Office for National Statistics

Article

# Prospective new method for setting mortality assumptions for national population projections, UK: January 2023

User engagement on a prospective model-based approach for producing mortality projections for use in national population projections (NPPs).

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# 1 . Main points

- We have been exploring a potential change to our mortality projection methodology to using a statistical model.
- This article explains the prospective methodology, and highlights findings from comparing this methodology with 2018-based and 2020-based interim National population projections (NPPs) produced using our current methodology.
- We are seeking feedback from our users on the impacts and implications that may arise from the prospective change.
- The user engagement exercise will run for six weeks from 9 January to 20 February 2023, and you can provide your feedback on the Office for National Statistics consultations website; see section 6 for how to respond.
- User feedback will contribute to decision-making on the mortality projection methodology used for NPPs.
- Going forward, we plan to decide on the methodology to be used in 2021-based NPPs in spring 2023.

These are not official statistics and should not be used for policymaking or decision-making. They are published as research into a new method for producing mortality projections for use in national population projections. We advise caution when using the data.

# 2 . Overview of mortality assumption setting

## Background

We publish national population projections (NPPs) by age and sex for the UK and its constituent countries every two years, although release timescales have changed around Census 2021. We base NPPs on the latest mid-year population estimates, together with assumptions of future age- and sex-specific levels of fertility, mortality and migration.

The main purpose of the projections is to give information on potential future population levels. They are used as a common framework for national planning and policymaking. NPPs are also used in the production of subnational population projections (for England), which are in turn used to produce household projections (for England). The latest set of NPPs were interim 2020-based projections published in January 2022. We plan for our next NPPs to be 2021-based with a provisional release date of December 2023.

We produce NPPs on behalf of the National Statistician and the Registrars General for Scotland and Northern Ireland. We agree the underlying assumptions with the devolved administrations:

- Welsh Government
- National Records of Scotland (NRS)
- Northern Ireland Statistics and Research Agency (NISRA)

Information on our assumption-setting process, which is always kept under review, can be found in our National population projections, background, methodology and assumption setting: 2020-based interim methodology.

The proposed model-based method aligns with the principles and practices of the UK Statistics Authority Code of Practice, and presents several important benefits including:

- better fit with the UK Statistics Authority Five year strategy 2020 to 2025 (PDF, 1,125 KB) which underpins the work of the UK statistical system with the aims of being Radical, Ambitious, Inclusive and Sustainable
- greater time and cost efficiencies compared with the current method
- improved reproducibility and a requirement for fewer manual adjustments compared with the current method, which requires extensive input from a limited number of experts
- continued flexibility to weight in expert opinion on the target rates of mortality improvement and the speed of convergence to these target rates, as well as the ability to take account of expert views on other aspects such as the treatment of “mortality shocks” in the base year of the projection

If we decide to adopt the new methodology, then it would be used for the 2021-based NPPs. The production of these is dependent on a reconciliation and rebasing exercise for population estimates following Census 2021. We have published our Population estimates for the UK, England, Wales, Scotland and Northern Ireland: mid-2021 and the reconciliation and rebasing exercise will create a consistent revised back-series of population estimates for mid-2012 to mid-2020. For more information on our planned timescales for reconciliation and rebasing, see our Population statistics and sources guide.

## Current method for producing mortality projections

We currently project future mortality trends in the form of mortality improvements, which are assumed annual percentage changes in mortality rates by age and sex.

We derive age-specific mortality improvements in the base year of the projection and assume they will converge to target rates of improvement by the 25th year. All future years' mortality improvements by age beyond the 25th year of the projection are held constant at the target rate for that age until the end of the projections.

As part of the assumption-setting process, a panel of mortality experts advises on:

- target rates of mortality improvement by the 25th year by age and sex
- method and speed of convergence of improvements between the base year and target year
- mortality improvement at the oldest ages
- how mortality improvement for each country of the UK might differ
- underlying factors that may influence future mortality

For the 2020-based interim NPPs, we initially followed our standard mortality projections methodology. We then adjusted the short-term improvement rates between 2019 and 2024 for people aged 30 years and over to account for the increased mortality recorded during the coronavirus (COVID-19) pandemic and the potential short-term effects on mortality.

For the UK, annual rates of mortality improvement were assumed to converge to 1.2% for ages 0 to 90 years by 2045 and remain constant thereafter. Annual improvement rates were set to decline linearly from 1.2% to 0% between ages 91 and 109 years. For ages above 110 years, a 0% improvement rate was assumed.

As in previous projections, mortality improvements for the UK for the base and subsequent years were adjusted for Scotland, while improvements for England, Wales and Northern Ireland were aligned to a set of improvements for the UK excluding Scotland. The same long-term rates of improvement were assumed for all constituent countries as for the UK.

For an overview of the assumptions developed for the 2020-based interim NPPs, please see our article National population projections, mortality assumptions: 2020-based interim.

Our National population projections: 2020-based interim were published in January 2022, alongside our Past and projected period and cohort life tables for 1981 to 2070.

# 3 . Proposed model for producing mortality projections

## Methodology

The proposed new mortality projection methodology uses an age-period-cohort (APC) model developed in collaboration with academics at the University of Southampton and the University of Warwick.

The model uses the same input data as the current method: UK mid-year population estimates and annual calendar year deaths from 1961 to the latest available year. The method projects future mortality rates, by single year of age and sex, based on the historical population and deaths data. This is done by fitting generalised linear models to mortality rates seen between 1961 and the base year, and then adjusting the model equations to project mortality rates up to 175 years into the future. The new methodology retains the input of expert opinion on long-term mortality improvement rates and the speed of convergence to these rates, which would be obtained using the current approach of convening the national population projection (NPP) mortality expert advisory panel.

The model separates the contribution of age, period and cohort effects on mortality improvement.

The age effect is the baseline annual mortality improvement at age x, for example to account for the observed improvement in mortality rates for females aged 70 years between 1961 and the base year.

The period effect is the mortality improvement in a given calendar year (period); this is a constant value for each calendar year and may be positive (denoting higher than average mortality rates), or negative (denoting lower than average mortality rates).

The cohort effect is mortality improvements for a given birth cohort, that is, people with the same year of birth. It has been shown in the past that some birth cohorts experience higher mortality improvements than others, for example the "golden cohort" born between 1924 and 1938.

There are three different parts to the model, each tailored to specific age ranges.

The main APC model models mortality improvement based on the age, period and cohort effects. It covers most ages, from age 1 year to  years. In the examples provided here,  is 90 years for females and 92 years for males; the specific values of  are chosen to allow for a smooth change in the mortality rates from the main model to the old age model and will be reviewed regularly.

The old age model is for ages  plus 1 years to 125 years. The old age model takes a different form (a logistic model) and models mortality rates rather than improvement rates. The use of a logistic model is to ensure that mortality rates converge on a constant value as age increases.

The third part of the model is for infants aged zero years. The infant model is the same as the main APC model, except that it does not include a period effect, and it uses estimates of the cohort effect from the main model.

It is beyond the scope of this article to outline the model equations in full but an explanation has been published in the Scandinavian Actuarial Journal Stochastic modelling and projection of mortality improvements using a hybrid parametric/semiparametric age-period-cohort model journal article (PDF, 3.3 MB).

Some adjustments have been made to a standard APC model, in order to retain desirable features from the current method for projecting future mortality.

### Expert opinion

In the first few years of the projection, the projected improvement rates are determined almost entirely by the fitted age and cohort effects from the model (the period effect is assumed to be zero). As we progress over the 25 years of the projection, the modelled improvements are weighted down and the expert opinion is weighted up, so that by the 25th year (and all subsequent years) the projected mortality improvements are determined solely by expert opinion. We can also adjust the speed of convergence between the base year and target improvement rates, for example to achieve a certain percentage of the convergence by a given year.

## Weighting input data

An advantage of the APC model is that it takes full account of the time series of input data, and each year is weighted equally. However, in the last decade, mortality improvements have slowed compared with previous decades. We have therefore added the flexibility to weight up more recent data, and weight down more historical data, in order to account for this. Any weighting used for the 2021-based NPPs would be discussed with the NPP mortality expert advisory panel. For illustrative purposes in this article, we have applied weights as follows: 1 divided by N for 1961, 2 divided by N for 1962, and so on, up to N divided by N for the latest year, where N is the number of years of data.

## Mortality shocks

The coronavirus (COVID-19) pandemic led to much higher-than-average mortality rates for certain age groups in 2020. We call this a "mortality shock" and need to make assumptions about the extent to which the shock will continue throughout the projection period. In the proposed model we have the flexibility to adjust for a mortality shock occurring in the base year of the projection by weighting down the period effect from that year so that it does not affect projected mortality rates beyond a specified number of years. For example, in this article, the following weighting has been applied:

- 50% recovery by the first year of the projection
- 75% recovery by the second year
- 87.5% recovery by the third year
- 100% recovery by the fourth year

We would seek the advice of the NPP expert advisory panel on how to appropriately adjust for a mortality shock, and whether it is correct to remove all the shock, or alternatively, to allow a proportion of the shock to continue throughout the projection.

## Mortality projections for England, Scotland, Wales and Northern Ireland

Although we initially produce our mortality projections at UK level, we need to produce a series of mortality rates and mortality improvement rates separately for each of the four nations of the UK to feed into the production of the NPPs.

In order to run data in the model, we need a complete series of population and deaths data back to 1961. We have this for the UK, for England and Wales combined, and for Scotland. The population of Scotland is also large enough that we can run the Scottish data in the model directly. As we do not have separate data for England, Wales and Northern Ireland back to 1961, we run data for the UK excluding Scotland directly in the model and then apply smoothed ratios derived from the National Life Tables to produce mortality rates for England, Wales and Northern Ireland. This is a similar approach to our current method.

## Variant projections

We can run variant projections through the model by changing the long-term target mortality improvement rates and the speed of convergence between the base year and the target improvement rates. We have not presented any variant projections in this user engagement exercise as the assumptions underlying these are specific to each projection round and would need to be determined through discussion with our NPP mortality expert advisory panel.

# 4 . Indicative results from the proposed model

This section presents indicative results from testing the proposed model compared with the current method. These results should not be taken as an indication of future mortality projections for the 2021-based national population projections (NPPs), which will be determined with our mortality expert advisory panel, with reference to the latest population estimates and deaths data.

The main findings are that the proposed model:

- produces similar fitted mortality rates in the base year to those produced by the current method of smoothing mortality rates over time
- projects lower mortality rates at ages 70 years and over compared with the current method; this results in slightly higher projections of life expectancy at birth and at age 65
- produces projections that are more stable over time (in the absence of any mortality shocks), meaning there is a greater degree of similarity between consecutive projection rounds
- produces projections that are less sensitive to the recent slowdown in mortality improvements; this can be mitigated to some extent by weighting up more recent input data
- is sensitive to unusually high mortality rates in the base year of the projection; a period weighting adjustment can be applied to remove all, or some, of the period effect in the base year from subsequent years of the projection

## 2018-based projections

The first set of comparisons between the proposed model and the current method are for 2018-based projections. The mortality projections for the 2018-based NPPs were produced using data up to the end of 2017. The proposed model has been run using data up to the end of 2018. Results from both methods were subsequently constrained to provisional deaths data up to mid-2019 at the time of running the projection. We have applied the target rates of mortality improvement by age and sex for 2043 as were used in the 2018-based projections. Comparing with 2018-based projections is useful because these are the last set of projections prior to the coronavirus (COVID-19) pandemic.

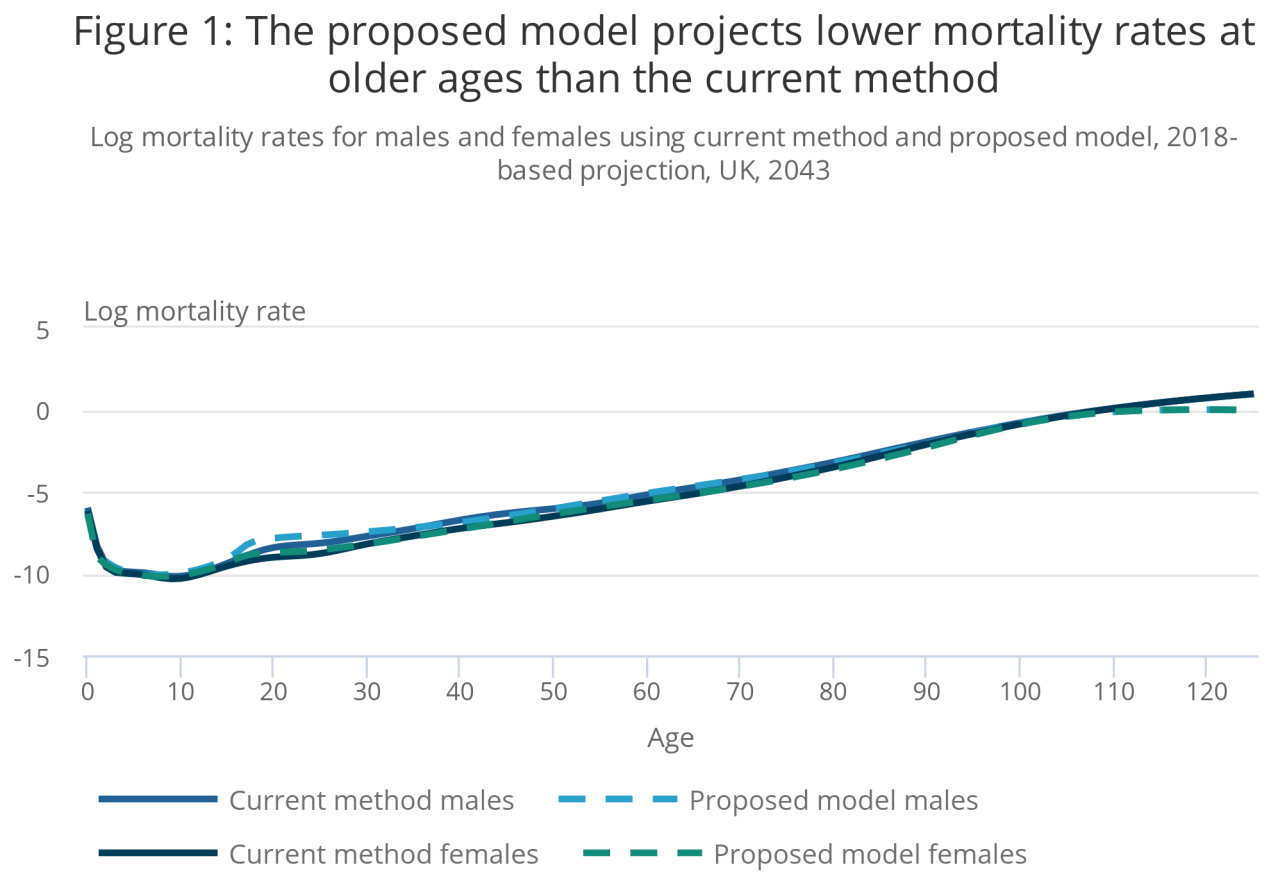
Figure 1 shows that in 2043 (the target year for the 2018-based projections) the proposed model projects higher mortality rates for those aged 10 to 30 years. This reflects the short period of higher mortality that young people, particularly males, experience, which is sometimes referred to as the "accident hump." This is less evident in more recent data and so has been less prominent in our current mortality assumptions.

From around age 70 years onwards, the proposed model projects lower mortality rates in the target year than the current method. This is partly because of the different ways in which the two methodologies extrapolate improvements at younger ages to derive mortality improvements at the very oldest ages (as a result of sparsity of data at these older ages).

The proposed model also projects forward stronger cohort effects, particularly for the "golden cohort" born between 1924 and 1938, and for "baby boomers" (born between the end of the Second World War and the 1960s). For the 2014-based and earlier projections, the current method incorporated higher improvements for the "golden cohort", but this was removed from more recent projections because the cohort is now reaching advanced age. Historically, the "golden cohort" have seen higher mortality improvements than the cohorts born either side of them. However, in the last decade, the improvements for this cohort have slowed considerably, and in recent years have shown little difference to those of adjacent cohorts.

**Figure 1: The proposed model projects lower mortality rates at older ages than the current method**

**Log mortality rates for males and females using current method and proposed model, 2018-based projection, UK, 2043**

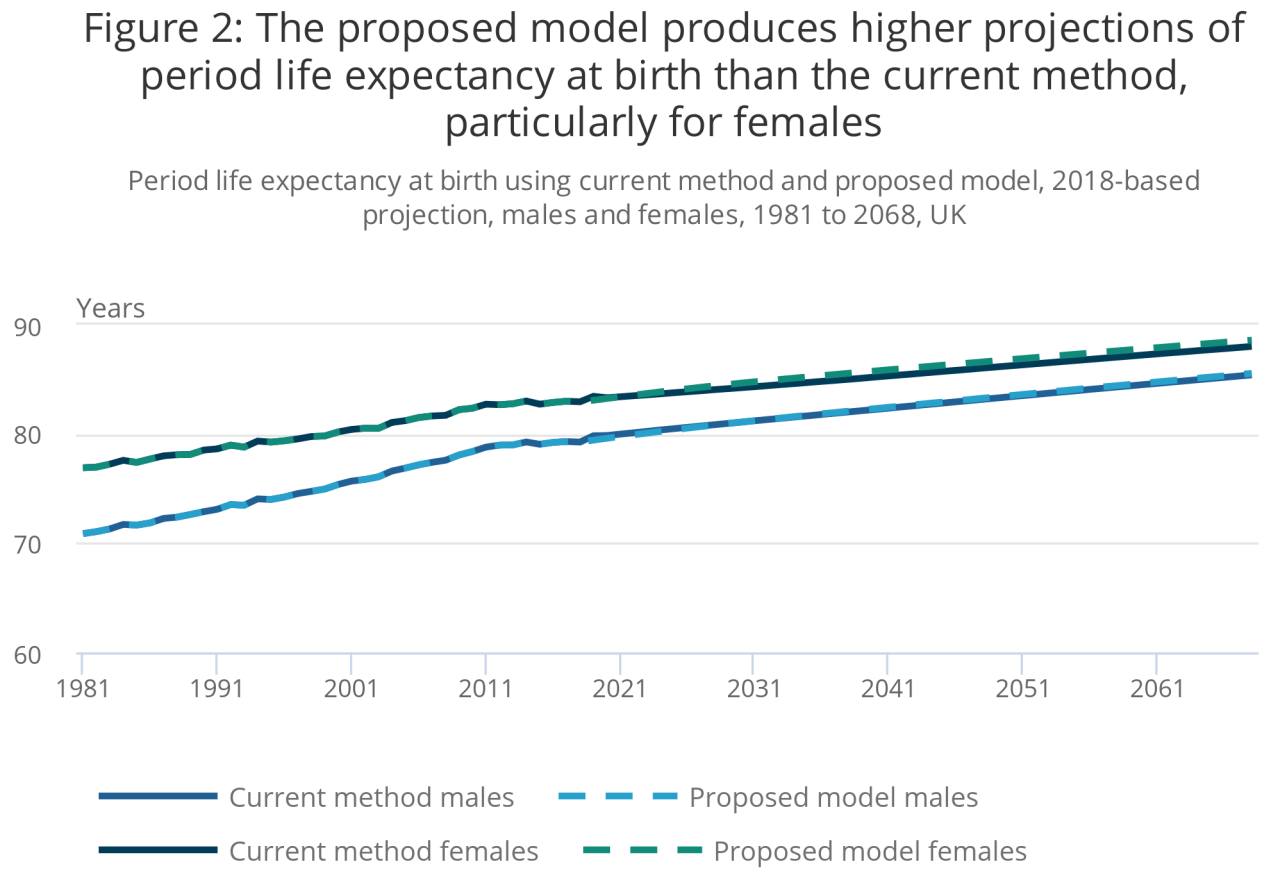



**Source: ONS – 2018-based projections and modelled outputs**

Primarily as a result of projecting lower mortality rates at older ages than the current method, the proposed model projects slightly higher period life expectancy at birth and at age 65 years than the current method. The difference is greater for females than for males. Although more recent data is weighted up in the proposed model, it still factors in the long time series of mortality improvements since 1961, and for much of that period, females experienced faster improvements than males.

**Figure 2: The proposed model produces higher projections of period life expectancy at birth than the current method, particularly for females**

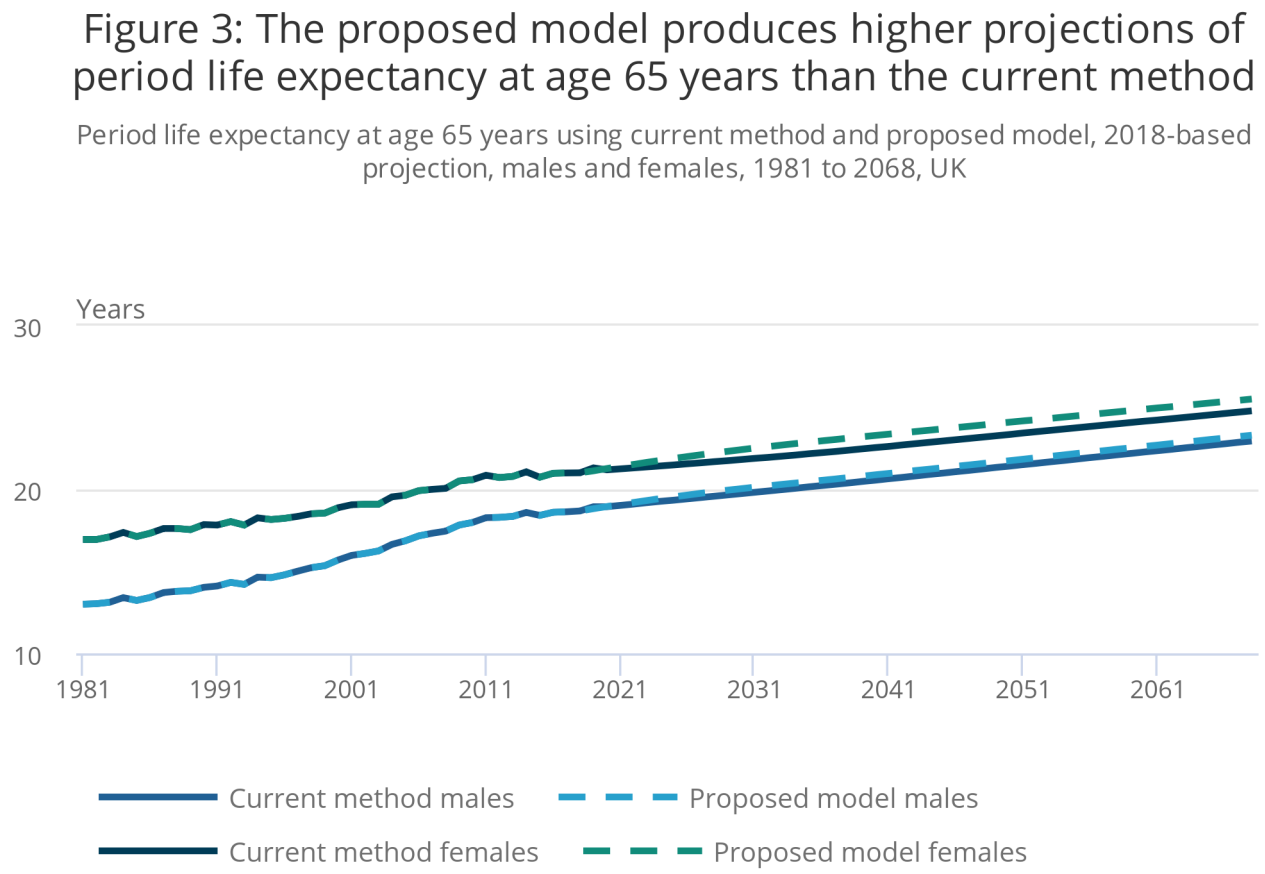
**Period life expectancy at birth using current method and proposed model, 2018-based projection, males and females, 1981 to 2068, UK**




**Source: ONS – 2018-based projections and modelled outputs**

**Figure 3: The proposed model produces higher projections of period life expectancy at age 65 years than the current method**

**Period life expectancy at age 65 years using current method and proposed model, 2018-based projection, males and females, 1981 to 2068, UK**

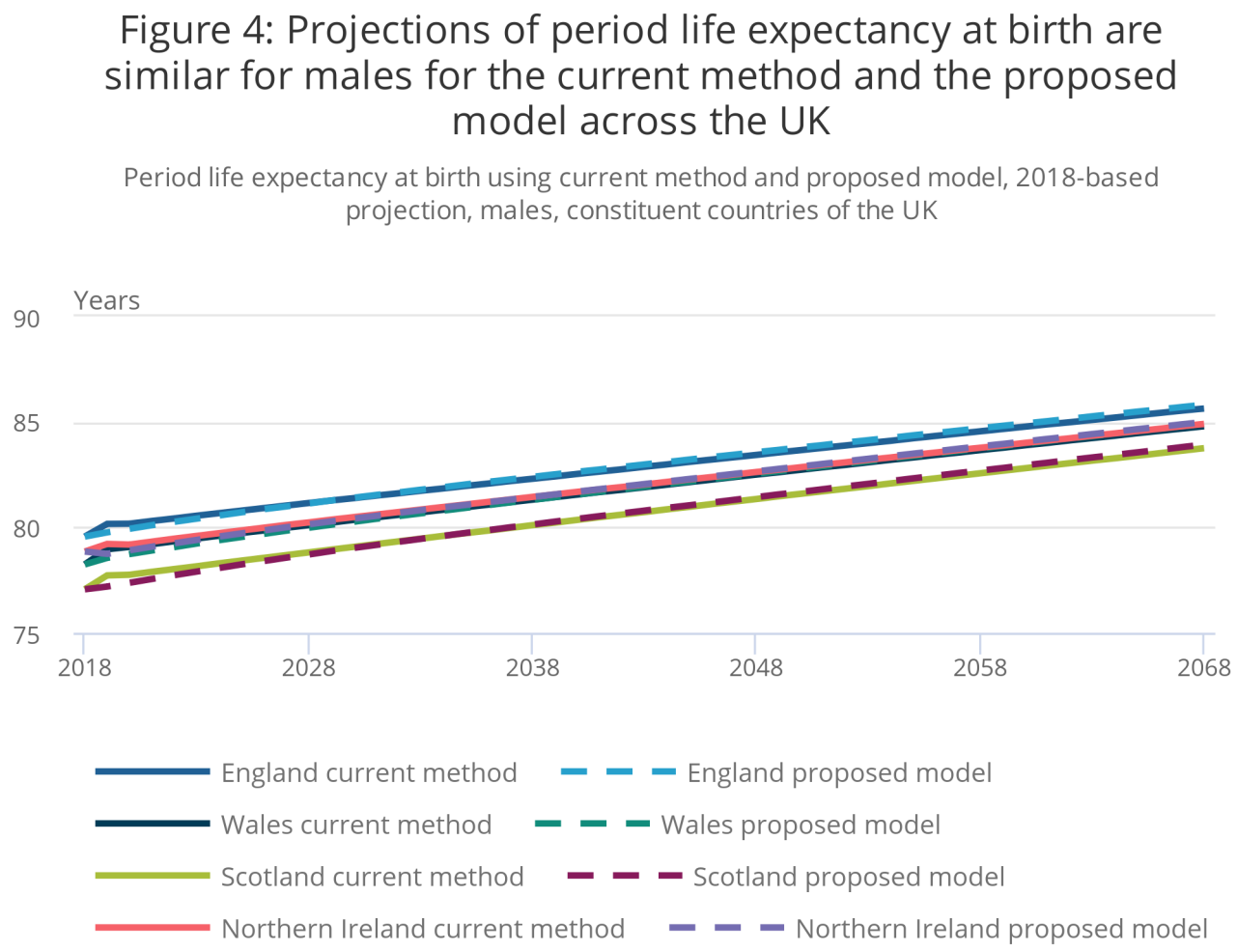



**Source: ONS – 2018-based projections and modelled outputs**

For the UK constituent countries, the proposed model projects values for period life expectancy that are closer to those from the current method for males than for females. As expected, period life expectancy is highest in England and lowest in Scotland.

**Figure 4: Projections of period life expectancy at birth are similar for males for the current method and the proposed model across the UK**

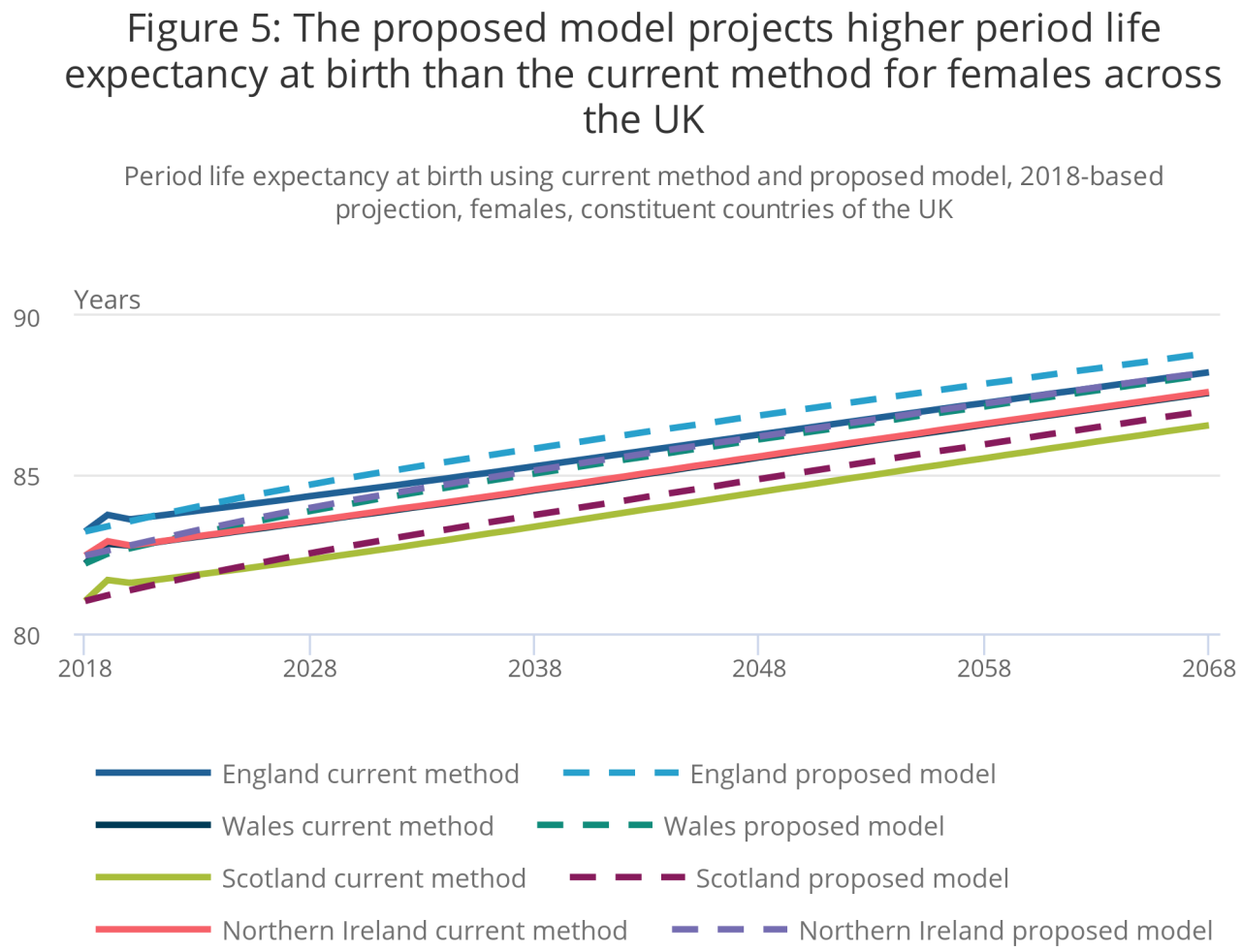
**Period life expectancy at birth using current method and proposed model, 2018-based projection, males, constituent countries of the UK**




**Source: ONS – 2018-based projections and modelled outputs**

**Figure 5: The proposed model projects higher period life expectancy at birth than the current method for females across the UK**

**Period life expectancy at birth using current method and proposed model, 2018-based projection, females, constituent countries of the UK**




**Source: ONS – 2018-based projections and modelled outputs**

Further analysis for 2018-based projections, including cohort life expectancy at birth and at age 65 years, is available in the data tables published with this release.

## 2020-based projections

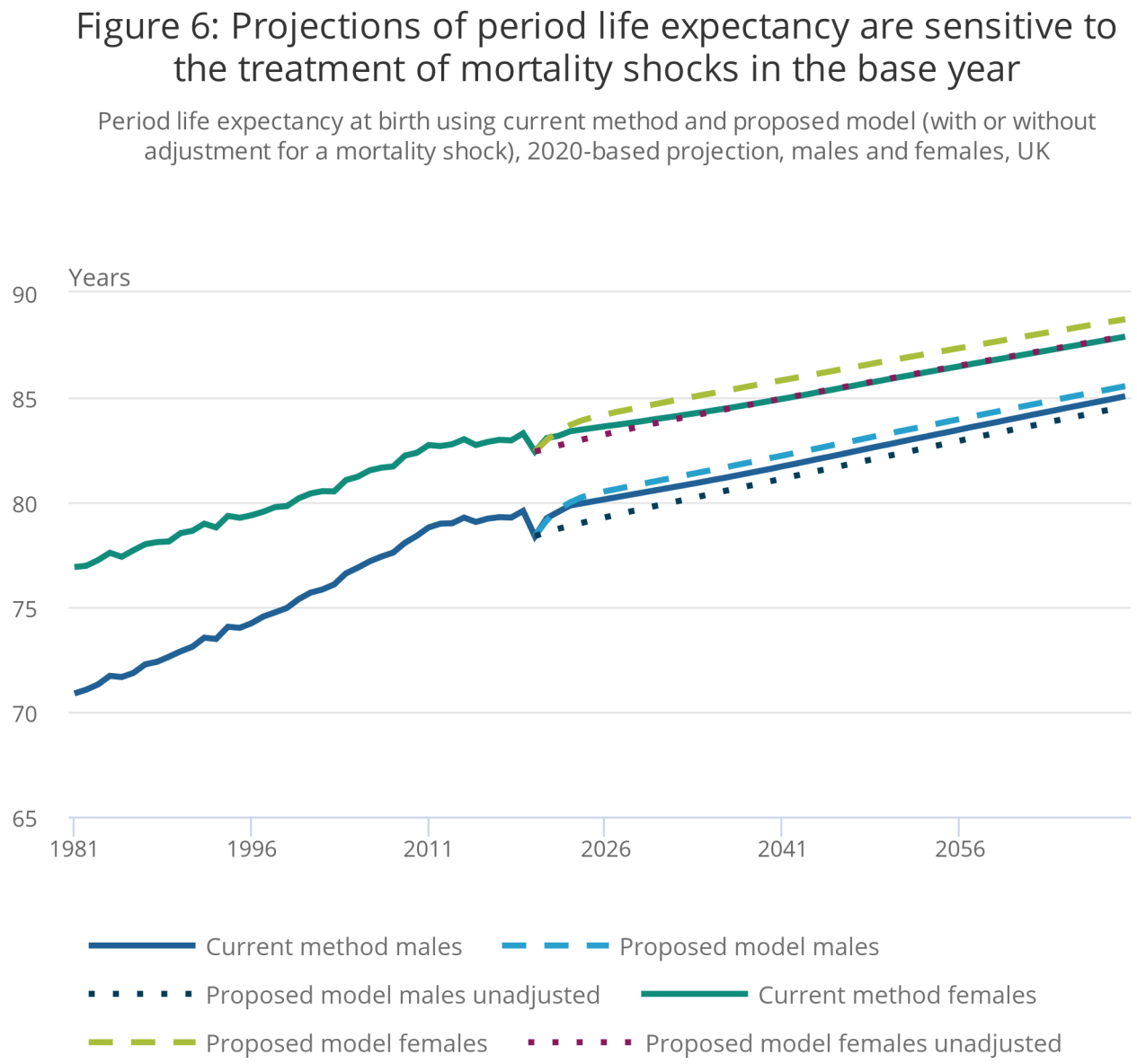
The next set of comparisons between the proposed model and the current method are for 2020-based projections. The mortality projections for the 2020-based interim NPPs were produced using data up to the end of 2019, before an adjustment for the impact of coronavirus on mortality was applied for 2019 to 2024. The proposed model has been run using data up to the end of 2020. Results from both methods were constrained to provisional deaths data up to mid-2021 at the time of running the projection. We have applied the same target rates of mortality improvement by age and sex for 2045 as were used in the 2020-based interim NPPs.

Much of the analysis for the 2020-based projections is similar to the 2018-based projections and users can find further information in the reference tables. Figures 6 and 7 show the impact of applying an adjustment to the projected mortality rates following the "mortality shock" observed in the base year (2020). In this example, we compare the impact on period life expectancy of unadjusted projections that fully take on board observed mortality in 2020 with adjusted projections for which we have removed the impact of the mortality shock in 2020 by the fourth year of the projection (see Section 3). The adjusted period life expectancy projections from the model are higher than those from the current method. The projections produced for the 2020-based interim NPPs were also adjusted to mitigate the impact of higher mortality because of the pandemic, but this adjustment was applied to the improvement rates rather than to the mortality rates. This is described in more detail in our National population projections, mortality assumptions: 2020-based interim article.

The NPP mortality expert advisory panel would advise on the proportion and rate of removal of a "mortality shock" for the 2021-based projections.

**Figure 6: Projections of period life expectancy are sensitive to the treatment of mortality shocks in the base year**

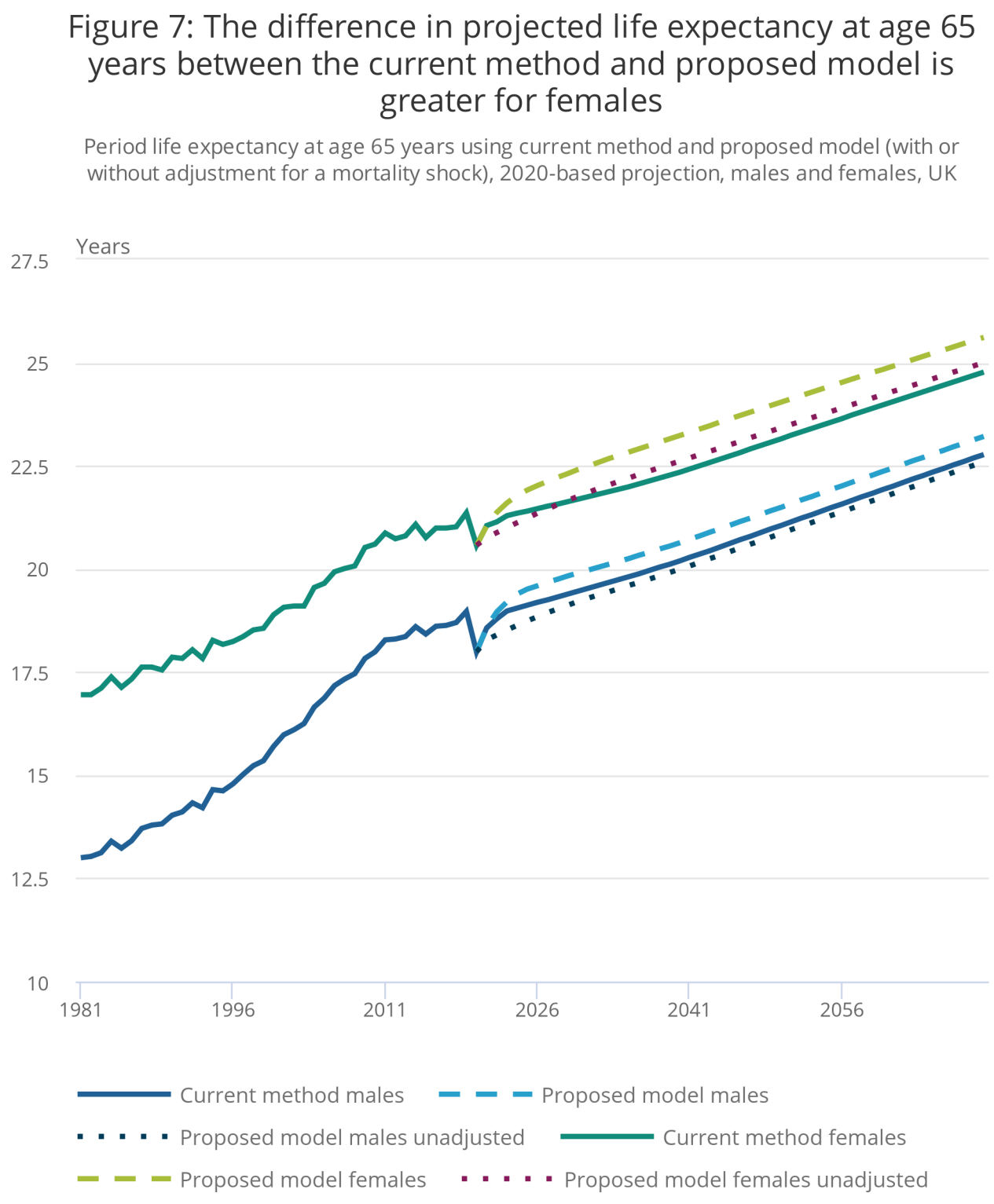
**Period life expectancy at birth using current method and proposed model (with or without adjustment for a mortality shock), 2020-based projection, males and females, UK**




**Source: ONS – 2020-based interim projections and modelled outputs**

**Figure 7: The difference in projected life expectancy at age 65 years between the current method and proposed model is greater for females**

**Period life expectancy at age 65 years using current method and proposed model (with or without adjustment for a mortality shock), 2020-based projection, males and females, UK**




**Source: ONS – 2020-based interim projections and modelled outputs**

## Comparisons of projected population between proposed and current method

Table 1 and Table 2 show, for 2018-based projections and 2020-based interim projections, the projected population of the UK in the target year by broad age groups for males and females, based on the current method and the proposed model. The differences between the two methods are relatively small for the overall population (less than 1%). However, the differences become more pronounced at age 85 years and over and are more pronounced for females than for males. The differences for England, Wales and Northern Ireland are of a similar magnitude to those for the UK, however differences for Scotland are greater (see the data tables published with this release). These differences are because of differences in the extrapolation of mortality improvements to older ages and to the proposed model projecting stronger cohort effects than the current method, resulting in lower projected mortality rates at ages 70 years and over.

Table 1: Comparisons of 2018-based population projections for 2043 using the current method and the proposed model, UK, males and females

| Sex | Age group | Projected population – current method | Projected population – proposed model | Numerical difference | Percentage difference |
|---|---|---|---|---|---|
| Males | **All ages** | 35,967,277 | 35,999,658 | 32,381 | 0.09 |
| | **Aged 0 to 15 years** | 6,315,706 | 6,316,578 | 872 | 0.01 |
| | **Aged 16 to 64 years** | 21,594,354 | 21,565,774 | -28,580 | -0.13 |
| | **Aged 65 to 84 years** | 6,794,455 | 6,749,881 | -44,574 | -0.66 |
| | **Aged 85 years and over** | 1,262,762 | 1,367,425 | 104,663 | 8.29 |
| Females | **All ages** | 36,449,563 | 36,661,352 | 211,789 | 0.58 |
| | **Aged 0 to 15 years** | 6,018,506 | 6,019,060 | 554 | 0.01 |
| | **Aged 16 to 64 years** | 21,103,091 | 21,078,730 | -24,361 | -0.12 |
| | **Aged 65 to 84 years** | 7,579,937 | 7,608,376 | 28,439 | 0.38 |
| | **Aged 85 years and over** | 1,748,029 | 1,955,186 | 207,157 | 11.85 |

Source: ONS – 2018-based projections and modelled outputs

Notes

1. Figures will not match those in the 2018-based and 2020-based interim national population projections release because errors as stated in the release “Corrections and notices” have been corrected.

Table 2: Comparisons of 2020-based population projections for 2045 using current method and proposed model, UK, males and females

| Sex | Age group | Projected population – current method | Projected population – proposed model | Numerical difference | Percentage difference |
|---|---|---|---|---|---|
| Males | **All ages** | 35,280,255 | 35,453,765 | 173,510 | 0.49 |
| | **Aged 0 to 15 years** | 5,739,107 | 5,744,263 | 5,156 | 0.09 |
| | **Aged 16 to 64 years** | 21,550,042 | 21,570,652 | 20,610 | 0.10 |
| | **Aged 65 to 84 years** | 6,723,406 | 6,750,731 | 27,325 | 0.41 |
| | **Aged 85 years and over** | 1,267,700 | 1,388,119 | 120,419 | 9.50 |
| Females | **All ages** | 35,687,989 | 36,020,028 | 332,039 | 0.93 |
| | **Aged 0 to 15 years** | 5,456,035 | 5,459,848 | 3,813 | 0.07 |
| | **Aged 16 to 64 years** | 20,892,198 | 20,892,066 | -132 | 0.00 |
| | **Aged 65 to 84 years** | 7,541,409 | 7,639,223 | 97,814 | 1.30 |
| | **Aged 85 years and over** | 1,798,347 | 2,028,891 | 230,544 | 12.82 |

Source: ONS – 2020-based interim projections and modelled outputs

Notes

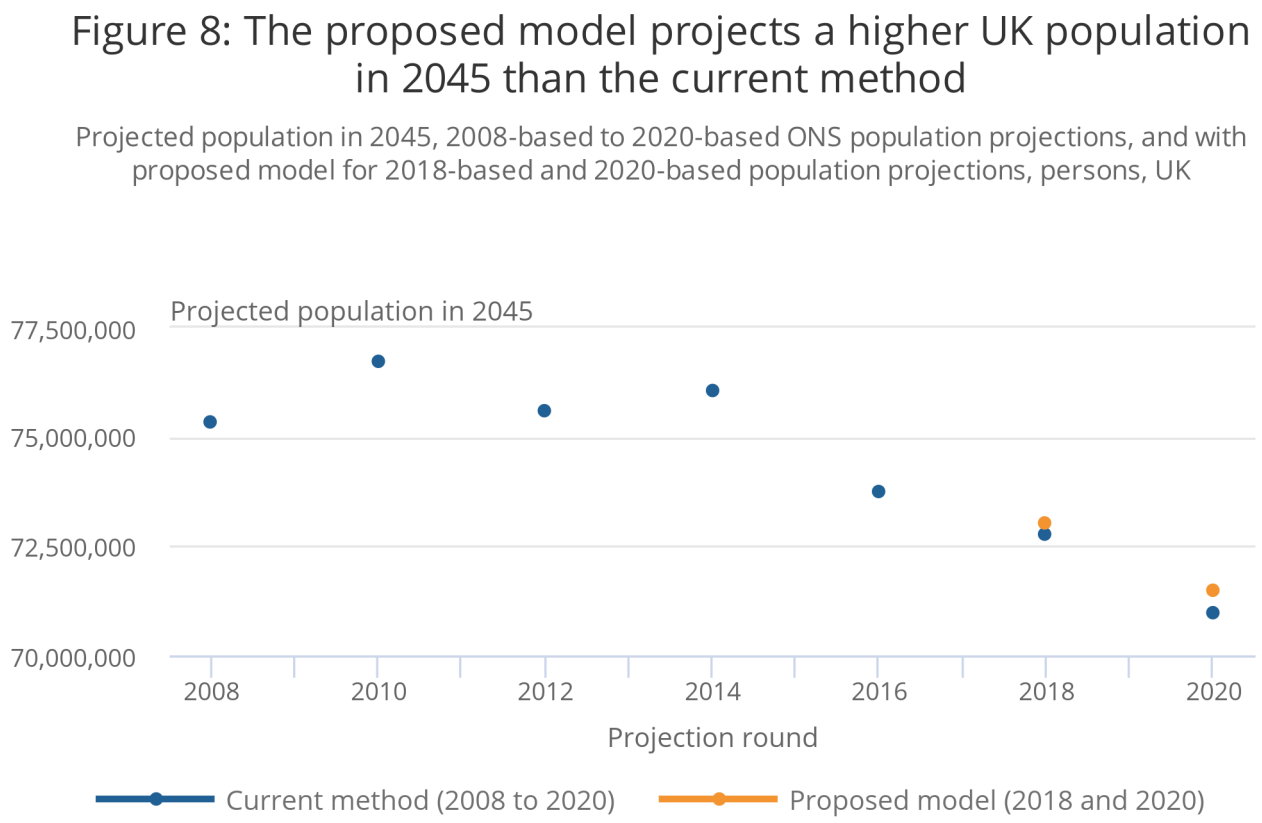
1. Figures will not match those in the 2018-based and 2020-based interim national population projections release because errors as stated in the release “Corrections and notices” have been corrected.

While these differences may have an impact for users of the projections, we do see quite significant changes in projected population from one round of projections to the next because of changes in the applied demographic assumptions (for mortality, fertility and migration).

Figure 8 shows that the projected population of the UK for 2045 decreased by 2.3 million between the 2014-based and 2016-based projections, a further 956,000 between the 2016-based and 2018-based projections and an additional 1.8 million between the 2018-based and 2020-based interim projections. If the mortality projections from the proposed model had been used for the 2018-based and 2020-based interim projections (alongside the existing projections of future trends in fertility and migration), the projected population of the UK in 2045 would have been 250,000 and 500,000 higher compared with 2018-based and 2020-based interim projections, respectively.

**Figure 8: The proposed model projects a higher UK population in 2045 than the current method**

**Projected population in 2045, 2008-based to 2020-based ONS population projections, and with proposed model for 2018-based and 2020-based population projections, persons, UK**




**Source: ONS – 2008-based projections to 2020-based interim projections and modelled outputs**

**Notes:**

1. Figures will not match those in the 2018-based and 2020-based interim national population projections release because errors as stated in the release “Corrections and notices” have been corrected.

# 5 . Mortality projections methods data

[Prospective new method for setting mortality assumptions for national population projections, UK: January 2023 - data tables]
Dataset | Released 9 January 2023
Data tables providing period and cohort life expectancy (ex) and projected population using the current mortality projections method and a proposed new method.

# 6 . Future developments

### How to respond to the user engagement exercise

We invite you to respond to the questions within this user engagement online via the Office for National Statistics consultations website. The user engagement will run from 9 January to 20 February 2023.

You can also download a copy of the questions and respond via email to projections@ons.gov.uk, indicating in the subject of your email that you are responding to the user engagement on population projections and who you are representing. You can also respond by post to Population and Household Projections, Room 4200S, Office for National Statistics, Segensworth Road West, Fareham, PO15 5RR.

Your response may be shared with our partners:

- National Records of Scotland (NRS) for Scotland
- Northern Ireland Statistics and Research Agency (NISRA) for Northern Ireland
- Welsh Government (WG) for Wales

All responses will be treated in accordance with our stakeholder privacy notice.

We will evaluate the responses to the user engagement exercise and plan to publish our response in spring 2023.

## 7 . Related links

National population projections, mortality assumptions: 2020-based interim
Article | 12 January 2022
The data sources and methodology used to produce mortality assumptions in the 2020-based interim national population projections.

National population projections: 2020-based interim
Bulletin | 12 January 2022
The potential future population size of the UK and its constituent countries. These statistics are widely used in planning, for example, fiscal projections, health, education and pensions.

Past and projected period and cohort life tables: 2020-based, UK, 1981 to 2070
Bulletin | 12 January 2022
Life expectancy (e), probability of dying (q) and number of persons surviving (l) from the period and cohort life tables, using past and projected mortality data from the 2020-based interim national population projections (NPPs), for the UK and constituent countries.

## 8 . Cite this article

Office for National Statistics (ONS), released 9 January 2023, ONS website, article, Prospective new method for setting mortality assumptions for national population projections, UK: January 2023