Decomposing the modal age at death, its number of deaths, and standard deviation.

Paola Vazquez-Castillo[1]

Vladimir Canudas-Romo[2]

[1]Interdisciplinary Center on Population Dynamics, University of Southern Denmark

[2]School of Demography, RSSS, CASS, Australian National University

Abstract

Background

The modal age at death is a longevity measure that summarizes the most common lifespan. Age-decomposition of longevity measures, such as life expectancy and lifespan deviation, are among the existing demographic tools. However, how different ages contribute to changes in the modal age at death and its related measures remains unknown.

Objective

To decompose the modal age at death, the number of deaths at the mode, and the standard deviation around the mode.

Methods

Using data from the Human Mortality Database, we present the decompositions of the modal age at death and its related measures from 1985 to 2019. The changes over time of these measures were decomposed using the stepwise algorithm by Andreev, Shkolnikov, and Begun (2002).

Results

A common trend in all studied countries is that the changes in the mode are mostly explained by the ages around it. Increases in the number of deaths concentrated at the mode are observed, suggesting mortality compression, with ages younger than the mode explaining this concentration. Furthermore, the standard deviation decreased in most countries, with ages around the mode having an important impact. The latter measure is still affected by the decrease in infant mortality.

Future steps

This project will focus on incorporating causes of death into the analysis to establish which ages and causes contribute the most to the changes in the modal age at death and its related measures. Additional sensitivity analysis will be performed using alternative ways of calculating the modal age at death (P-splines).

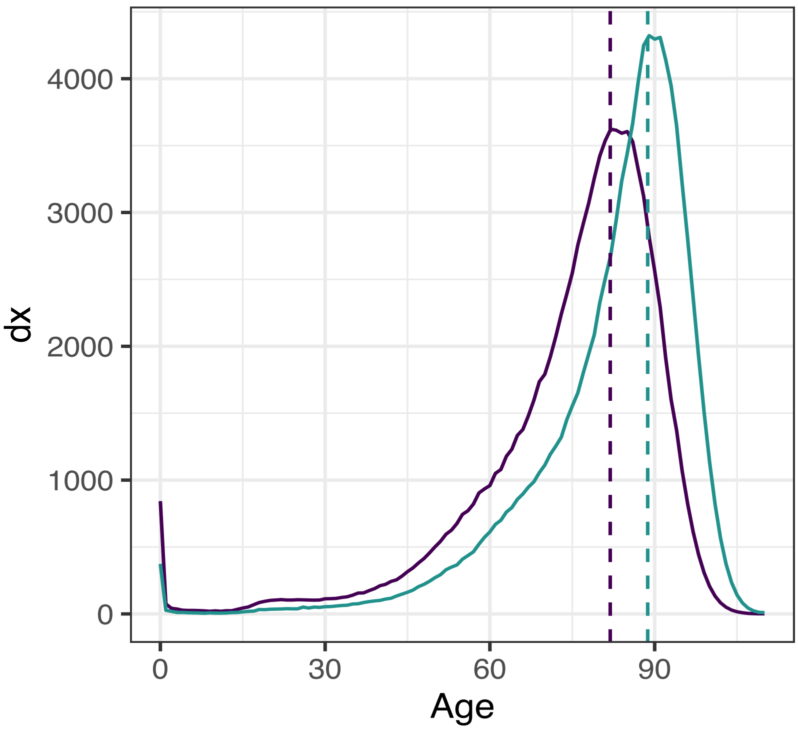
Keywords: decomposition, modal age at death, distribution of deaths, standard deviation.

Introduction

Mortality progress at almost all ages has led to a postponement of deaths. The rise in longevity has multiple consequences for society, especially for its pension and healthcare systems. As a result, it is necessary to capture accurately the pace and the determinants of longevity extension. Given the increasing use of the modal age at death, or mode, as a longevity indicator (Horiuchi et al., 2013; Bergeron-Boucher et al., 2015; Robine, 2018; Diaconu et al., 2020, 2022), decomposing its main drivers can shed light on the overall longevity increase process. For instance, the mode of the French population in 1985 was 81.9 years, while in 2020, it was 88.7 (see Figure 1). Decomposing the mode can explain the change.

According to Horiuchi et al. (2013), the mode is solely determined by old-age mortality, but no one has previously decomposed it to empirically show this. Figure 1 shows that the life table distribution of deaths has shifted towards older ages. Nevertheless, the changes that came with it are reflected not only in the mode, denoted as *M,* but in the measures around it. For example, we can see that there was an increase in the life table number of deaths accumulated at the mode, d_M, and a change in the dispersion of deaths around it, or *SD(M)*. Thus, in this research, we propose to analyze the age-specific contributions in changes in the modal age at death and its related measures (d_M and *SD(M)*).

Figure 1. Life table death distribution by age for the French population in 1985 (purple) and 2019 (green) and their modal age at death (dotted line).



Source: HMD (2023).

Data and methods

Female and male life table age-specific mortality rates were obtained from the Human Mortality Database (HMD, 2023) from 1985 to 2019 from ages 0 to 110 by single ages. All HMD countries with available data during the selected period were included in the analysis.

For these preliminary results, the method by Kannisto (2001) to estimate the mode with decimal precision was used. Thus, the mode at time *t* was calculated as:

$$M_t = x_t + \frac{d_{x_t} - d_{x_t-1}}{(d_{x_t} - d_{x_t-1}) + (d_{x_t} - d_{x_t+1})}, \quad (1)$$

where x_t is the age with the highest lifetable death counts at time *t* and d_{x_t} is its life table distribution of deaths. We use a linear interpolation between the two ages around the mode to estimate the number of death counts at the mode. Whereas for the estimation of the standard deviation around the mode (Canudas-Romo, 2008), we used the formula:

$$SD(M) = \sum_{0}^{\omega} (a - M)^2 * d_a \,, \quad (2)$$

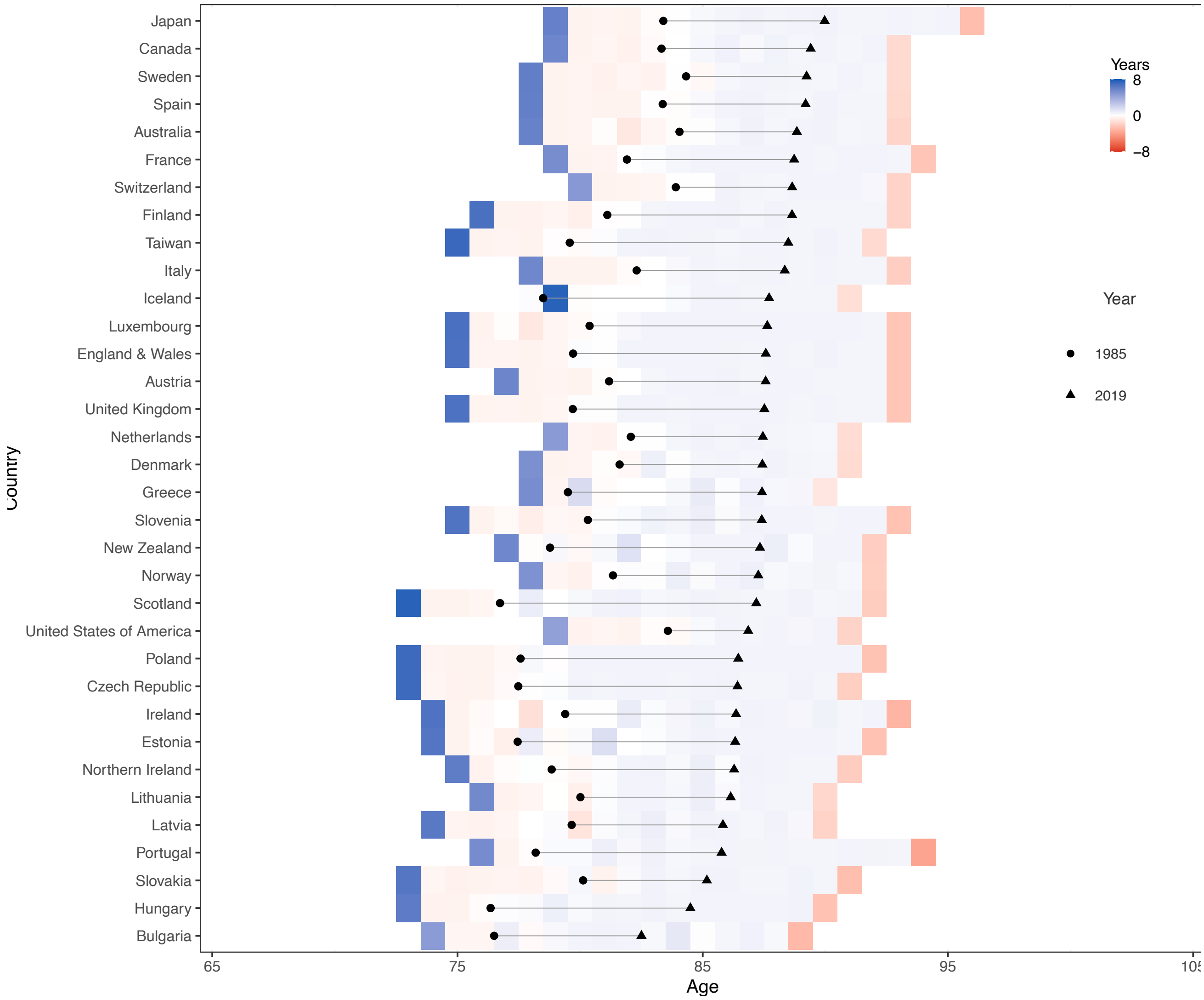
where, *a* is age and *ω* is the open-ended interval.

The stepwise decomposition method by Andreev et al., (2002) was used for decomposing the three measures related to the mode. The method returns age-decomposition of differences in aggregate demographic measures, such as life expectancy, between two populations or two times. In our case, the aggregate measures are the mode, the difference of deaths at the mode, and the standard deviation. The algorithm replaces each single cell of the matrix at time one with the respective cell of the matrix at time two, one at a time. This algorithm is rooted on the general idea of standardization. The replacement can be done in both directions (from time one to time two and reversed) and from top to bottom (from age 0 to 110, or reversed). We used the DemoDecomp (Riffe, 2018) package to calculate the stepwise decomposition method for the measures of interest using the average of both replacements and a top to buttom approach (as recommended by the Algorithm's authors).

Results

For these preliminary results, the decomposition of the three measures are displayed. Figure 2 presents the changes in the modal age at death from 1985 to 2019. During the last 30 years, there was an increase in the modal age at death for all HMD countries; however, the magnitude of the increases was substantially different from country to country. Scotland and New Zealand had the highest increases, whereas Israel and Belarus had the lowest. Across the general age structure of the decomposition, we can notice two things. First, the range of ages that affect the changes in the mode is concentrated mostly at ages older than the 1985 mode, but there is a contribution of some ages before. This is an unexpected finding. The ages older than the 1985 mode contribute to its increase (positive contributions) while the ages younger than the mode oppose its increase (negative contributions).

Figure 2. Age decomposition of the change in the modal age at death from 1985 to 2019

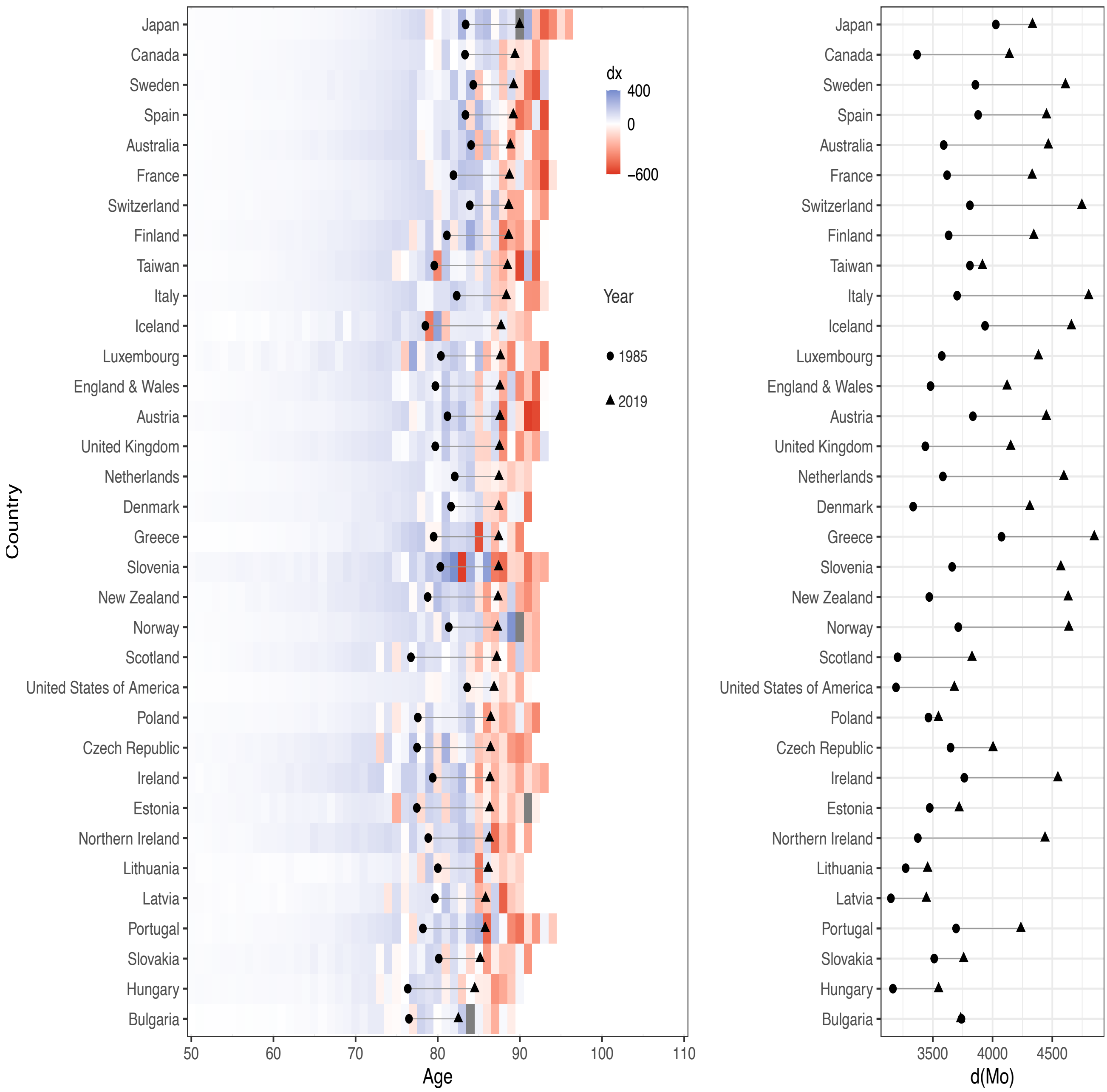


Source: authors' calculations based on HMD(2023).

Figure 3 presents the changes in the number of deaths at the mode. For most countries, there has been an increase in the concentration of deaths. This means more deaths are happening now at the mode than before, a natural result of the ongoing process of compression of deaths. However, the age-specific mortality components reveal interesting results. While younger ages are contributing to the increase in the number deaths, older ages are opposing this concentration, this is particularly observed after the later year of 2019 modal age.

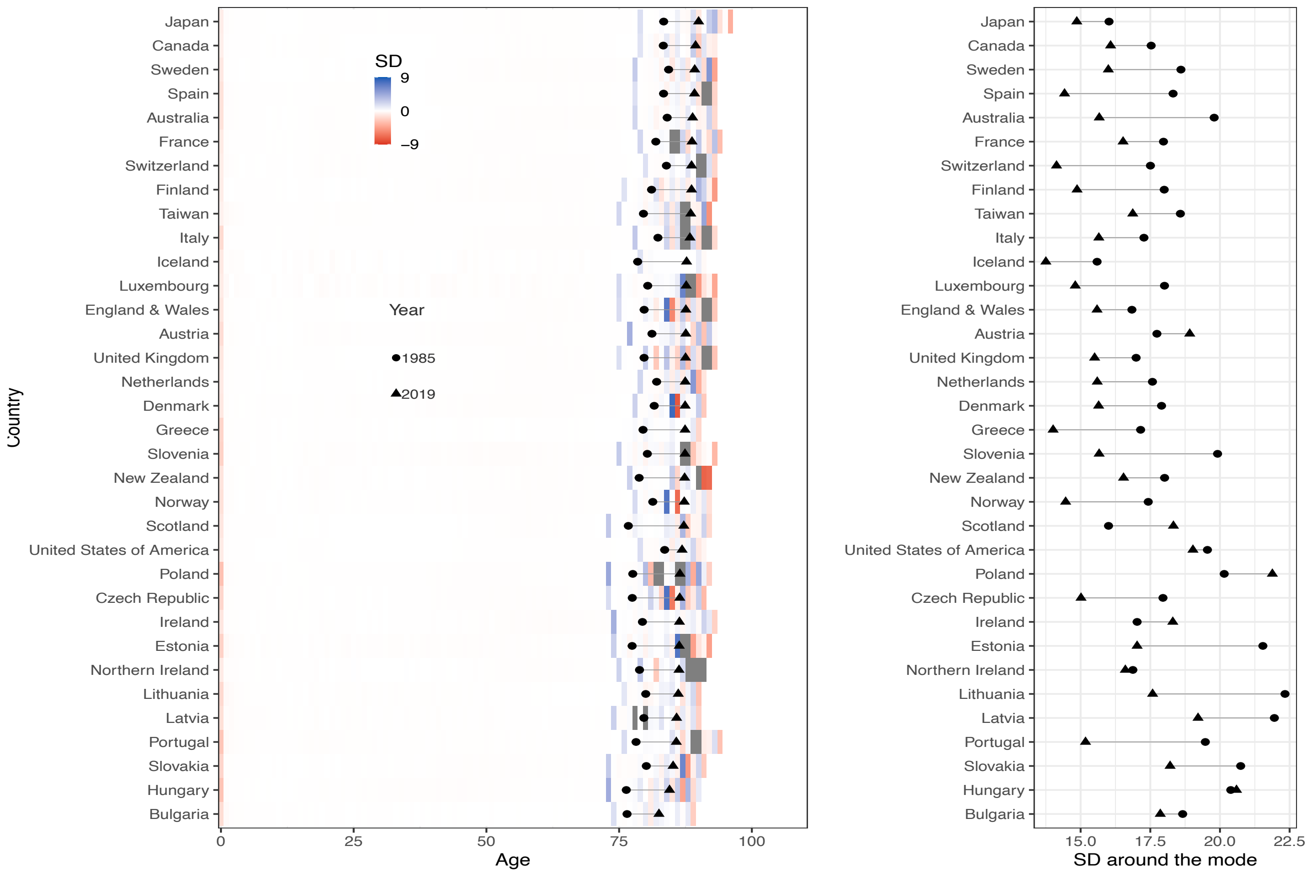
In Figure 4, the changes in the standard deviation around the mode are analyzed to understand the transitions of the dispersion of mortality. As expected, the *SD(M)* has decreased since 1985 for most countries, highlighting the compression process that these countries have experienced. Although mainly low mortality countries are included in the HMD the decomposition shows that changes in infant mortality still contribute to the decline in *SD(M)*.

Figure 3. Age contribution to the change in d_M from 1985 to 2019 (left), and d_M (right)



Source: authors' calculations based on HMD(2023).

Figure 4. Age contribution to the change in the standard deviation around Mo from 1985 to 2019 (left) and *SD* (right)



Source: authors' calculations based on HMD(2023).

Discussion and next steps

Our results show that the three measures analyzed provide a broader understanding of mortality and the drivers of longevity. To our knowledge, this is the first empirical finding of the age-decomposition of the modal age at death and its related measures. To summarize, most countries' modal age at death has increased and is highly determined by the ages around it. The number of deaths at the mode has increased for all countries (mortality compression) and is mostly pushed by the adult ages before the mode. Finally, the standard deviation around the mode has reduced for most countries. Infant mortality still has a contribution to the dispersion around the mode. The study has some limitations due to its methods. The decomposition is highly dependent on the sequence of the replacement; to overcome this we averaged the two possible directions (and the up/down directions) of replacement.

In addition to what is presented in this document, the analysis will be extended before the European Population Conference 2024 by: 1) Adjusting the p-splines method to estimate the mode and analyze the differences in the methods, 2) Providing a female-male analysis and differences of the three indexes, 3) Analyzing what happened to the mode during 2020, and 4) Extending the analysis to causes of death.

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