



Research Brief

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Communicating population forecast uncertainty using perishable food terminology

Tom Wilson

Northern Institute/ College of Indigenous Futures, Arts and Society

tom.wilson@cdu.edu.au

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NorthernInstitute



@cdu_ni



Abstract

Despite many decades of research on probabilistic methods, population forecasts with predictive distributions remain relatively rare amongst official population forecasts. Partly as a result, little attention has been given to communicating forecast uncertainty to users, especially non-technical users. The aim of this paper is to propose the adoption of perishable food labels such as ‘shelf life’, ‘use by’ date, and ‘best before’ date to describe forecast uncertainty in a simple manner. These terms can be applied to both fully probabilistic forecasts and those with empirical prediction intervals based on past error distributions. Examples of their use are presented using population forecasts for the World, Australia, and the Northern Territory of Australia. It is suggested that these labels could prove helpful in describing uncertainty to non-technical users of population forecasts.

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Introduction

The development of methods to quantify population forecast uncertainty over the last couple of decades or so represents a major advance in demographic modelling research. A large number of papers, reports and books describing methodological refinements and new applications can be found in the literature, with many recent papers dealing with the issue of ensuring consistency when forecasting two or more sub-populations (e.g. Enchev et al. 2017; Sanderson et al. 2017; Sevcikova et al. 2018; Wisniowski and Raymer 2016). Probabilistic forecasting methods are now widely used by academic researchers preparing demographic forecasts.

However, probabilistic methods and predictive distributions of future population have gained relatively little traction amongst statistical offices. There are some notable exceptions, of course. The United Nations Population Division's population forecasts for countries and territories of the world are now presented with predictive distributions based on probabilistic fertility and mortality inputs (UN 2017). Statistics Netherlands and Statistics New Zealand also routinely prepare probabilistic national population forecasts now (Statistics Netherlands 2017; Statistics New Zealand 2016). But most national statistical offices and consultants continue to prepare deterministic population forecasts. Perhaps this is due to the perceived complexity of the methods and concepts, the large amount of input data required, the lack of suitable methods or off-the-shelf software for subnational and sub-population applications, or the perception that users are resistant to the idea of uncertainty and dislike predictive distributions. Partly as a result of the rarity of official forecasts with predictive distributions, little attention has been devoted to the communication of forecast uncertainty to users.

But the presumed resistance of users to uncertainty has recently been proved not to be the case, at least in Australia. In an online survey and subsequent focus groups of subnational population forecast users, Wilson and Shalley (2018) discovered the vast majority of users were in favour of receiving information on forecast uncertainty. Survey participants also supported the use of plain language and analogous concepts to describe uncertainty. One analogy tested and found to have strong support was the idea that population forecasts, like perishable foods, have a 'shelf life'. The idea was briefly introduced by Wilson et al. (2018). The aim of this research note is to extend the analogy, and discuss the potential use of perishable food labels like 'shelf life', 'use by' date, and 'best before' date to communicate population forecast uncertainty to users. These terms do not replace traditional tables and graphs illustrating predictive distributions, but are complementary to them, and may prove helpful in describing the uncertainty of population forecasts to users uncomfortable with technical details.



More generally, there is a need to devote further attention to communicating the uncertainty of demographic forecasts to users (UNECE 2018). Several instructive studies on the communication of forecasts to the general public have been undertaken in meteorology (e.g. Joslyn and Savelli 2010; Morss et al. 2008; WMO 2008). Indeed, the effective communication of forecasts should be seen as ‘completing the forecast’ (the title of a book by meteorologists on communicating uncertainty in weather forecasts (Committee on Estimating and Communicating Uncertainty in Weather and Climate Forecasts, 2006). With better communication of forecasts and uncertainty, users should be able to make better decisions (Savelli and Joslyn 2013), and thus the work undertaken by demographers to generate the forecasts gains greater value. With a greater variety of communication tools and evidence of user acceptance of uncertainty, there is a stronger case for national statistical offices and other demographers to prepare population forecasts with measures of uncertainty.

The paper continues as follows. In the following section the application of perishable food labels to describe population forecast uncertainty is described. Some simple example applications are presented in the next section, and then the paper finishes with some concluding remarks.



Perishable food labels

The **use by** date of a perishable food item is an estimate of “the last date on which the food may be eaten safely, provided it has been stored according to any stated storage conditions and the package is unopened.” (Food Standards Australia New Zealand 2013 p. 3). The **best before** date is “the last date on which you can expect a food to retain all of its quality attributes, provided it has been stored according to any stated storage conditions and the package is unopened.” (Food Standards Australia New Zealand 2013 p. 3) and is the date “up to which the food for sale will remain fully marketable” (Australian Government 2017). The best before date occurs before the use by date. Food can be safely consumed past its best before date, though it may have diminished in quality somewhat, but it should definitely not be consumed after the use by date. The **shelf life** of food is the “period of time for which it remains safe and suitable for consumption, provided the food has been stored in accordance with any stated storage conditions” (New Zealand Ministry for Primary Industries 2016 p. 7). Implicit in this definition is that the end of the shelf life is marked by the use by date.

These labels are applicable to population forecasts because, like food, they are expected to decline in quality with increasing time into the future. Many studies have shown that forecast errors tend to increase approximately linearly the further into the future a forecast extends (e.g. Tayman 2011; Wilson and Rowe 2011). Figure 1 illustrates selected labels applied to population forecasts.

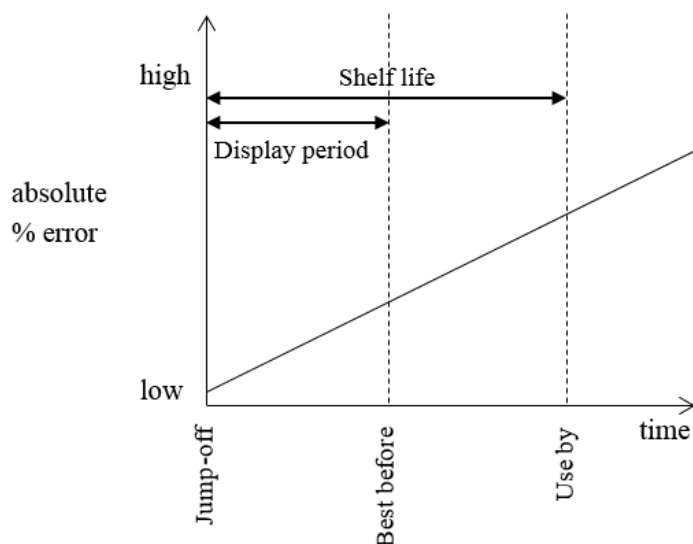


Figure 1: The shelf life and display period of population forecasts



The use by date can be defined as the date in the forecast horizon after which forecast population numbers should not be used because there is too much uncertainty. In practice this might be defined by the 80% prediction interval reaching $\pm 10\%$ error. The error tolerance is likely to vary between users and applications, but for the purposes of illustration a value of 10% is used here. The shelf life of the forecast is defined as the period from the jump-off year to the use by date. Forecasts with prediction intervals – such as those created from probabilistic models or derived empirically from past error distributions – are therefore required to determine the best before and use by dates.

The best before date is the date up to which the forecast is of good quality. A decision must be made as to what percentage error cut-off is appropriate. A $\pm 5\%$ error, half the value of the use by date tolerance, is selected for illustrative purposes. The period from the jump-off year to the best before date is assumed to be equivalent to the maximum period retailers display food for sale, and is referred to here as the display period. This could be used by publishers of population forecasts to determine the time period when the forecasts should be available to consumers, and then when to remove them from 'display' and create an updated set of forecasts.

One issue to be aware of is the fact that different variables from a forecast will have different shelf lives and display periods, because each forecast variable has its own predictive distribution. For example, the predictive distribution for the total population will vary from that of the population of females aged 20-24, children aged 5-12, or the elderly dependency ratio. And therefore the shelf lives and display periods will differ in length. This reflects the reality of population forecast uncertainty. Users who are concerned with planning school places, assisted living demand, maternity bed numbers, and new dwelling requirements will work with different levels of uncertainty and different shelf lives and display periods.



Examples

In this section, shelf lives and display periods are presented for three example population forecasts. It is assumed that a $\pm 10\%$ error cut-off determines the use by date and $\pm 5\%$ error indicates the best before date.

World

The first example is the United Nations Population Division's 2015-based probabilistic population forecast for the World (UN 2017). Figure 2a shows the UN's forecast of the World's population accompanied by the upper and lower bounds of the 80% prediction interval. By 2100 the median forecast is 11.2 billion with the 80% interval spanning 10.1 to 12.4 billion. Figure 2b shows the forecast from a different perspective: it illustrates the percentage error of the forecast if future population were to be at the upper and lower bounds of the 80% interval. Percentage error is calculated as the median forecast minus the 'actual' at the upper or lower bound of the 80% interval divided by the 'actual' and multiplied by 100. The prediction interval is very slightly asymmetrical so the $\pm 10\%$ cut-off is calculated when the 80% interval between the upper and lower bounds spans fully 20%. This occurs in 2097. Thus the use by date is 2097 and the shelf life extends 82 years from 2015 to 2097. The best before date is calculated when the 80% interval spans 10%, which is in 2067. The display period is therefore 52 years. The UN World population forecast is likely to be of good quality for a very long time!

Australia

The second example is a 2010-based probabilistic population forecast for Australia prepared several years ago by the author and reported in Bell et al. (2011). It is shown in Figure 3. The median of the forecast has Australia's population at 36.1 million by 2051, with the 80% prediction interval spanning 31.7 to 40.7 million (Figure 3a). The percentage errors of the upper and lower bounds of the 80% interval are shown in Figure 3b. The best before date at $\pm 5\%$ error occurs in 2026, while the use by date when error is $\pm 10\%$ occurs in 2042. Therefore the display period extends from 2010 to 2026 (16 years) while the shelf life extends 32 years (from 2010 to 2042).

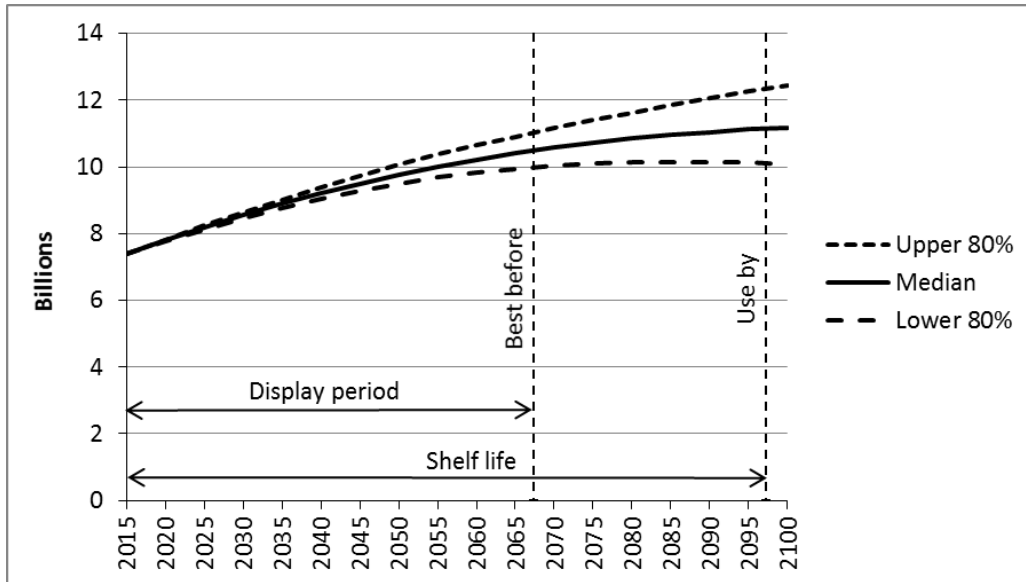
Northern Territory

The third example is a 2012-based forecast for the Northern Territory of Australia prepared by the Australian Bureau of Statistics (ABS 2013). (ABS emphasises that it only produces "projections" but most users interpret the middle Series B projections as forecasts, so they are described as forecasts here). This

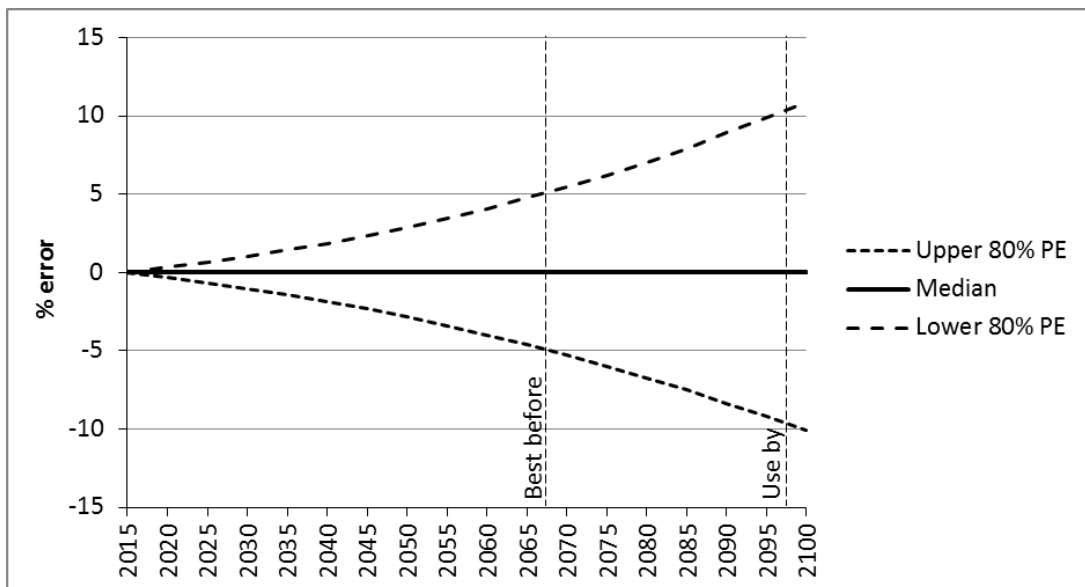


example is a little different because prediction intervals have been derived from errors of past ABS forecasts of the Northern Territory's total population from all forecasts from 1970 onwards. It demonstrates that probabilistic population forecasts are not essential to providing shelf life and display period values. Figure 4a shows the observed pattern of past errors over the first 20 years of a forecast horizon at 80% of the absolute percentage error distribution (i.e. 80% of past errors are smaller than those shown whilst 20% are greater). The dashed line is simply a straight line applied to smooth the data.

Figure 4b shows the ABS Series B forecast for the Northern Territory along with empirical 80% prediction intervals. The populations at the upper and lower bounds of the 80% interval were calculated assuming the smoothed absolute percentage errors applied either side of the forecast. The forecast has the Northern Territory's population increasing from 235,000 in 2012 to 321,000 in 2032. The 80% prediction interval by this time spans 267,000 to 403,000. The best before date at $\pm 5\%$ error occurs after just 3.3 years (in 2015), while the use by date when error is $\pm 10\%$ occurs after 8.7 years (2021). The Northern Territory's population forecast has a relatively short shelf life.



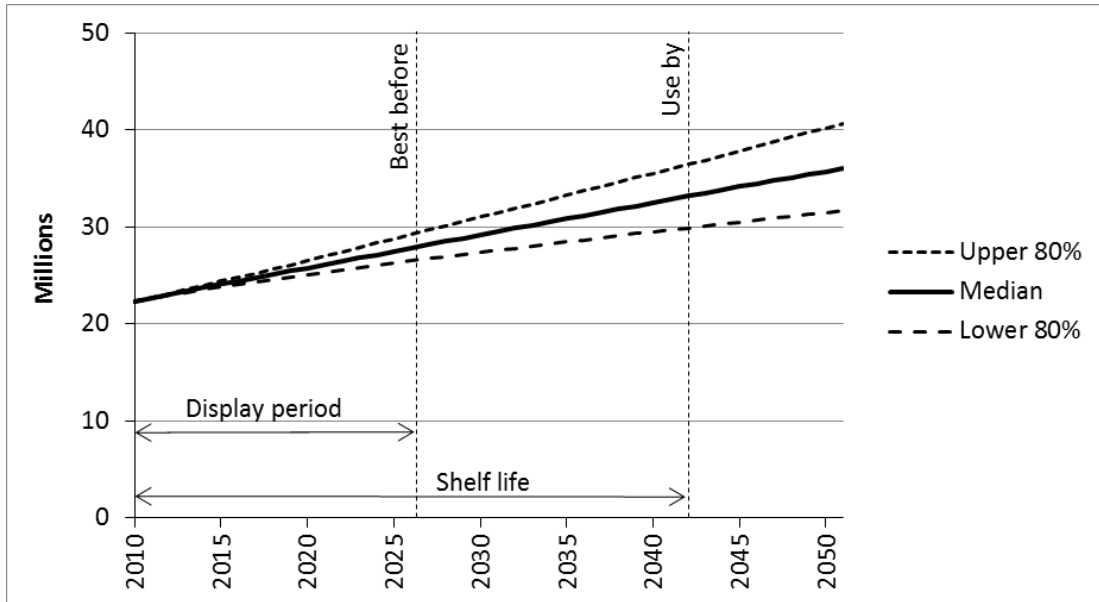
(a) Population forecast



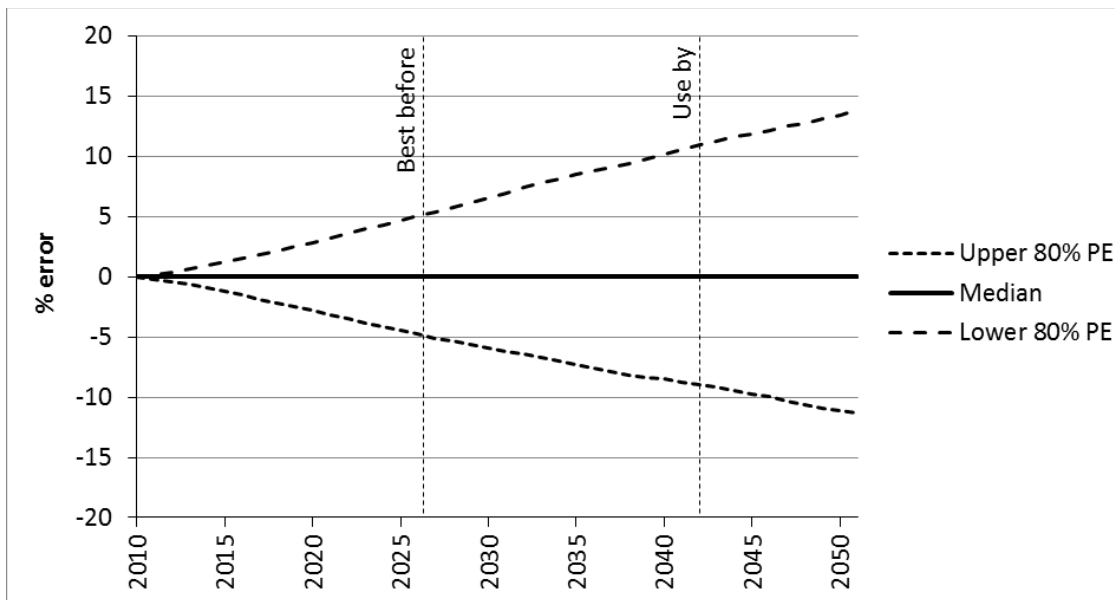
(b) 80% prediction interval expressed as percentage error

Figure 2: Population forecast for the World, 2015-2100

Source: UN (2017)



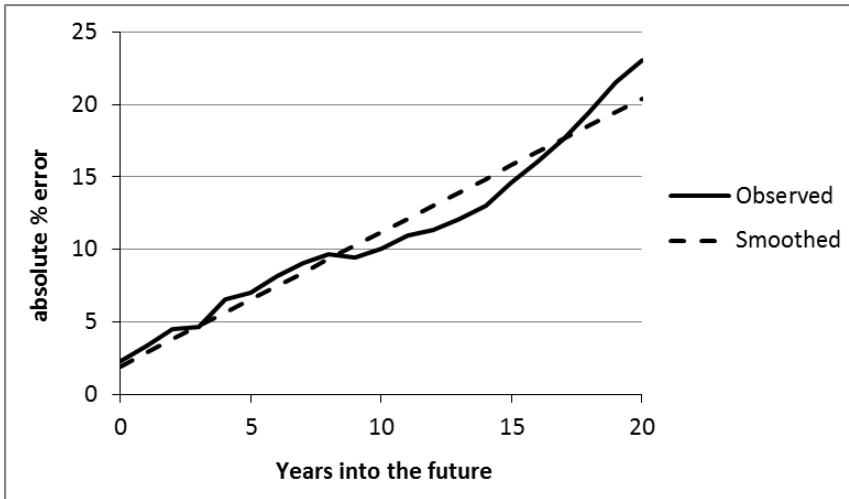
(a) Population forecast



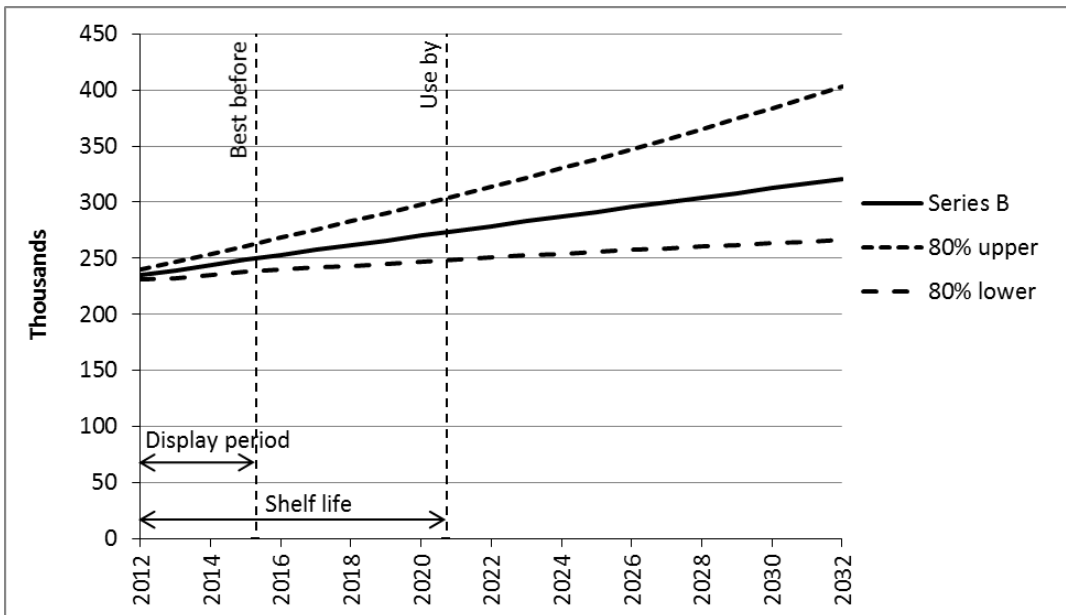
(b) 80% prediction interval expressed as percentage error

Figure 3: Population forecast for Australia, 2010-2051

Source: Bell et al. (2011)



(a) 80% absolute percentage errors from past population forecasts



(b) Population forecast

Figure 4: Population forecast for the Northern Territory, 2012-32

Source: Series B forecast from ABS (2013); 80% prediction interval based on author's analysis of past forecast errors.

Note: The 80% prediction interval shown in part (b) of the Figure is based on the smoothed absolute percentage error values shown in part (a). Populations at the upper and lower 80% of the prediction interval were calculated assuming positive and negative values of the 80% absolute percentage error applied.



Conclusions

This research note has described the use of perishable food terms to provide simple descriptions of population forecast uncertainty. These could be used alongside data visualisations, tables, infographics and other communication tools so that a variety of user groups can easily interpret forecast uncertainty. The shelf life and display period labels should be helpful for users who feel uncomfortable with the technical details of probabilistic forecasts and prediction intervals but still wish to gain a basic understanding of forecast uncertainty. Producers of forecasts could provide labels such as ‘Best before 2026: forecasts should be of good quality up to 2026’ and ‘Use by 2038: forecasts should be of acceptable quality up to 2038’ alongside other data and information about the forecasts. Importantly, these labels can be applied to forecasts which are not probabilistic but for which there are only past error distributions.

These labels may also be helpful to producers of population forecasts. The best before date should prove useful in indicating when an updated forecast is required. Ideally, it should not occur before forecasts are published! The shelf life could provide guidance on how far out into the future forecast population numbers are made publicly available.

There are some limitations, of course. Perishable food labels are quite basic and provide only limited information about population forecast uncertainty. In addition, best before and use by dates applied to food products are essentially estimates based on past experience under certain conditions. Food may last longer than expected, or spoil faster than suggested by the date labelling. The same may occur with population forecasts. The prediction intervals, and therefore shelf life and best before dates, are estimates. Forecasts may not prove to be of acceptable quality for the entire estimated shelf life, in which case they should be discarded when that occurs. Conversely, they may remain highly accurate for far longer than the estimated shelf life.

Furthermore, because there are separate predictive distributions for different forecast variables (such as specific age groups or derived indicators like dependency ratios) there are in theory separate best before and use by dates for every variable. These can be easily calculated from a probabilistic forecast database but will probably be more challenging if based on past errors – a demographically detailed dataset of past error distributions which includes all the required variables will be necessary. However, it might be best to advertise just one shelf life per country or region which refers to the forecast of total population, and warn users that this does not apply to specific age groups and derived indicators.



Finally, the effectiveness of labels such as ‘shelf life’, ‘display period’ and the accompanying ‘best before’ and ‘use by’ dates will be determined by users. Although initial responses in a small survey and focus groups to the concept of a forecast ‘shelf life’ were supportive, wider testing amongst a variety of user groups would be beneficial.



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