Females</b>							
0	2.62	2.34	1.70	1.20	37.3	1.85	34.2
2	2.69	2.39	1.72	1.20	37.8	1.88	34.1
12	2.84	2.52	1.77	1.20	38.9	1.95	37.3
22	2.55	2.29	1.67	1.20	36.8	1.82	34.1
32	0.06	0.28	0.80	1.20	15.7	0.68	13.7
42	0.90	0.96	1.09	1.20	23.4	1.06	24.7
52	1.41	1.37	1.27	1.20	27.8	1.30	30.9
62	2.10	1.68	1.41	1.20	31.7	1.51	30.7
72	1.30	1.61	1.41	1.20	30.7	1.46	31.6
82	1.33	1.25	1.38	1.20	27.8	1.29	31.4
92	0.08	0.54	1.22	1.20	22.2	1.00	32.2

One of the easier ways to present a comparison between the mortality assumptions for Scotland and for the UK over the projection period is to look at the differences in period expectations of life at various ages. Table 5 gives figures for projected period expectations of life for Scotland for selected ages and years and the differences with those proposed for the UK as a whole. The table shows that there will be convergence between projected period expectations of life for Scotland and for the UK over time for males and divergence in the initial years of the projection period followed by convergence in later years for females. The resulting long-term differentials with the UK for period life expectancy at birth are around 0.3 years less compared to those for the 2014-based projections for females and around 0.1 year less for males (by 2056).

The difference between female and male period expectations of life at birth for Scotland is projected to decrease over the projection period from around 3.9 years in 2016 to 2.6 years in 2056. A similar decrease in absolute terms is projected for the UK from around 3.6 years in 2016 to 2.6 years in 2056.

Table 5: Proposed period expectations of life for Scotland and the UK for the 2016-based projections

Year	Age 0			Age 65		
	Scotland	UK	Difference	Scotland	UK	Difference
<b>Males</b>						
2016	77.59	79.56	-1.97	17.62	18.77	-1.15
2026	79.54	81.39	-1.85	18.92	20.03	-1.11
2036	81.13	82.85	-1.72	20.08	21.11	-1.04
2046	82.41	84.06	-1.65	21.02	22.03	-1.02
2056	83.65	85.24	-1.59	21.95	22.95	-1.00
<b>Females</b>						
2016	81.47	83.13	-1.66	19.90	21.09	-1.19
2026	82.75	84.47	-1.72	20.82	22.08	-1.26
2036	84.02	85.70	-1.68	21.80	23.04	-1.24
2046	85.16	86.78	-1.62	22.69	23.91	-1.22
2056	86.28	87.85	-1.57	23.59	24.79	-1.20

## 5.2 Comparisons of the proposed 2016-based mortality projections for Scotland and mortality projections assuming the same rates of mortality improvement for Scotland as for the UK

A comparison of the expectations of life at birth and at age 65 for males and females using the proposed assumptions compared to those resulting from assuming the same rates of improvement for Scotland as for the UK is given in Table 6. As can be seen, changing the assumptions results in little change in period life expectancy for males at birth or at age 65. The differences between the two are broadly similar to those arising in the 2014-based projections for males. However, it should be noted that the table only shows results for life expectancy at two ages.

For females, adopting the proposed improvement rates for Scotland would result in slightly lower period life expectancies at birth and at age 65 (of around 0.1 to 0.2 years) than if those derived for the UK as a whole were used. However, the reductions in period life expectancy at birth and at age 65 are smaller for females than for the 2014-based projections (by around 0.15 and 0.13 years in 2056 respectively).

These results suggest that the proposed changes to the initial rates of mortality improvement for Scotland will have a similar effect in decreasing life expectancies for Scotland relative to those for the rest of the UK compared to the 2014-based projections for males and less of an effect for females.

Table 6: Projected period expectations of life for Scotland compared with 2016-based projections assuming same rates of improvement for Scotland as for UK

Year	Age 0			Age 65		
	2016-based proposed EOL	EOL based on same improvements as for UK	Difference	2016-based proposed EOL	EOL based on same improvements as for UK	Difference
<i>Males</i>						
2016	77.59	77.59	0.00	17.62	17.62	0.00
2026	79.54	79.53	0.00	17.62	17.62	0.00
2036	81.13	81.09	0.04	20.08	20.03	0.05
2046	82.41	82.37	0.04	21.02	20.97	0.04
2056	83.65	83.62	0.03	21.95	21.92	0.03
<i>Females</i>						
2016	81.47	81.47	0.00	19.90	19.90	0.00
2026	82.75	82.89	-0.14	20.82	20.93	-0.12
2036	84.02	84.18	-0.16	21.80	21.92	-0.12
2046	85.16	85.33	-0.16	22.69	22.82	-0.13
2056	86.28	86.45	-0.17	23.59	23.73	-0.14

### 5.3 Comparisons of the proposed 2016-based mortality projections for Scotland and the 2014-based projections for years beyond 2016

A comparison of the expectations of life at birth and at age 65 for Scotland under the proposed assumptions compared to those assumed in the 2014-based projections for Scotland is given in Table 7.

Table 7: Projected period expectations of life for Scotland on proposed assumptions compared with the 2014-based projections

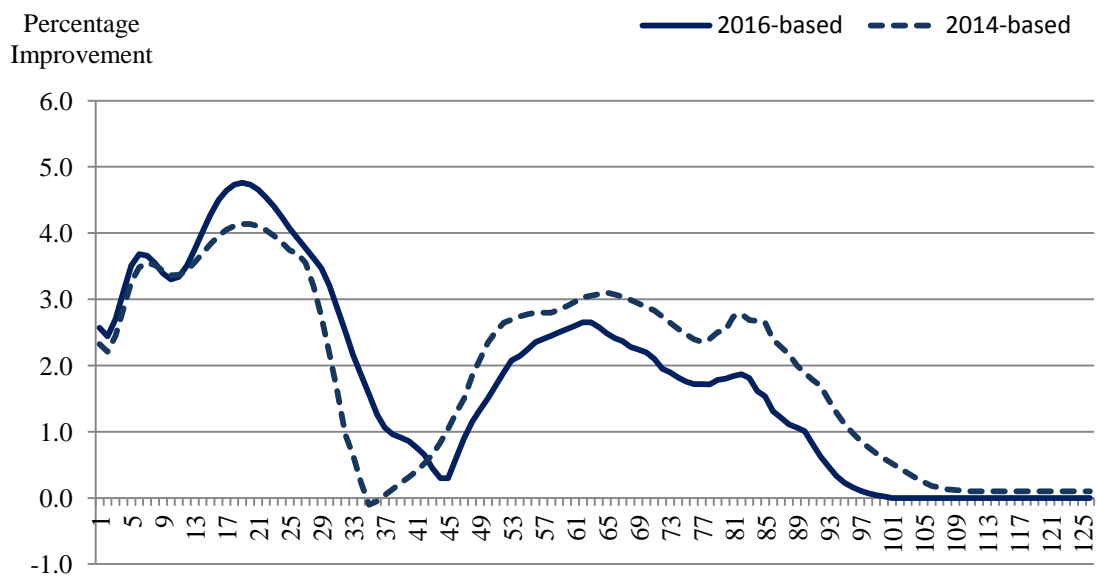
Year	Males				Females			
	Age 0		Age 65		Age 0		Age 65	
	Proposed 2016 based EoL	Change over 2014-based projection	Proposed 2016 based EoL	Change over 2014-based projection	Proposed 2016 based EoL	Change over 2014-based projection	Proposed 2016 based EoL	Change over 2014-based projection
2016	77.59	-0.22	17.62	-0.35	81.47	-0.17	19.90	-0.23
2026	79.54	-0.65	18.92	-0.80	82.75	-0.52	20.82	-0.61
2041	81.79	-0.81	20.56	-0.96	84.60	-0.66	22.25	-0.76
2056	83.65	-0.90	21.95	-1.04	86.28	-0.76	23.59	-0.84

As can be seen, the proposed assumptions for the 2016-based projections would lead to lower period expectations of life at birth for males and females than in the 2014-based projections. By 2056, period expectations of life at birth for males will be around 0.9 years lower for males and 0.8 years lower for females. Period life expectancies at age 65 in 2056 would be lower by around 1.0 years lower for males and 0.8 years lower for females. A graphical representation of the data can be found in Figures A2 and A3 in the Annex to this paper.

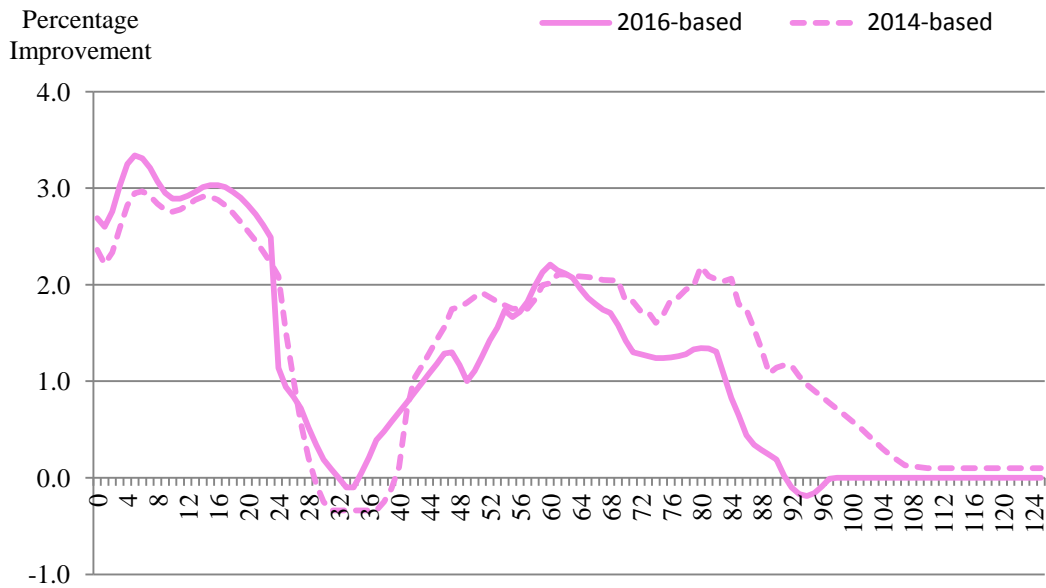
Figure 13 provides a comparison of the proposed rates of improvement in Scottish mortality rates for 2015-16 for the 2016-based projections against those projected for 2015-16 in the 2014-based projections. For males, the improvement rates follow a similar pattern although they are generally lower from age 43 than previously projected and similar or higher at younger ages. The patterns are comparable for females although the proposed improvement rates may be wider apart where they are lower at older ages and there is greater cross over between the projections.

Figure 13: Comparison of Scottish improvements for base year: 2016-proposed and 2014-based projection

(a) Males



(b) Females

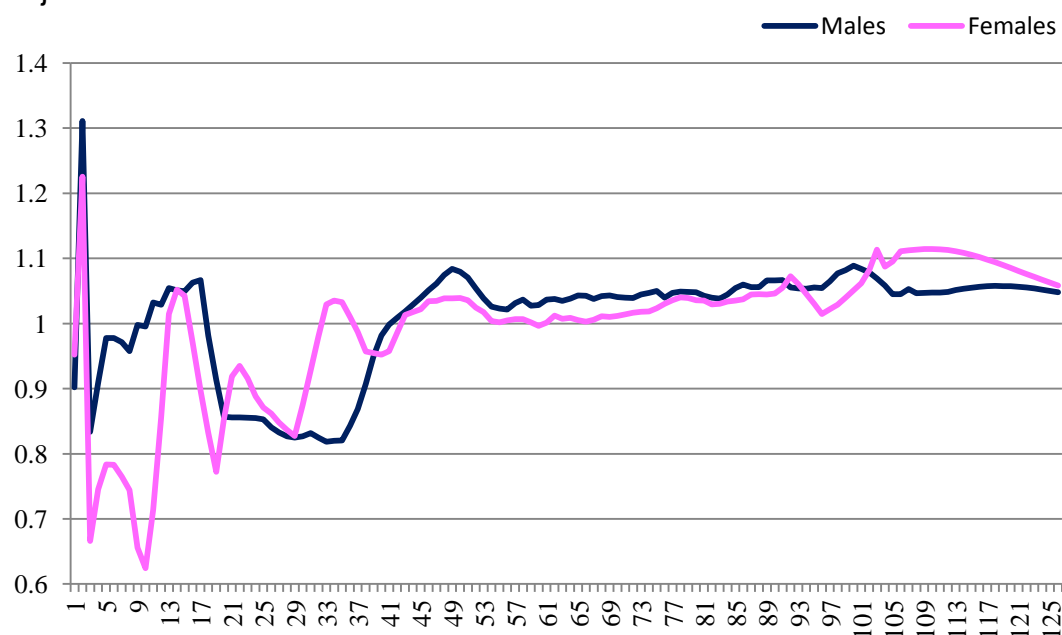


As the proposed long term rates of mortality improvement are the same as in the 2014-based projections, if the age specific mortality rates assumed for 2016 were the same as those projected for 2016 in the 2014-based projections, the period life expectancies would be expected to be lower than previously projected because of the generally lower assumed rates of improvement at older ages in the early years of the projection period.

Figure 14 provides a comparison of the derived age specific mortality rates for 2016 with those projected for 2016 in the 2014-based projections. The rates are lower for most ages up to age 40 and then similar or higher than previously projected for ages 40 and higher. Over the age range age 50 to 75 the ratios are relatively constant for both males (at 103% to 104%) and for females (at 101% to 102%); the ratios then increase at ages over 75. There is more variation at younger ages but mortality rates at these ages are low and have little effect on the overall expectation of life at birth.

Hence, if the annual rates of improvement proposed for the 2016-based projections were the same for each year as projected in the 2014-based projections, the mortality rates would be higher than those previously projected at older ages, leading to reductions in projected period life expectancies at older ages.

Figure 14: Ratio of mortality rates (mx) 2016-proposed to 2014-based projection



## 6. Conclusions

These proposals relate to the initial mortality improvement factors to be assumed for Scotland in the base year of the projections using the current ONS method. If agreed, these initial factors would still converge to the common target rates of improvement for both males and females in 2041 proposed for the UK and all constituent countries. These are 1.2% for most ages (unlike the previous projection the rates of improvement in and after 2041 for those born between 1924 and 1939 will be assumed to be 1.2% as well rather than being higher than 1.2%). The magnitudes of the initial differences, where incorporated for Scottish males and females, do not suggest that different target rates of improvement in 2041 are required for Scotland.

The proposed assumptions lead to projected period life expectancies at birth for Scotland which are lower to those in the 2014-based projections for both males and females over the period 2016 to 2056 with differentials rising from around 0.2 years lower in 2016 for both males and females to 0.9 years lower in 2056 for males (and 0.8 years lower for females). Period life expectancy at age 65 is projected to be around 0.3 years lower for males in 2016 increasing to around 1.0 years lower in 2056. For females the differentials increase from 0.2 years lower in 2016 to 0.8 years lower in 2056.

As described in Section 6, the decreases in projected period life expectancies over the next 40 years for both males and females are driven mainly by the higher initial mortality rates at older ages in 2016 compared to those projected for 2016 in the 2014-based projections coupled with lower rates of mortality improvement at older ages over the first 25 years of the projections.

The analyses in this paper suggest that the mortality improvement factors assumed for Scottish males for the first year of the projection be amended from those proposed for the UK for ages 29 to 88 for males. For females, amendments would occur at ages 24 to 89. A comparison of the proposed rates of improvement in the base year for males in Scotland and the UK is shown in Figure 9 and for females in Figure 11.

The change in the base year rates of improvement for males and females means that the rates of improvement assumed for later years at these ages (or cohorts for those born before 1960) will also be different than those for the UK although they will all converge to the same annual rates of improvement as for the UK by 2041.

The proposed assumptions result in smaller differentials compared to the UK for period life expectancy at birth of around 0.1 to 0.2 years for males and 0.1 to 0.3 years for females than in the 2014-based projections, although the actual figures may change slightly when the final results for the UK are calculated from aggregating the results for each individual country. The differentials for period life expectancy at age 65 are broadly the same as in the 2014-based projections for males and around 0.1 to 0.2 years less for females.

Alternative assumptions have been derived using the UoS method applied to historical Scottish data. Overall the current version of the UoS method would project lower period life expectancies at birth than the ONS method for males of between 0.5 and 0.8 years over the 40 year period shown, whereas the period life expectancy at age 65 are broadly similar under the two methods. For females the period life expectancies at birth are broadly similar, whereas those at age 65 are generally higher under the UoS method than the ONS method.

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## Annex

### UoS method approach

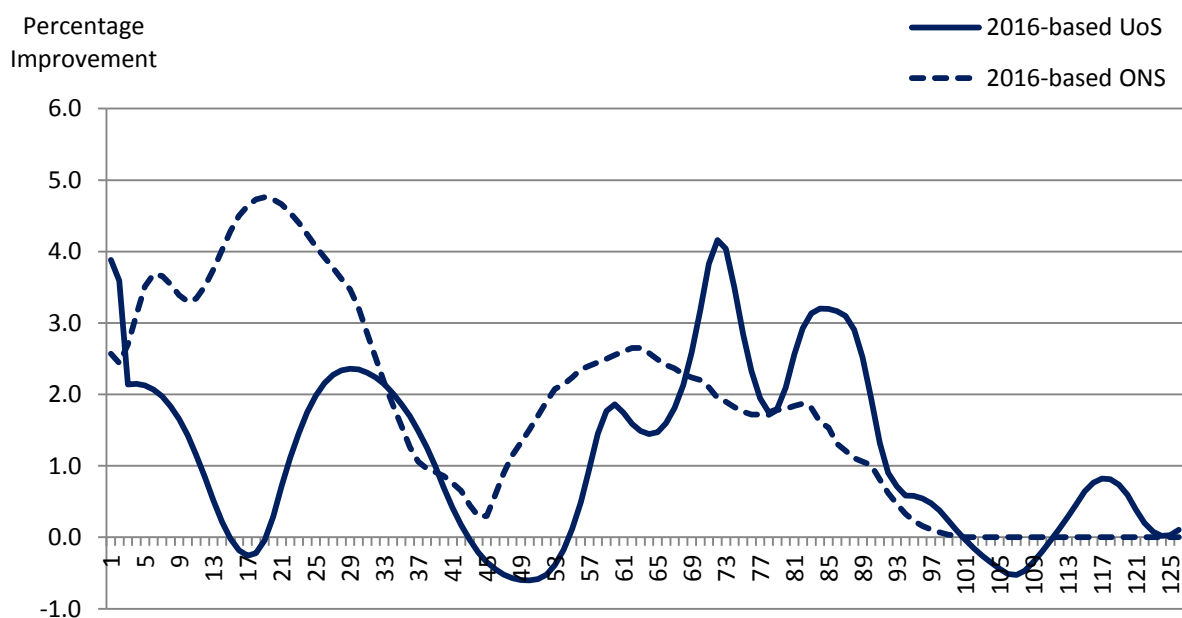
In addition to producing assumptions for projecting mortality in Scotland using the current ONS methodology used for previous projections, assumptions for base mortality rates in 2016 and rates of mortality improvement in 2015-16 for Scotland have also been derived using an alternative methodology developed by the University of Southampton (UoS).

The UoS methodology models mortality improvement rates using a generalised additive model, using a smoothed combination of age, age-specific improvement, period and cohort effects, with the relative size of each determined by the input data (Dodd et al., 2017). Separate models are used for infants and old ages. More detail on the UoS methodology is described in section 2 of NPP paper 17(3) 'Mortality assumptions for the 2016-based national population projections'.

Figure A1 shows the resulting improvement rates for 2015/16 derived using the current version of the UoS method (labelled UoS in the following) compared with those derived for the 2016-based projections under the current ONS method.

Figure A1: Proposed mortality improvements rates for base year of the projections – Scotland, UoS method and current ONS method

#### a) Males





(b) Females



Table A1 shows the proposed reductions in death rates for Scotland using the UoS method for various ages in selected future years and the total reduction over twenty-five years from 2016 to 2041. The figures shown in italics in the final column are the corresponding reductions over the twenty-five year period 2016 to 2041 assumed in the 2014-based projections.

Table A2 shows projected period life expectancies under the two methods for selected ages and years. Overall the UoS method projects lower period life expectancies at birth than the ONS method for males of between 0.5 and 0.8 years over the 40 year period shown, whereas the period life expectancy at age 65 are broadly similar under the two methods. For females the period life expectancies at birth are broadly similar, whereas those at age 65 are generally higher under the UoS method than the ONS method.

Table A1: Proposed percentage reduction in death rates, mx, between consecutive calendar years in the projection period and the total reduction over 25 years, UoS method, Scotland

Age	2016 to 2017	2020 to 2021	2030 to 2031	2040 to 2041	Reduction in mx over 25 yrs	Equivalent annual reduction	Reduction 2016-2041 (2014 projns)
<b>Males</b>							
0	3.9	3.6	2.1	1.2	45.8	2.4	34.0
2	3.6	3.4	2.0	1.2	44.1	2.3	34.8
12	0.6	0.8	1.6	1.2	25.3	1.2	41.8
22	1.0	-0.9	0.4	1.2	-8.2	-0.3	44.1
32	2.3	2.4	-0.5	-0.3	14.5	0.6	34.0
42	0.3	1.8	3.5	0.0	42.5	2.2	24.7
52	-0.5	-0.3	2.4	3.8	34.6	1.7	34.0
62	1.6	1.6	-0.1	2.5	18.3	0.8	33.2
72	4.2	2.2	1.5	-0.2	27.2	1.3	34.8
82	2.9	1.6	1.8	1.3	40.4	2.0	37.1
92	0.8	2.5	1.1	1.6	41.8	2.1	38.4
	3.9	3.6	2.1	1.2	45.8	2.4	34.0
<b>Females</b>							
0	4.4	4.1	2.3	1.2	49.2	2.7	37.4
2	4.1	3.9	2.2	1.2	47.6	2.5	37.2
12	2.3	2.2	1.6	1.2	35.0	1.7	40.3
22	1.5	1.1	1.1	1.2	24.6	1.1	37.3
32	0.6	1.1	1.1	1.1	24.4	1.1	29.5
42	0.1	0.4	1.4	1.3	22.4	1.0	31.7
52	0.3	-0.1	0.6	1.5	12.1	0.5	34.2
62	1.3	1.4	0.1	0.7	15.3	0.7	33.1
72	3.1	2.0	1.5	0.1	29.8	1.4	34.1
82	2.7	2.1	1.9	1.4	39.5	2.0	35.9
92	0.5	1.8	1.6	1.7	38.0	1.9	30.7

Table A2 Projected period expectations of life for Scotland ONS method and UoS method

Year	Males				Females			
	Age 0		Age 65		Age 0		Age 65	
	ONS	UoS	ONS	UoS	ONS	UoS	ONS	UoS
2016	77.59	76.85	17.62	17.51	81.47	81.10	19.90	19.79
2026	79.54	78.78	18.92	19.24	82.75	82.75	20.82	21.30
2036	81.13	80.35	20.08	20.39	84.02	84.10	21.80	22.52
2046	82.41	81.73	21.02	21.05	85.16	85.19	22.69	23.33
2056	83.65	83.12	21.95	22.05	86.28	86.13	23.59	23.93

Figures A2 and A3 show projected life expectancies at birth and at age 65 for males and females for each year from 2016 to 2062 under both methods, together with those projected in the previous 2014-based projections.

Figure A2: Period expectation of life at birth in Scotland, comparing the 2014-based and the 2016-based projections, 1981-2062.

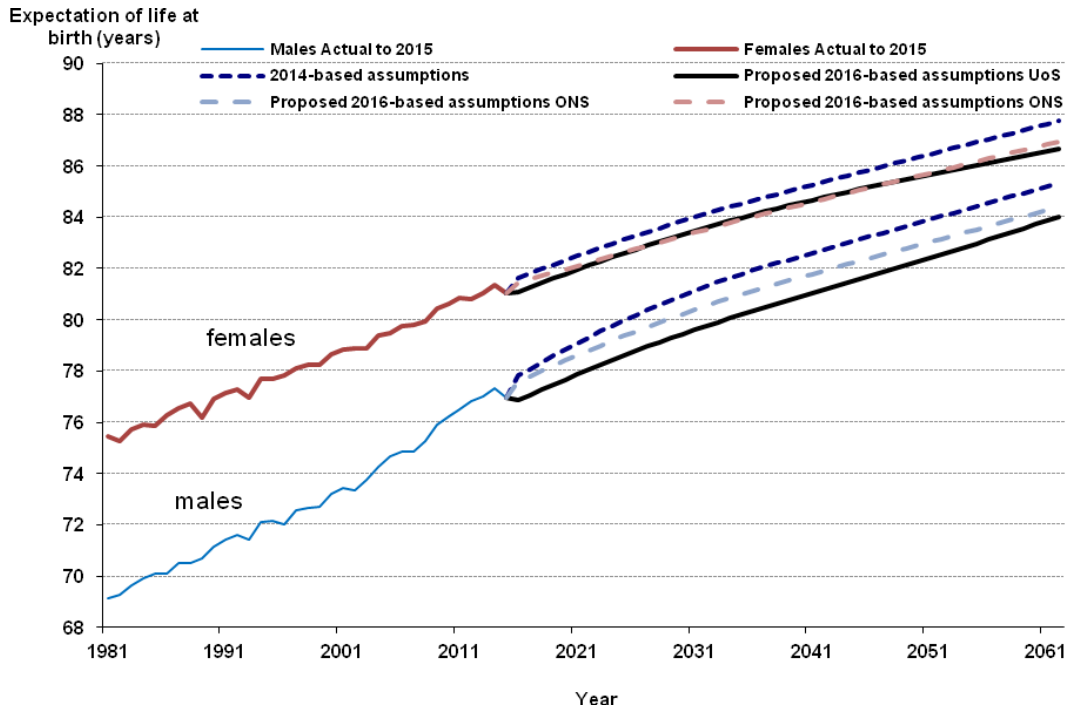


Figure A3: Period expectation of life at age 65 in Scotland, comparing the 2014-based and the 2016-based projections, 1981-2062.

