Mortality Projections Committee

CMI_2018 v03 software user guide

Supplement to Working Paper 119

November 2019

Contents

Reliances and limitations

The purpose of the CMI Model is to allow users to produce projections of annual rates of mortality improvement. Specifically, the Model:

- is updated – typically annually – to reflect recent experience of mortality in the population of England & Wales, based on data published by the Office for National Statistics (ONS); and
- allows users the flexibility to modify projections tailored to their own views and purpose.

The CMI aims to produce high-quality outputs and takes considerable care to ensure that the Model and the accompanying documentation are accurate. However:

- We cannot guarantee their accuracy (see the Disclaimer on the last page of this document).
- There is a reliance on the underlying data, published by the ONS; although we have exercised judgement in the choice of age range and period and in the adjustments we apply to the data.
- We have also applied judgement and assumptions in:
    - the choice of the default parameters in the Core version of the Model; and
    - in deciding how to illustrate the results.
- Anyone using the Model should ensure that it is appropriate for their particular use and that suitable values are used for the parameters.

1. Introduction

This is the user guide for version "CMI_2018 v03 2019-11-13.xlsm" of the CMI Mortality Projections Model ("the Model"). Changes to the previous version of the Model are described in Section 1.3. The user guide will be updated should the software be amended further.

The intention of the user guide is to describe the format of the software and explain how to run it. The formulae and algorithms are documented in "CMI_2018 methods" (the "methods" paper) and results from the Model are shown in Working Paper 119.

The Committee anticipates that it will publish a new results paper and software each year, to reflect changes in the Model due to new data. However, the methods paper and user guide should change little, if at all, from year to year; at least until the next review of the method. This guide is similar to the user guide to the previous version of the Model, CMI_2017.

1.1 Overview

The software is provided as a Microsoft Excel® workbook. It has only been tested using Excel 2010 and Excel 2016 in a Windows environment. We do not know how it will perform in other versions or operating systems.

The software's structure differs from CMI_2015 and earlier versions. In CMI_2016 to CMI_2018, all calculations use Visual Basic for Applications (VBA) macros, rather than spreadsheet formulae. Because of this, **macros and events must be enabled in order to use the software.** See Section 5.2 for comments on this.

To produce results from the Model:
- Fill in the Input worksheets to specify the calculation (described in Section 2).
- Press either of the "Run" buttons, on the "InputsMain" sheet.
- The software will then produce a new Excel workbook that contains results (described in Section 4).

1.2 Feedback

Feedback is welcome. Any comments on the software or this user guide can be sent to projections@cmilimited.co.uk and will be considered for future work. However, the CMI is unable to provide support for the software.

1.3 Changes in this version

This section describes the changes since CMI_2017.

Changes between CMI_2017 and CMI_2018 v01

Version "CMI_2018 v01" works in the similar way to "CMI_2017 v03".

The routine changes are:
- adding the CMI_2018 dataset and removing the CMI_2016 dataset;
- updating the start year from 2017 to 2018;
- updating the default calculation date from 1 January 2018 to 1 January 2019;
- amending the Core parameters to calibrate to data from 1978-2018, rather than 1977-2017; and
- replacing the 2014-16 National Life Table with the 2015-17 version.

The other changes are:
- adding the S3PMA and S3PFA mortality tables;
- changing the Core value of the period smoothing parameter, S_κ, to 7;
- pre-calculating results for the Extended Model for values of S_κ from 6 to 8.5 in steps of 0.25, rather than from 6.5 to 8.5;

- adding a new "initial addition to mortality improvements" Extended parameter; and
- allowing the "constant addition to mortality improvements" parameter to vary by age.

Changes between CMI_2018 v01 and CMI_2018 v02

Version "CMI_2018 v02" works in the same way as "CMI_2018 v01" but corrects an issue with the user interface that may lead to incorrect results.

The issue in CMI_2018 v01 is that if a user:

- opted to use the Advanced parameters and specified any non-zero value for the constant additions to mortality improvements by age, and
- reselected the Core parameters,

then

- the resulting projection used the values from the Advanced parameters, not the Core value of nil at all ages, and
- the output from the Model in this scenario would state invalidly that it is from the Core version.

We have also corrected a separate issue that would have prevented the Model from running if the user chose to enable automatic adjustment of smoothing parameters for other populations.

Changes between CMI_2018 v02 and CMI_2018 v03 beta

We have made CMI_2018 v3 available on request as a "beta" version. Assuming that no issues emerge, we intend to include the new features in CMI_2019.

A number of Subscribers noted that while the initial addition parameter ("A") was useful, it could only be used as an Extended parameter, and not with Advanced parameters. We have updated the interface of the software so that "A" can be set either:

- by choosing "Extended" projection assumptions on the "InputsMain" sheet, and specifying a value for "A" on that sheet; or
- by choosing "Advanced" projection assumptions on the "InputsMain" sheet, and specifying a value for "A" on the "InputsProj" sheet. If this option is chosen, then "A" can be specified either:
    - as a scalar (in which case the specified value applies to age 85, then tapers to nil at age 110); or
    - as an array, allowing the user complete control over how "A" varies by age.

We have also made other changes to the user interface:

- Highlighting a cell in gold when a parameter has been set to a value other than its Core value. This was previously done on the "InputsAPCI" sheet, and is now also done on the "InputsMain" and "InputsProj" sheets. There is still no such highlighting on the "InputsInitial" sheet.
- Adding an option to automatically save the results workbook to a specified filepath.

None of these changes affect the projected results.

2.   Inputs

Throughout the software, required input cells are coloured grey. Other cells, containing descriptions of the inputs, are protected so they cannot be changed.

The software has a large number of inputs, but many of these are not needed for simpler uses of the Model. When the software is first opened from the CMI pages of the Institute and Faculty of Actuaries' website, the only input sheet that will be visible is "InputsMain". Further input cells and input sheets will be revealed only if they are necessary, according to choices made by the user.

Core and Extended uses of the Model, described in Table 2.1, require fewer inputs than Advanced use.

Table 2.1: Description of Core, Extended and Advanced layers of parameters

Layer	Core	Extended	Advanced
Contents	Long-term rate of mortality improvement (LTR)	Period smoothing parameter (S_κ) Initial addition to mortality improvements (A)	All other parameters
Definition	The "Core" parameter must be determined by users of the Model; as no default value is provided	The "Extended" parameters have default values, but the Committee encourages users to consider them carefully	The "Advanced" parameters are those which are less likely to be amended by the user
"… Model"	The description "Core Model" should be used only if no Extended or Advanced parameter has been changed from its default value	The description "Extended Model" should be used only if (i) at least one or of the parameters S_κ and A has been given a value other than its default, and (ii) no Advanced parameter has been changed from its default value	The description "Advanced Model" should be used if any Advanced parameter has been given a value other than its default
Naming convention	CMI_Y_G [L%] where: Y is the four-digit model version (e.g. 2018) G is gender ("M" or "F") L is the long-term rate	CMI_Y_G [L%;S=S_κ] or CMI_Y_G [L%;A=A] or CMI_Y_G [L%;S=S_κ;A=A] where: S_κ is the period smoothing parameter A is the initial addition to mortality improvements A parameter does not need to be shown if its Core value is used	CMI_Y_G [L%;S=S_κ; A=A] Advanced and any Advanced parameters that take values other than the default should be described
Example name	CMI_2018_F [2%]	CMI_2018_F [2%;S=8]	CMI_2018_F [2%;S=8; A=0] with LTR tapering to zero between 90 and 110

2.1   InputsMain sheet

The "InputsMain" sheet is the first input sheet, and the only one that is necessary for Core and Extended uses of the Model.

Figure 2.1 shows a screenshot of the InputsMain sheet, as it appears when the software is first opened from the website.

Figure 2.1: The InputsMain sheet

We consider each of these inputs in turn.

Gender

Gender must be Male, Female, or Other.

- We expect that for the vast majority of uses of the software, Gender will be Male or Female. "Other" is provided for completeness for unusual cases, such as unisex mortality.
- The software for CMI_2015 and earlier versions had room for Advanced inputs for males and females, and selecting gender could toggle between these. In contrast, this software only contains Advanced inputs for one gender.

APCI model and period smoothing parameter

There are four options:

- "Core". This will use the Core parameters
- "Extended". This will use the Extended parameters. If this option is selected then an input for Period Smoothing Parameter (S_κ) will be revealed, and this can be varied.
- "Advanced – APCI model". This will generate initial improvements using the APCI model. If this option is selected then the sheet InputsAPCI will be revealed. This is described in Section 2.2 and is initially populated with Core values, which can be changed by the user.
- "Advanced – other". This allows users to specify the initial improvements in any way they choose, without being constrained to use the APCI model. If this option is selected then the sheet InputsInitial will be revealed. This is described in Section 2.4.

Projection assumptions and long-term rate

There are three options:

- "Core". This will use the Core parameters. If this option is selected then the long-term rate must be entered in the cell immediately below.
- "Extended". This will use the Extended parameters. If this option is selected then an input for the initial addition to mortality improvements will be revealed, and this can be varied. The long-term rate must also be entered on this sheet.
- "Advanced". This will use Advanced parameters. If this option is selected then the long-term rate input will be hidden, and the sheet InputsProj (described in Section 2.5) will be revealed and must be completed.

Calculation date

The calculation date does not affect the calculation of mortality improvements, but is used to specify the timing of projected mortality rates, reduction factors, life expectancies and annuities. These outputs will be calculated on anniversaries of the calculation date; e.g. if the calculation date is 6 April 2019, then these outputs will be calculated on 6 April in each year. (If the calculation date is 29 February, then outputs will be at 1 March in years which are not leap years.)

Other inputs for life expectancies and annuities

The following inputs are used to calculate life expectancies and annuities:

- Options for the base mortality table are described in detail in Section 2.6. We expect that most users will choose one of the first five options. These are all existing CMI mortality tables, and mortality rates will be chosen according to the specified Gender.
- The base mortality table is multiplied by the scaling factor before use. The precise application of the scaling factor is described in Section 2.6.
- The retirement age and interest rate only affect annuity values, not life expectancies. The calculation of annuities is documented in Section 6.3 of the CMI_2018 methods paper.

Controlling the output

The option "Summary or full output" allows the user to control the volume of outputs – either "Full" or "Summary", described in Section 4.

Users can provide an optional "Description of the run" as free text. This will be included in the header of every output sheet and may be helpful in distinguishing between multiple runs of the software.

Users can provide an optional "File path to save results". If this is specified then the code will save the results file to this location. We recommend specifying a full file path (e.g. "X:\Folder\Subfolder\Filename.xlsx").

2.2 InputsAPCI

The sheet InputsAPCI will be revealed if the option "Advanced – APCI model" is chosen for "APCI model" on the InputsMain sheet.

This is initially populated with Core parameter values. When an input is set to an Advanced value, this is highlighted and the Core parameter value is shown to the right, for ease of reference.

The methods paper describes how the parameters on this sheet are used:
- Section 3.5 describes the exposure adjustment method.
- Section 4 describes the APCI model.
- Sections 5.2 and 5.3 describe the calculation of initial mortality improvements, and Section 5.6 describes the calculation of historical improvements.

Calibration dataset

Users can specify the data to be used to calibrate the APCI model either:
- by specifying worksheets within the software that contain the data; or
- by specifying a dataset contained within the Human Mortality Database (HMD).

If the data is contained within the software, then it must be in two worksheets, one for deaths and one for exposures. These sheets must be named using the format {Prefix}_{GenderLetter}_Dth for deaths and {Prefix}_{GenderLetter}_Exp where:
- the Prefix is specified on the InputsAPCI sheet, and must not end in "@HMD"
- the GenderLetter depends on Gender on InputsMain, with M for Male, F for Female, and X for Other.
- The data sheets must be in a standard format, described in Section 2.3.

If the data is to be extracted from the HMD, then this must be entered in the form "{CountryCode}@HMD". More information on the HMD data and its use is in Section 2.7.

Unsmoothed results

Section 4.2 of the methods paper describes smoothing in the APCI model. Some users may wish to see the impact of not smoothing some set of parameters; i.e. by setting a hyperparameter λ to zero. It is not possible to do this directly in the software, but this can be achieved by setting $S = -1000$, due to the accuracy of Excel's floating point arithmetic. For example, setting $S_\kappa = -1000$ would lead to $\lambda_\kappa = 0$ and would not smooth the period parameters.

Adjusting smoothing parameters

Section 5 of Working Paper 115 shows how the Core smoothing parameters can be adjusted when calibrating to another dataset so that they have a similar impact on the chosen dataset as the Core smoothing parameters have on the England & Wales dataset.

If the input "Whether to adjust smoothing parameters for population size" in cell E30 is set to "No" then the smoothing parameters in cells E25:E28 will be used without adjustment.

If the input "Whether to adjust smoothing parameters for population size" in cell E30 is set to "Yes" then the software will treat the values of S_α, S_β, S_κ and S_γ in cells E25:28 as applying to the CMI_2018 calibration dataset for England & Wales for the specified gender, and will adjust these before calibrating the APCI model. The outputs will show the values of the smoothing parameters before and after adjustment.

If this option is chosen, the following adjustment will be applied to each smoothing parameter:

$$S_i^{(New)} = S_i^{(C)} + \log_{10}\left(D_{Total}^{(New)} \div D_{Total}^{(E\&W)}\right)$$

where

- $D_{Total}^{(E\&W)}$ for the total number of deaths in England & Wales in the calibration dataset (e.g. years 1978-2018 and ages 20-100 for CMI_2018)
- $D_{Total}^{(New)}$ for the total number of deaths in the calibration dataset for the new population
- $S_i^{(C)}$ for the Core smoothing parameter of some type ($\alpha, \beta, \kappa, \gamma$)
- $S_i^{(New)}$ for the equivalent smoothing parameter of the same type for the new population

i.e. the same adjustment is applied to each parameter.

2.3 Data sheet format

Data sheets, for deaths and exposures, must be in a standard format.

Metadata

Cells B1 to B16 contain "metadata" – information about the data. Some of these cells are free text, and can contain any value. The following are constrained, in order to reduce the risk of errors:

- "Name" in B1 must match the name of the worksheet.
- "Sex" in B11 must be "M", "F" or "X" and correspond to the name of the worksheet.
- "Type" in B12 must be "Exp" for exposures or "Dth" for deaths, and correspond to the name of the worksheet.
- The age and year ranges in B13 to B16 must correspond to the size of the data.

Data headings

The data must have headings to explicitly indicate the age and year of each value:

- Row 18, starting at column B, must contain calendar years. These must be consecutive integers, and agree with the minimum and maximum values in B15 and B16.
- Column A, starting at row 19, must contain ages. These must be consecutive integers, and agree with the minimum and maximum values in B13 and B14.

Data

The data itself is contained in a rectangular array, with B19 as its top-left cell. The data must be numeric.

2.4 InputsInitial

The sheet InputsInitial will be revealed, and must be completed, if the option "Advanced – other" is chosen for "ACPI model" on the InputsMain sheet.

The inputs to the top-left of the sheet specify the age and calendar year range to use:

- Cell E5 specifies the minimum age to use in the calculations. The maximum age will always be 150.
- Cell E7 specifies the year at which the initial mortality improvements apply.
- Cell E9 specifies the first year for which historical mortality improvements are provided. It is necessary to provide improvements as far back as the effective date of the base mortality table.

The other inputs are arrays by age. The sheet has room for inputs for ages 20 to 150 inclusive. If the minimum age in cell E5 is greater than 20, then inputs for younger ages will be ignored.

- The age-period and cohort components of initial mortality improvements are provided in columns H and I. Column J calculates their sum, and column K warns if the totals do not agree with the corresponding values from the grid of historical improvements.
- The initial central mortality rates are entered in column M. These are necessary in order to convert from m-type improvements to q-type improvements.
- Column O contains the direction of travel. This is optional, and is needed only the if the Advanced option "APCI/initial direction of travel" is chosen for the age-period convergence shape on the InputsProj sheet.
- Historical mortality improvements are entered in columns Q to EM, although usually many of these will be hidden, depending on which years are specified in cells E7 and E9.

2.5 Projection assumptions

The sheet InputsProj will be revealed, and must be completed, if the Advanced option is chosen for "Projection assumptions" on the InputsMain sheet.

Cells E7, E9, E10, E12, E13 and E14 are used to specify if certain aspects of the projection should use Core or Advanced parameters. If Advanced parameters are chosen, then arrays of inputs by age will be revealed, in columns H onwards, and must also be completed.

The sheet has room for inputs for ages 20 to 150 inclusive. If a minimum age is specified on InputsAPCI or InputsInitial and is greater than 20, then inputs for younger ages will be ignored.

Column P specifies the constant addition to mortality improvements, by age. This is added to the projected m-style mortality improvements.

Initial addition assumption

This can be Core, or a value can be specified by choosing either:

- "Specify a single value", in which case the single value must be specified in the cell below; or
- "Specify an array by age", in which case the user must specify values for every required age.

While the initial addition can be varied by age, as above, it does not vary by calendar year and the same addition is applied to all historical improvements. If you would like the addition to vary by calendar year, then that could be accomplished by the following steps:

- First run the Core model without any initial addition, specifying "Full" output.
- Take the historical mortality improvements from the output sheet "MI_m_proj" and make whatever adjustment you wish to these. Make consistent adjustments to the age-period and cohort components ("MI_m_AP_proj" and "MI_m_Co_proj") in the final year, as these will be needed to specify the adjusted initial improvements.
- Run the Model again, this time selecting the "Advanced – other" option for the ACPI model, and completing the "InputsInitial" sheet with the adjusted initial improvements and historical improvements that you calculated above.

Long-term rate assumption (Age-period)

This can be Core or Advanced. If Core is chosen, then a single value must be specified in the cell below. If Advanced is chosen then the user must specify values for every required age.

Convergence period (Age-period)

This can be Core or Advanced. If Advanced is chosen then the user must specify values for every required age.

Convergence shape (Age-period)

There are four options:

- "Core". The Core parameters will be used.
- "APCI/initial direction of travel". Convergence will be controlled by direction of travel, and the initial direction of travel will, depending on the choice made for initial improvements, be either:
  - derived from the APCI model (as described in Section 5.8 of the methods paper), and applied up to age 85, then taper to nil at age 110; or
  - taken from the InputsInitial sheet, if the APCI model is not used.
- "Specify direction of travel". Convergence is specified in terms of direction of travel, and the user specifies values for every required age.
- "Specify proportion at midpoint". Convergence is specified in terms of proportion remaining at midpoint, and the user specifies values for every required age.

Cohort assumptions

The options for convergence by cohort are similar to those for age-period convergence, except:

- If Core is chosen for the long-term rate, there is no need to specify its value.
- There is no option to derive direction of travel from the APCI model.

2.6 Base mortality tables

The choice of base mortality table does not affect the calculation of mortality improvements, only the calculation of life expectancies and annuities.

CMI tables

The following CMI mortality tables[1] are contained within the software:

- PCFA00 and PCMA00 (assumed timing 1 July 2000)
- PFA08 and PMA08 (assumed timing 1 July 2008)
- S1PFA and S1PMA (assumed timing 1 September 2002)
- S2PFA and S2PMA (assumed timing 1 January 2007)
- S3PFA and S3PMA (assumed timing 1 January 2013)
- AFC00 ult and AMC00 ult (assumed timing 1 July 2000)

The "assumed timing" above is the date at which each table is deemed to apply. e.g. a value of q_x in the PCFA00 table is assumed to be the probability that a person aged x on 1 July 2000 dies before reaching age $x + 1$ on 1 July 2001.

National Life Tables

The software also contains the National Life Tables for England & Wales for the period 2015-2017[2]. We use the shorthand "NLT 15-17 E&W M" and "NLT 15-17 E&W F" to refer to these. These are produced by the Office for National Statistics (ONS) and are assumed to apply on 1 January 2016.

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[1] Further information can be found at https://www.actuaries.org.uk/learn-and-develop/continuous-mortality-investigation/cmi-mortality-and-morbidity-tables which provides links to working papers that describe the construction of these tables.

[2] The tables are published at https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/lifeexpectancies/datasets/nationallifetablesenglandandwalesreferencetables

Use of "Underscore" tables

When selecting a table in the software, it is possible to select a version which contains an underscore – e.g. "S1P_A". If this is selected, then the software will use the corresponding table based on the gender specified on the InputsMain sheet. This is likely to be the most convenient way of specifying a table for most users of the software, as long as Gender is male or female rather than "Other".

It is also possible to choose the table by specifying the gender explicitly – e.g. choosing "S1PMA" or "S1PFA". In this case, if the gender of the table does not match that on the InputsMain sheet then a warning will be generated.

Custom tables

In addition to the tables listed earlier, it is possible to specify up to five "Custom" base mortality tables. This is done on the worksheet "CustomBaseTables" by specifying:

- a name for the table (which will then appear as an option on InputsMain);
- the date at which the table is deemed to apply; and
- mortality rates (q_x) for each age.

Scaling factor

The base mortality table will be multiplied by the scaling factor before use as shown below. Note that the resulting mortality rate is limited to a value of 1.

$$q_x^{Use} = \min(q_x^{Base} \times ScalingFactor, 1)$$

where q_x^{Use} is the mortality rate used to calculate life expectancies and annuities, q_x^{Base} is the mortality rate from the specified base table, and $ScalingFactor$ is the chosen scaling factor.

2.7 Use of HMD data

To aid testing and review of the Model, the Committee has run the software using various datasets from the Human Mortality Database (HMD). To do so, it has added functionality to the software to automatically extract the data from the HMD using a "live link", without needing to perform a manual extract. The Committee has made this feature available to users from version "CMI_2016 v02 2017-11-08.xlsm" of the software, as this may be of interest to them.

The Committee reminds users that it is their responsibility to ensure that any data that they use is suitable for their purpose, and provides no assurances or warranties about (i) the quality of the HMD data, (ii) its suitability for any specific purpose, nor does it (iii) guarantee any outcome or result from the application of this data.

Please note that the Core parameters have been selected for the ONS England & Wales dataset and therefore should be reviewed before being applied to other datasets.

To make use of the live HMD link, the dataset must be specified on the "InputsAPCI" sheet in the form "{CountryCode}@HMD", where "{CountryCode}" is the HMD's code for the chosen country.

The available countries are listed at https://www.mortality.org/cgi-bin/hmd/DataAvailability.php. Clicking on the name of a country will lead to a page that contains the country code in its URL; e.g. clicking on Australia leads to the page https://www.mortality.org/cgi-bin/hmd/country.php?level=1&cntr=AUS. The final part of this URL gives the country code as "AUS", so this would be specified within the software as "AUS@HMD".

To use the live HMD link within the software, users must first register with the HMD and comply with its user agreement. Registration is free of charge and can be done by clicking "New User" on the page https://www.mortality.org/mp/auth.pl. When using the live HMD link within the software you will be prompted for your username and password (although Excel may 'remember' these so that you are not prompted on each subsequent use).

3. Running the software

Once the inputs have been specified, the software is run by pressing either of the "Run" buttons on the sheet InputsMain.

The time taken to perform the calculations and produce the results workbook is typically about ten seconds, or less for Core and some Extended uses of the Model (see Section 3.1 below). While the software is running, the statusbar will show its progress.

3.1 Pre-calculated APCI model

As noted in Section 2.1, the user can choose how the APCI model is determined. If Core is chosen, or Extended is chosen with a period smoothing parameter of 6, 6.25, 6.5, 6.75, 7, 7.25, 7.5, 7.75, 8, 8.25 or 8.5, then the software will use pre-calculated values for the initial mortality improvements, rather than running the APCI model. This makes it faster to produce results.

If this is the case then not all of the output sheets are available. If full output is wanted in this case, users may wish to force the APCI model to run, by selecting the "Advanced – APCI model" option, but choosing Core or Extended parameter values.

3.2 Errors and Warnings

The software will alert the user in the event of most problems. It distinguishes between Errors and Warnings.

We use the term "Error" to describe something that prevents the software from running successfully. This is typically due to the chosen inputs (e.g. a missing value). If an Error is encountered, the code will stop running and a message box will pop up to alert the user and describe the error.

A "Warning" is shown if an input is unusual (e.g. a negative value for the long-term rate) but does not prevent the software from running. The user can choose to continue, or to stop the software. If the user continues, then the Warnings will be included in the results file.

Users can disable the message box for Warnings (but not Errors) by changing the "Show warning" input on the Settings sheet. We discourage this (and the Settings sheet is initially hidden) but it may be useful in some cases, e.g. if a user wishes to use code to make bulk runs of the software without manual intervention. Warnings will be shown in the results file even if the message box is disabled.

For both Errors and Warnings, the message box may describe multiple problems at once. The text in the message box can be selected and users may wish to copy and paste it to another application for later reference.

3.3 Failure to converge

The procedure used to fit the APCI model is iterative. As described in Section 4.3 of the methods paper, the software repeatedly calculates improved sets of parameters and stops once the objective function is no longer improving materially. For the standard dataset this happens quickly, in fewer than 100 iterations.

It is conceivable that for some datasets convergence may be slow. If the objective function has not converged to the required tolerance within 10,000 iterations then the software will stop and will not produce results. We would like to be informed of any such cases.

4.   Outputs

Results from the software are produced in a new Excel workbook. The software is capable of producing a large number of output worksheets. Users can choose between "Full" and "Summary" outputs.

4.1   Output worksheets

Table 4.1 lists all of the possible output sheets, together with brief descriptions, and their timing. For the timing column, "User-specified" means that the timing will correspond to the calculation date on the InputsMain sheet.

- Sheets shown in bold are included in the "Summary" output option.
- Other sheets are only included under the "Full" option. But, as noted in Section 3.1, some sheets will not be produced if pre-calculated initial initial improvements are used.

Each output sheet is labelled with basic details of the run, as well as the optional "Description of the run" input, if used.

Table 4.1: Contents of the results workbook

Sheet name	Description	Timing
Warnings	A list of warnings (if any) produced by the software	
Contents	Contents of the results workbook	
Audit	Details of who ran the software and when	
Charts	Charts of key results	
Summary	Summary of life expectancies and annuities	User-specified
Inputs_Main	High-level parameters used to specify the software run	
Inputs_APCI	Parameters used to specify the calibration process	
CalibDth	Deaths data used for calibration	Calendar year
CalibExp	Exposure data used for calibration	Calendar year
CalibExpRaw	Exposure data before adjustment	Calendar year
Iterations	Progress of deviance, penalty and objective during the fitting process	
OutputsAPCI	Fitted parameters for the APCI model	
logm_fit	Fitted log central mortality rates	Calendar year
m_fit	Fitted central mortality rates	Calendar year
DevRes	Deviance and deviance residuals	Calendar year
MI_fit	Fitted mortality improvements	Calendar year
ParamsProj	Parameters used to specify the projection process	

Sheet name	Description	Timing
MI_m_AP_proj	Projected age-period component of mortality improvements in terms of m	Calendar year
MI_m_C_proj	Projected cohort component of mortality improvements in terms of m	Calendar year
MI_m_proj	Projected mortality improvements in terms of m	Calendar year
logm_proj	Projected log central mortality rates, using calibration data	Calendar year
m_proj	Projected central mortality rates, using calibration data	Calendar year
q_proj	Projected mortality rates, using calibration data	As at 1 January
MI_q_proj	Projected mortality improvements in terms of q	Calendar year
ParamsSample	Parameters used to specify the sample life expectancies	
q_base_proj_1_Jan	Projected mortality rates, using specified base table	As at 1 January
q_base_proj_calcdate	Projected mortality rates, using specified base table	User-specified
RF_base_proj_calcdate	Reduction factors, from base table date	User-specified
LE_P	Period life expectancies, using the specified base table	User-specified
LE_C	Cohort life expectancies, using the specified base table	User-specified
Annuity_P	Period annuities, using the specified assumptions	User-specified
Annuity_C	Cohort annuities, using the specified assumptions	User-specified
OutputChecks	Showing how rates and improvements have been calculated	

Sections 4.3 onwards describe the output worksheets.

4.2　Outputs for future cohorts

For the Core and Extended versions of the CMI Model, projections will be made for cohorts born later than those in the calibration data.

For Advanced uses of the Model, projections will only be made for cohorts born later than those in the calibration data if the cohort component of mortality improvement at the youngest age in the calibration data is constrained to be nil.

For example, consider an Advanced version of the CMI_2018 Model, which uses the APCI model:

- If the minimum age to use for calibration is 50, but all other parameters are unchanged, then no projections will be made for the 1969 cohort or later (aged 49 in 2018, the last year of the calibration data), as the cohort component of initial mortality improvements cannot be determined from the calibration data for these birth years.
- If the minimum age to use for calibration is 50 and cohort components of initial mortality improvements are constrained to be nil at ages 50 and below, then projections will be made for later cohorts, as their cohort components are determined by the constraint.

If initial improvements are specified using the "InputsInitial" sheet (i.e. using the "Advanced – other" option) then no projections will be made for future cohorts, as the cohort component for those cohorts is unspecified.

4.3　Warnings

If there are any warnings, due to unusual inputs, then these will be shown on a Warnings sheet, included as the first sheet of the results file. If there are no warnings then no Warnings sheet will be produced.

4.4　Contents

The Contents sheet lists the sheets contained in the results workbook, similar to Table 4.1 above. It contains hyperlinks to the other sheets, and they each contain a hyperlink back to the Contents sheet.

4.5　Audit

The Audit sheet contains basic information about when the software was run, and by whom. The username is the Windows username if this is available, otherwise the Excel username.

4.6　Charts

The Charts sheet shows charts of key inputs and results.

Four line charts show:

- Total initial mortality improvements
- Age-period and cohort components of initial mortality improvements
- Long-term rates for age-period and cohort components
- Convergence periods for age-period and cohort components

There is also a "heatmap" of historical and projected mortality improvements. This is coloured, using the key shown below the chart, according to the value of the mortality improvement at a given age and year.

4.7　Summary

The Summary sheet shows a summary of life expectancies and annuities at five-year intervals of age and time. These are a subset of the results from the sheets LE_P, LE_C, Ann_P and Ann_C described in Section 4.18.

4.8 InputsMain

This shows those inputs from the InputsMain sheet that relate to the projection of mortality improvements, rather than the calculation of life expectancies and annuities.

4.9 InputsAPCI

This shows inputs from the InputsAPCI sheet. It includes the values of λ derived from the input values of S.

If the user chooses to make an automated adjustment to the smoothing parameters then values of S will be shown both before and after adjustment.

4.10 Calibration data

Sheets with the prefix "Calib" show the dataset used to calibrate the APCI model. They show data for those ages and years that are used in the calibration, rather than the entire input data sheets:

- CalibDth shows deaths.
- CalibExp shows the exposure data used to calibrate the APCI model.
- If exposures have been adjusted by the software then CalibExpRaw will show the unadjusted exposure data, and cells that have been adjusted will be highlighted.

4.11 Iterations

As noted in Section 3.3, the fitting procedure for the APCI model is iterative. The Iterations sheet shows the Deviance, Penalty and total Objective function after each iteration. This helps the user to verify that the fitting procedure has converged satisfactorily.

4.12 OutputsAPCI

This sheet shows outputs from the fitted APCI model:

- Columns Alpha, Beta, Kappa and Gamma are parameters α_x, β_x, κ_t and γ_{t-x}
- Columns MI_Age, MI_Period and MI_Cohort are derived components of mortality improvements
- The value of DoT is the direction of travel in the final year.

4.13 Fitted mortality rates and improvements

The sheets logm_fit, m_fit and MI_fit show, for each age and calendar year, results from the APCI model:

- logm_fit shows $\log m_{x,t}$
- m_fit shows $m_{x,t}$
- MI_fit shows $MI^*_{x,t}$; i.e. m-style mortality improvements.

4.14 DevRes

This sheet shows deviance residuals defined by

$$r_{x,t} = \text{sign}(D_{x,t} - E_{x,t} m_{x,t}) \sqrt{2\left(D_{x,t} \log\left(\frac{D_{x,t}}{E_{x,t} m_{x,t}}\right) - (D_{x,t} - E_{x,t} m_{x,t})\right)}$$

Cell A10 shows the deviance of the fitted APCI model. This is equal to the sum of squares of the deviance residuals.

4.15 ParamsProj

The sheet ParamsProj has the parameters used in the projection of the Model. We use "AP" and "Co" to identify age-period and cohort components respectively.

Depending on the choices made by the user, values will only be shown for direction of travel or for proportion remaining at midpoint, and the other will be shown as "n/a".

4.16 Projected mortality improvements

Four sheets show grids of projected mortality improvements by age and time:

- MI_m_AP_proj shows the age-period component of m-style improvements ($MI_{x,t}^{AP*}$)
- MI_m_C_proj shows the cohort component of m-style improvements ($MI_{x,t}^{C*}$)
- MI_m_proj shows the total m-style improvements ($MI_{x,t}^{*}$)
- MI_q_proj shows the total q-style improvements ($MI_{x,t}$)

4.17 Projected mortality rates

Three sheets show grids of projected mortality rates by age and time:

- logm_proj shows logarithms of central mortality rates; i.e. $\log m_{x,t}$
- m_proj shows central mortality rates $m_{x,t}$
- q_proj shows mortality rates $q_{x,t}$

4.18 Sample outputs

ParamsSample shows the parameters used to calculate illustrative life expectancies and annuities.

The following seven sheets show grids of output by age and time:

- q_base_proj_1_Jan shows projected mortality rates at the start of each year
- q_base_proj_calcdate shows projected mortality rates at anniversaries of the specified calculation date
- RF_base_proj_calcdate shows reduction factors (defined in Section 6.1 of the methods paper) relative to the date of the specified base mortality table
- LE_P and LE_C show period and cohort life expectancies
- Ann_P and Ann_C show period and cohort life annuity values

4.19 OutputChecks

The OutputChecks sheet provides an interactive demonstration of how the projections are done. This is intended to make the projection method more transparent than the VBA code. The grey cells D16 and D17 can be varied by the user.

The calculations compare projections:

- taken from other sheets in the results workbook (calculated using VBA code); and
- calculated on this worksheet, based on parameter values and projection formulae.

Cells with names beginning with "Agrees" compare the two methods, and should show "TRUE".

5. Miscellaneous

This section describes a number of items that do not naturally fit in one of the previous sections.

5.1 Data sheets

This version of the software includes data for CMI_2017 and CMI_2018.

Data for CMI_2016 is available in the CMI_2016 software.

Data for CMI_2015 and earlier versions of the Model, in a different format, is available from https://www.actuaries.org.uk/documents/cmi-working-paper-84-exposure-and-deaths-dataset-used-preparation-cmi2015. In order to use this in the software, it would need to be re-formatted as described in Section 2.3.

While CMI_2018 uses 41 calendar years of data to calibrate the APCI model, the data sheets in the software contain data for earlier years as well, starting in 1961. This is included as it may be of interest to users; e.g. for back-testing. However, the Committee cautions that it made a conscious decision not to calibrate the Model to a longer period of data, informed by the concerns raised in Appendix D of Working Paper 74 about the quality of data in earlier years.

5.2 Macros and events

The software requires macros to be enabled.

The method to enable macros varies between versions of Excel, and in some organisations may be restricted by a system administrator. In later versions of Excel, macro settings can be found in the "Trust Center".

The user interface relies on events being enabled in order to show and hide inputs depending on choices made by the user. If the user interface does not appear to work correctly (i.e. rows and sheets are not shown and hidden as expected) then it may be possible to remedy this by running the macro "EnableEvents".

5.3 Passwords

The software's worksheets and VBA code, and results workbooks, are password-protected. This is intended to prevent errors arising from unintentional changes.

These can be unprotected by using the password "CMI", but the Committee warns that this is at a user's own risk, and changes to the software could result in it not working as intended.

6. VBA code

As noted in Section 1.1, the calculations are performed entirely using VBA code. For most users of the software, there is no need to access the VBA code, as calculations can be done entirely using the Excel interface.

However, some users may wish to investigate the VBA code; e.g. in order to replicate the calculations in another computer system, to extend the calculations or outputs, or to automate the production of multiple runs. This section provides a very brief introduction and orientation to the code for such users.

The main procedural code is in Main and Output:

- Main – the main function that reads the input parameters, loads the data, fits the APCI model and makes the projection
- Output – various routines for producing the results file

The code is largely object-oriented. The bulk of the work is done in the following classes:

- RunParams – various parameters relating to the particular run of the software
- Data – the data, loaded from the Excel workbook or the HMD, that is used to calibrate the APCI model
- APCI – the APCI model, including its fitting procedure and derivation of initial mortality rates and improvements
- Projection – projection of mortality improvements and calculation of outputs, including life expectancies

There are also a number of other classes and procedures:

- Problems – used to manage messages about Errors and Warnings
- Interface – used to manage the user interface, showing and hiding sheets and rows
- Misc – various functions, including those that are used by multiple classes
- CMIChart, CMIColours and CMIHeatmap – used for various charts
- EnumCMIColours and EnumMisc – containing enumerations

References

Working Paper 74 "The CMI Mortality Projections Model, CMI_2014". (2014)

Working Paper 115: "CMI Mortality Projections Model: Interim update" (2018)

Working Paper 119: "CMI Mortality Projections Model: CMI_2018" (2019)

"CMI_2018 methods" (2019)

Human Mortality Database (2019) University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany). Available at www.mortality.org or www.humanmortality.de

CMI working papers may be accessed and downloaded from the Mortality Projections Committee section of the Institute and Faculty of Actuaries' website: https://www.actuaries.org.uk/learn-and-develop/continuous-mortality-investigation/cmi-working-papers/mortality-projections.

Most of these outputs are only accessible to Authorised Users (i.e. to employees of subscribers and to researchers, for non-commercial use).