Is it time to reconsider the relevance of tempo effects in mortality?

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Short Abstract

In 2002, Bongaarts and Feeney claimed in a controversially discussed paper that period life expectancy (LE) could be biased by—what they called—"tempo effects" (TE). They demonstrated their idea of this bias with a modelled scenario which was considered to be too hypothetical to describe a practically relevant situation of changing mortality. Seeming as the force of destiny, the hypothetical scenario of Bongaarts and Feeney became a reality in the years 2014 and 2015 what explains, at least, most of the decrease in LE which almost all European countries experienced between these two years. Almost paradoxically, the consideration of TE turns the interpretation of the 2015 decrease in LE into a very different direction: instead of being seen as an indicator for very unfavourable mortality conditions in 2015, it becomes a consequence of very favourable mortality conditions in 2014 which led to a shift of deaths from 2014 to 2015. We demonstrate the potentially strong impact of TE in recent LE trends with empirical data for several populations of Europe, and we discuss the factors which possibly caused the exceptional shift of deaths from 2014 to 2015 with the consequential tempo bias in LE in both years.

Extended Abstract

1. Introduction

The story of our paper starts with the surprising decrease in life expectancy (LE) in 2015, which has been intensively thematised and hotly debated for the US population—and this not only in the US, but also in the European media. The most common explanation for the decrease in LE is the opioid crisis among young adults (e.g., Dowell et al. 2017; Ho 2017; Ho and Hendi 2018). Some added an increased mortality due to suicides and liver diseases as further reasons and introduced for all these causes the term "deaths of despair" (Case and Deaton 2017).

However, in this discussion, it is widely unnoticed that the 2015 decrease in LE occurred not only in the US, but also in most countries of Europe (Eurostat 2019). The decrease in LE was strongest in Germany and Italy with an amount of half a year. Interestingly, this decrease in LE is noticed and thematised only in a few countries. Like in the US, the explanations are sought in very country-specific factors, such as a vaccination crisis in Italy (Francia et al. 2017; Manzoli et al. 2018) or a healthcare crisis in the UK (Hiam et al. 2017a, 2017b). However, a decline in LE in more than 20 countries at the same time speaks against exclusively country-specific factors. We hypothesize that these decreases in LE are caused by so-called "tempo effects". The results of all our analyses so far confirm this hypothesis.

2. Tempo effects in period LE

17 years ago, Bongaarts and Feeney (2002) claimed in a controversially discussed paper that period LE could be biased by—what they called—"tempo effects" (TE). They demonstrated their idea of this bias with a hypothetical scenario based on a stable population with a LE of 75 years (Figure 1). In a stable population, period LE is identical to cohort LE, and thus is the same as the average lifetime of all cohorts living in a particular year, what Bongaarts and Feeney termed "mean age at death". Then, they assumed that during a year T—and only in year T—mortality is decreasing in a way that the mean age at death is rising to the level of 75.3, at which it remains stable from year T+1 onwards. Albeit this change in the mean age at death is only small and gradual, it leads to huge jumps in period LE: first, an increase from 75 to 78 in year T, and then a decrease from 78 to 75.3 in year T+1. These jumps are caused by the shift of deaths from year T to year T+1 as a consequence of the decrease in mortality. These shifts have a much stronger (relative) effect on the numerators of the death rates then on their denominators what boosts the rates—and consequently LE which is derived from these rates—disproportionately in year T (Luy 2008). The hypothetical example shown in Figure 1 leads to two central messages:

1. Changes in the mean age at death—or in other words, changes in mortality—during the observation period can inflate period LE, and
2. Period LE can decrease without an actual increase in mortality (decrease in the mean age at death), but as consequence of shifted deaths.

Seeming as the force of destiny, the hypothetical scenario of Bongaarts and Feeney became a reality in the years 2014 and 2015 what explains at least most the decrease in LE. Figure 2 shows empirical data for German women for the years 2013, 2014 and 2015, with the trends in period LE in black and in the annual number of deaths in grey. The empirical data resembles almost exactly the hypothetical scenario of Bongaarts and Feeney (Figure 1) what leads to the two central conclusions of this paper:

1. The 2015 decrease in LE is a consequence of the tempo-inflated LE increase in 2014, and
2. The increase in the number of deaths in 2015 is primarily a consequence of the low mortality in 2014, what led to a shift of deaths from 2014 to 2015.

This means, in other words, that the decrease in LE in 2015 results primarily from exceptional good survival in 2014, and not—at least not so much—from a mortality crisis in 2015. Albeit this might seem intuitively convincing, the question is, how can we quantify these effects? Is there a statistical rather than this intuitive way to demonstrate the relationship between shift of deaths, TE and LE?

3. Estimating the impact of tempo effects

A useful—but only rarely used—demographic indicator is the Total Mortality Rate (TMR) because it quantifies the amount of shifted deaths (delayed or speeded up) in a period. The TMR has been introduced by Sardon (1993) as mortality equivalent to the Total Fertility Rate (TFR) and it represents the sum of—or the integral of—the number of lifetime deaths divided by the initial size of the cohort. This means that the TMR is the sum of age-specific death rates of "second kind" where the denominator of the rates includes not only the actual population alive and at risk, but also those who died before (i.e. all people ever born). For a cohort—regardless whether a real or a synthetic cohort—the TMR is always one because every member of the cohort dies, and each member dies exactly once. However, when we calculate the TMR for periods, its value is usually not one. In fact, the TMR would be one only in a year in which mortality does not change at all. What makes the TMR so interesting for our analysis is that it deviates from one exactly by the proportion of deaths that are shifted out of or into the period of observation, relative to the hypothetical situation of constant mortality (for details, see Guillot 2006).

We estimated the TMR for all populations with decreasing LE in 2015 for which we had the necessary series of cohort data. In fact, trends in the TMR confirm the strong association between altering changes—or more exactly altering "pace of changes"—in mortality and LE. Figure 3(a) shows the trends in LE (solid black line) referring to the left axis and the TMR (dashed grey line) referring to the right axis from 2009 to 2015 for German women, i.e. the same population we used before in the comparison to the Bongaarts and Feeney scenario in Figure 2. A look at the decisive years 2013 to 2015 reveals that the strong increase in LE in 2014 coincides with a strong decrease of the TMR, illustrating the impact of TE in the sense of Bongaarts and Feeney's approach. Likewise, the decrease in LE in 2015 coincides with a corresponding increase of the TMR. The same can be seen for all the other populations of which only three more are shown in Figure 3: Belgium, France, and the Netherlands. (The figures for men are not shown because they are identical to those for women.)

4. Adjustment of tempo effects: alternative indicators for period longevity

Figure 4 illustrates the possible impact of TE caused by the shift of deaths by comparing the trends in conventional LE with three alternative measures for period longevity which are unbiased by TE: Bongaarts and Feeney's tempo-adjusted Life Expectancy (LE*), the "Cross-sectional Average Length of life" (CAL), and the "Mean Age at Death" (MAD).[1] Eight countries are included in the figure: Germany, Belgium, France, the Netherlands, Italy, Portugal, United Kingdom, and United States. The results reveal the strong potential contribution of TE to the decrease in LE in all populations: LE*, CAL and MAD continued to increase in 2015 without marked fluctuations. Thus, once TE are taken into account, we find no indication of a health crisis that has affected the mortality conditions of the total populations. This is even more evident by the fact that the TMR for the year 2015 lies below 1.0 (see Figure 3). This indicates that even in the year of declining LE, mortality has still been decreasing rather than increasing among the currently living cohorts.

Note, however, that the situation is different in the US because LE continued to decline slightly—or stalled—in 2016. This indicates that other respective additional mechanisms are at play compared to the European countries, most likely related to the increasing disparities in mortality between socio-

[1] A description of the indicators' features and estimation methods can be found in Bongaarts (2005). Note that four different methods have been developed to estimate tempo-adjusted LE* (Bongaarts and Feeney 2003). These methods are, however, only variants for performing mortality tempo adjustment and arrive essentially at the same estimates (see Luy 2010). We used the TMR-method because it utilizes the property of the TMR to directly reflect the level of TE in a particular period. The age-specific death rates were thus adjusted by division with the corresponding annual TMR values. It should be noted, however, that all four methods for estimating LE* imply that the schedule of age-specific death rates shifts proportionally across all ages. This assumption is violated during the changes between 2014 and 2015. In some age groups, death rates increased in 2015 compared to 2014, in other age groups they decreased. Nonetheless, we performed test simulations which revealed that the estimations are not affected by the constant shape assumption of the Bongaarts-Feeney-model.

economic subgroups. Nonetheless, adjustment for TE led LE continue to increase also in the US, as it is the case for the European populations.

5. Summary, discussion, and next steps

We demonstrated the actual relevance of TE with the example of the almost Europe-wide decrease in LE in the year 2015. The results of our analyses can be summarized as follows:

1. The 2015 decrease in LE occurred simultaneously in the majority of European countries. This suggests no exclusive effect of country-specific factors on which most of the corresponding publications focused. These might have contributed to an increase in mortality in 2015, but obviously there were significant mechanisms at play which exceed the borders of single countries.
2. The decrease in LE between 2014 and 2015 primarily occurred because of an exceptionally low mortality in 2014 and less because of an exceptionally high mortality in 2015.
3. The shift of deaths created TE which caused an inflated decrease in death rates in 2014 and an inflated increase in death rates in 2015, thus boosting the difference in LE between the two years. The empirical results for trends in LE*, CAL and MAD indicate that the bias caused by TE might be even the primary factor which caused the picture of worsening mortality conditions.

The consideration of TE caused by a shift of deaths turns the interpretation of the 2015 decrease in LE in a very different direction: instead of being seen as an indicator for very unfavourable mortality conditions in 2015, it becomes a consequence of very favourable mortality conditions in 2014. Thus, taking into account the potential impact of TE leads to the conclusion that the 2015 decrease in LE might not be a matter of big concern regarding the total population level. It is important to note, however, that this does not mean that there is nothing to worry about. Conditions like the healthcare crisis in the UK, the flu vaccination crisis in Italy or the opioid misuse in the US are important issues for many individuals and specific subpopulations, and it is very important to fight these crises. Nonetheless, it is highly unlikely that these factors caused the decrease in LE of the total populations.

The most evident support for our conclusion comes from the fact that no specific factor could be identified so far that explains more than a fraction of the LE decrease in 2015. The supposed causes seem convincing at a first glance, but none of them was supported with empirical data. Decomposition analyses of changes in LE by age and cause of death did not lead to conclusive results either (Ho and Hendi 2018; Mølbak et al. 2015). Further, it is important to note that the decrease in LE seems to be primarily an effect of only one single year. Between 2015 and 2016, LE increased again in all of the

European countries which experienced a decrease between 2014 and 2015, in many cases even to a higher level than in 2014 (Eurostat 2019).

The still open question is what led to the exceptionally low mortality in 2014 with an increased number of survivors compared to “normal” conditions. Different influenza-types in the winter months are likely a driving force behind these fluctuations, with a mild influenza-type in 2013/14 followed by a strong one in 2014/15 (Euromomo 2014, 2015; Nielsen, Krause and Mølbak 2018). Naturally, a certain proportion of the 2014 survivors can be considered frail survivors (Armstrong et al. 2017; Huynen et al. 2001; Rocklöv, Forsberg and Meister 2009). Thus, many of these additional survivors died in 2015, increasing the number of deaths and resulting in increased death rates and a decrease in LE. Nonetheless, there might be also other factors behind the shift of deaths which are not explored yet. We are currently testing several potential explanations and we expect the results to be ready for presentation at the time of EPC 2020.

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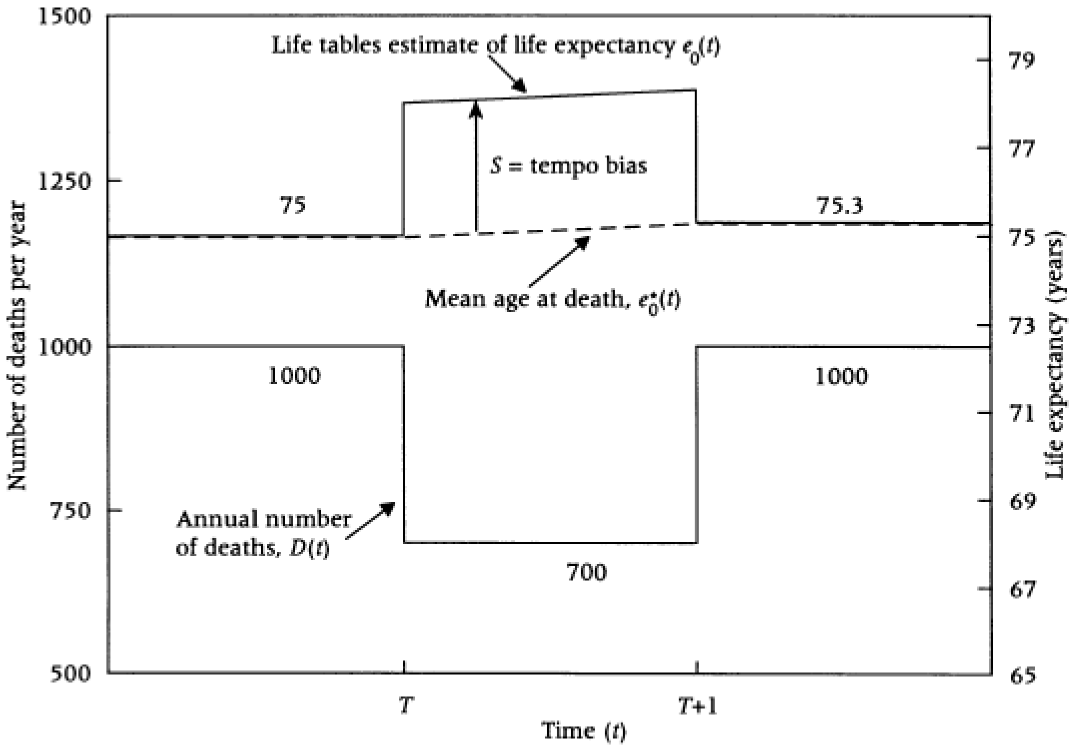
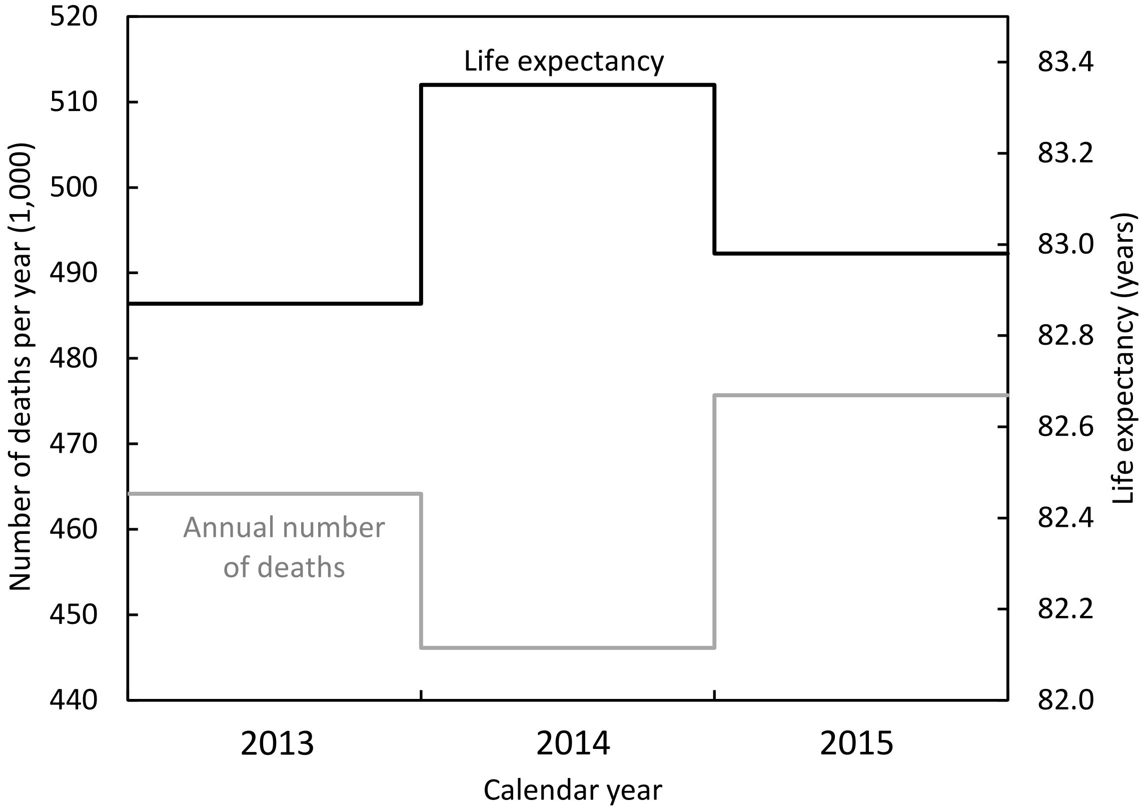
Figures

Figure 1: Bongaarts and Feeney's hypothetical example to demonstrate the impact of tempo effects on trends in period life expectancy under changing mortality



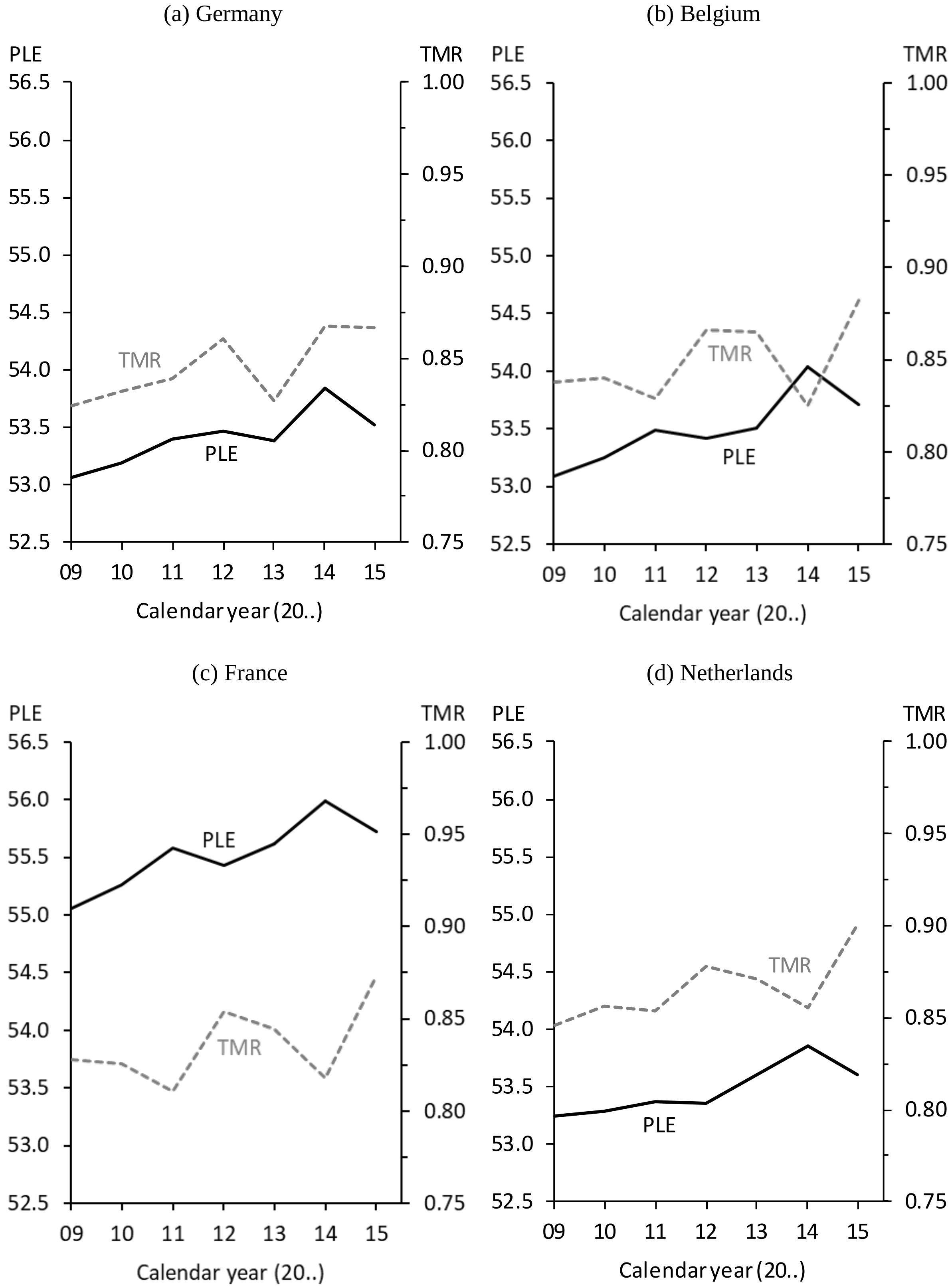
Source: Bongaarts and Feeney (2002), p. 19; original title of the graph: Trends in the total number of deaths and life expectancy, hypothetical population, changing mortality.

Figure 2: Total number of deaths and life expectancy in 2013, 2014 and 2015 in Germany, data for women



Source: own calculations with data from the German Statistical Office.

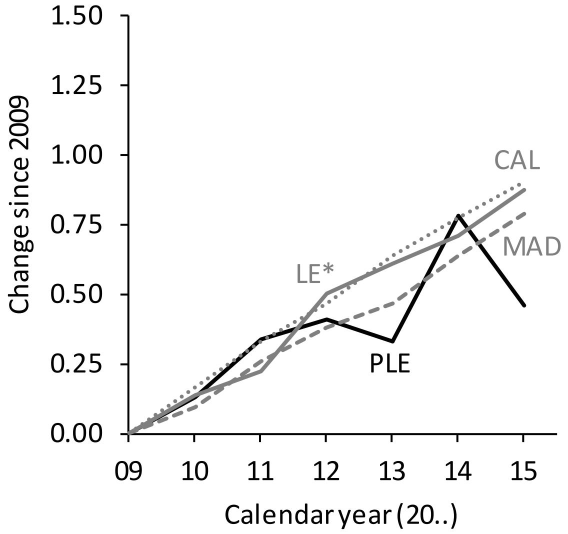
Figure 3: Trends in Period Life Expectancy (PLE, left y-axes) and the Total Mortality Rate (TMR, right y-axes) in selected countries, women, 2009-2015



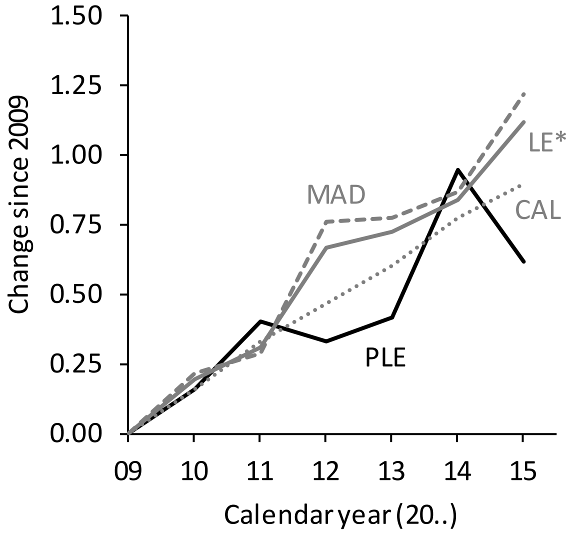
Source: authors' own calculations with data of the Human Mortality Database (2019);
Note: all data referring to ages 30+.

Figure 4: Changes in Period Life Expectancy (PLE), tempo-adjusted Life Expectancy (LE*), Cross-sectional Average Length of life (CAL), and Mean Age at Death (MAD) relative to 2009 in selected countries, women, 2009-2015

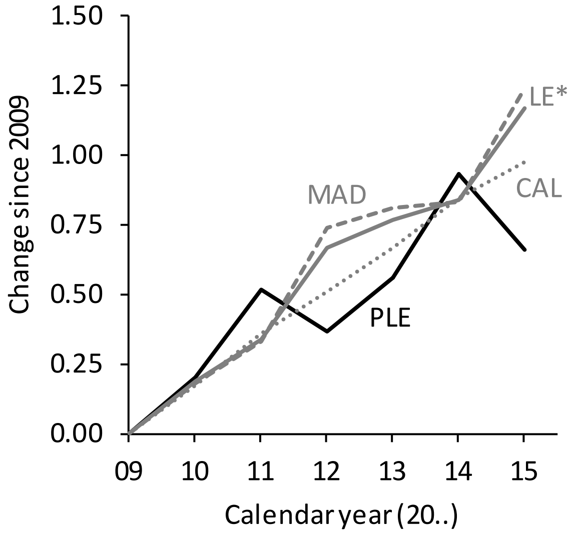
(a) Germany



(b) Belgium



(c) France



(d) Netherlands

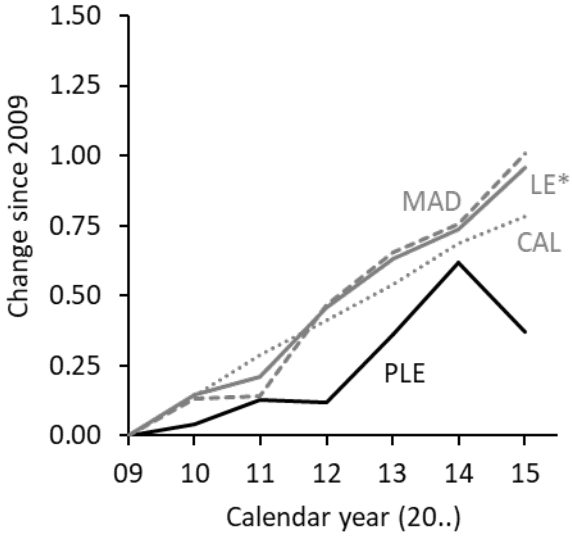
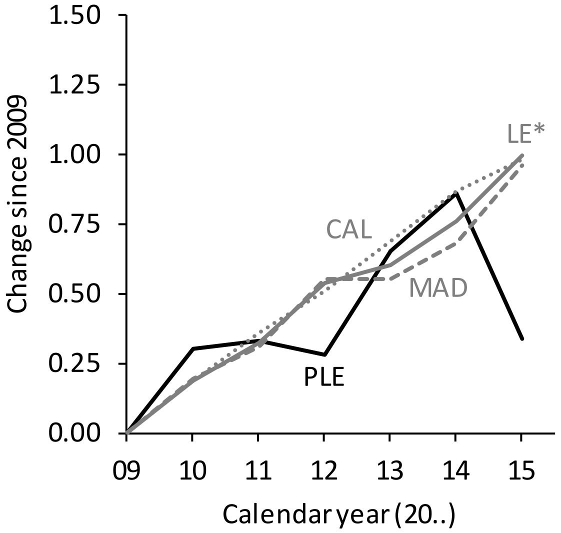
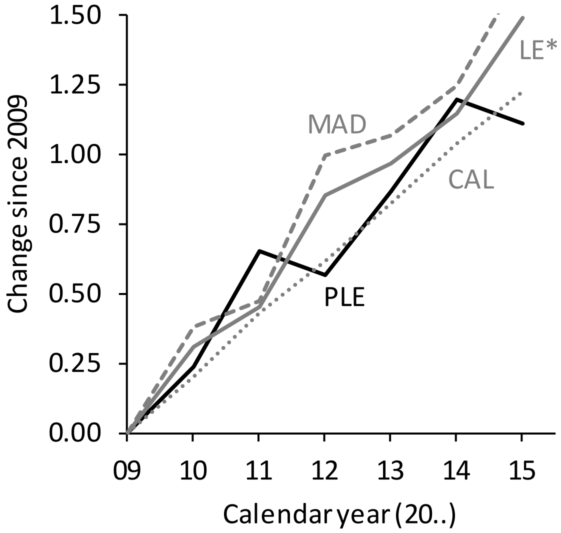


Figure 4, cont.:

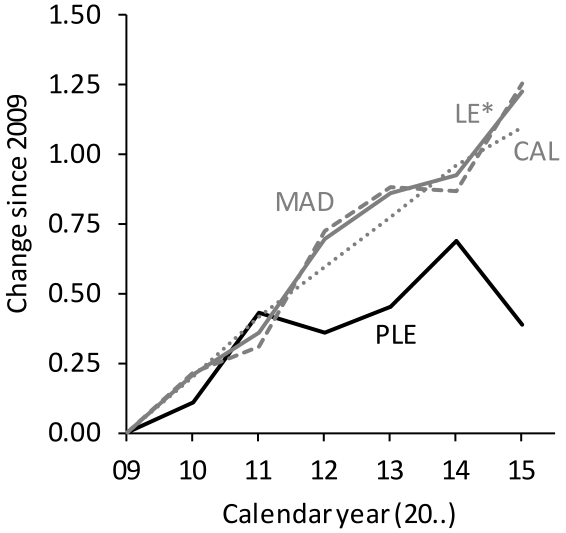
(e) Italy



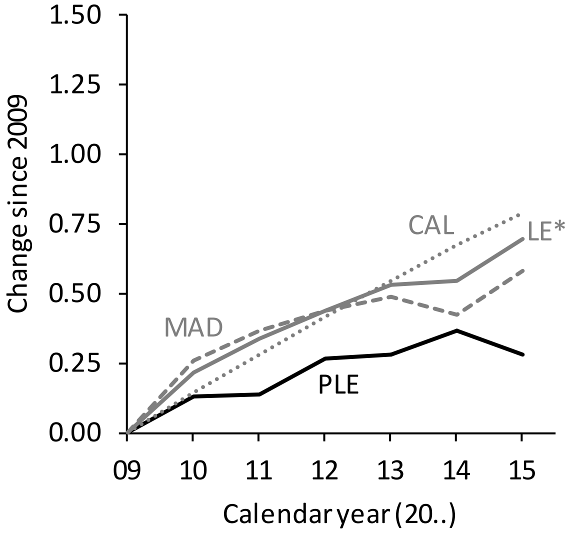
(f) Portugal



(g) United Kingdom



(h) United States



Source: authors' own calculation with data from the Human Mortality Database (2019);
Note: all data referring to ages 30+.