LIFE EXPECTANCY IMPROVEMENTS BY AGE, CLASS, AND MORTALITY CHAPTER IN FRANCE, CZECHIA, AND THE UNITED STATES

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Abstract
Using the decomposition method, this article examines the dynamics of life expectancy. Three developed countries with relevant differences, Czechia, France, and the United States, were chosen for analysis in order to highlight similarities and differences. The analysis covers more than 40 years, 12 age groups, and 20 mortality chapters. The results reveal a pattern: first, mortality at birth improves; then the survival of lives under 65 increases; finally, improvements come from extending the life of seniors.

Keywords: life expectancy, decomposition method, mortality chapters, France, Czechia, United States

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1 INTRODUCTION

Understanding and explaining the sources of changes in demographic indicators such as life expectancy at different ages has been in the interest of researchers for a long time. However, the topic has gained relevance in recent decades owing to the financial difficulties that have affected, or are expected to affect, pension fund schemes, and social security systems in general. Because of this, attention has increasingly turned to obtaining a better understanding of mortality, the patterns that existed in the past, and how these patterns have been evolving over time, as a way of enhancing the scientific knowledge that will enable the community to better predict the future. Contributions of age and causes of death to life expectancy at birth (LE) can be calculated with decomposition methods (*Andreev – Shkolnikov – Begun*, 2002), (*Arriaga*, 1984; 1989), (*Das Gupta*, 1978). This approach has been widely used for various purposes, in particular, to research the effects on mortality of inequalities in socioeconomic conditions and access to health care, in different countries and regions (*Agyepong et al.*, 2017; *Bergeron-Boucher – Ebeling – Canudas-Romo*, 2015; *Khang et al.*, 2010; *Liu et al.*, 2016; *Martikainen – Valkonen – Martelin*, 2001; *Martikainen – Makela – Peltonen – Myrskyla*, 2014; *Mondal – Shitan*, 2014; *Murwirapachena – Mlambo*, 2015; *Preston – Stokes*, 2012; *Shkolnikov – Andreev – McKee – Leon*, 2013; *Tarkiainen – Martikainen – Laaksonen – Valkonen*, 2012; *Wang et al.*, 2016; *Yang et al.*, 2012). Many other studies focus on the gender gap or other life expectancy issues (*Al-Ramadhan*, 2008; *Auger et al.*, 2014; *Auger et al.*, 2012; *Hosseinpoor et al.*, 2012;

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Le et al., 2015; *Rosella et al.*, 2016; *Simmons*, 2018; *Trovato – Heyen*, 2006; *Trovato – Lalu*, 1997; *Trovato – Odynak*, 2011; *Vaupel – Romo*, 2002; *Waldon*, 1983; *Waldon – McCloskey – Earl*e, 2005; and again *Yang et al.*, 2012).

These works decompose the contributions of age and cause-specific mortality to changes in life expectancy. In our work, we apply the same methodology to obtain deeper knowledge of the dynamics behind life expectancy changes, not only because the analysis covers a very long period of time, but mostly because more than 12 age groups and 20 mortality chapters, as defined by the International Classification of Diseases, are under study. Three developed countries with significant historical differences with respect to mortality (France, Czechia, and the United States) have been chosen here as case studies in order to enable direct comparisons. These countries were selected for three main reasons: they belong to the small group of countries with cause-of-death (CoD) information available in the Human Mortality Database (HMD); they have nearly the same range of the gross national income of this group (available at https://data.worldbank.org/indicator/ny.gnp.pcap.pp.cd); and they have populations with very different sizes and quite different histories. Other choices could have been made, but these specific ones seemed the most interesting to us.

We can find a number of studies on mortality and longevity that have applied the decomposition method and other methods as well that give particular attention to some (or sometimes all) of these countries (for more, see, e.g., *Ho – Hendi*, 2018; *Hulíková Tesárková – Kašpar – Zimmermann*, 2015; *Leon*, 2011; *Meslé*, 2004; *Meslé – Vallin*, 2017; *Meslé – Vallin – Pyrozhkov*, 2012; and *Woolf – Schoomaker*, 2019). This is important, as it sometimes allows for a comparison of results.

Our research focuses on quantifying the changes in LE and on estimating the contributions attributable to each of the different age groups and mortality chapters in an exhaustive and in depth way across a period of over four decades. In some of the cited works, this type of exercise has also been carried out, but our research design contributes to a better understanding of mortality and longevity differences and their origins, the evolution of observed patterns over time, and the historical change in the decomposition of these patterns.

In the following sections, we analyse *in depth and for a 44-year period* the changes in LE. To achieve this, mortality variations are decomposed according to age, cause of death, and the relationship between them.

The information available in the Cause of Death Database (CoDD) covers a period from 1959 to 2013 for the United States, 1958 to 2015 for France, and 1968 to 2015 for Czechia. In order to make the results comparable, a common time interval is necessary. Furthermore, it was important to break the timeline into three shorter periods, to better capture the evolution of the phenomenon studied here. Although other criteria could have been used, a 'neutral' rule was that they should be approximately the same length. As a result, the analysis goes from 1970 to 2013, dividing the timeline from 1970 to 1984, from 1985 to 1998, and from 1999 to 2013.

2 BACKGROUND, DATA, AND METHOD

In general, life expectancy is one of the most popular concepts to use to analyse mortality. It is normally taken as an indicator of human health owing to its capacity to 'summarize mortality in a single measure' (*Augern et. al*, 2014). The picture of the indicator internationally shows a range of shades that have been changing through the years, and they are of value for understanding the situation today. Three aspects of longevity are worth mentioning.

First, global LE for both sexes went from 66.5 years in 2000 to 72 years in 2015 (*World Health Organization*, 2019). According to the United Nations (2019), it increased from 64.2 years in 1990 to 72.6 years in 2019 and it is expected to increase further to 77.1 years in 2050. While considerable progress has been made in closing the longevity differential between countries, large gaps remain. In 2019, LE in the least developed countries was 7.4 years below the global average, largely because of persistently high levels of child and maternal mortality, as well as high levels of violence and conflict and the continuing impact of the HIV epidemic. Second, the number of people in the world aged 60 and older has doubled compared to the number

in 1980, and it is expected that by 2050 16% of the world's population will be aged 65 and over – compared to 9% in 2019 (cf. *United Nations*, 2019). Third, there seems to be a growing interest in what are known as the 'Blue Zones' (see *Poulant – Buettner – Pes*, 2019), a selected group of places with an extraordinarily high concentration of people living beyond the age of 100. According to *Buettner and Skemp* (2016), members of this select group include Loma Linda in California (USA), Nicoya in Costa Rica, Sardinia in Italy, Icaria in Greece, and Okinawa in Japan.

A tool called the Mortality Analysis Calculator (MAC) was developed to analyse the mortality information from the HMD and the CoDD. The MAC was created by Ugarte for the Department of Research of the Society of Actuaries – actuaries have become players in the search for solutions and contingency plans for countries facing issues associated with population ageing. *The Actuarial Association of Europe* (2019, p. 7) found that because of population ageing 'costs are projected to rise in every country on health and long-term care spending. These projections depend not only on the population projections but also on how life expectancy increases translate into healthy life expectancy and how the demand for health and long-term care services evolve'. One of the main features of the Mortality Analysis Calculator is that it decomposes the changes in a mortality indicator by the contribution to this change that can be attributed to each age group and mortality chapter, when applicable. In order to decompose the variations, the tool uses algorithms that already exist in the literature, relying mostly on the seminal contributions from *Andreev, Shkolnikov and Begun* (2002) and *Arriaga* (1984; 1989).

2.1 Decomposition of the changes in a mortality indicator by age group

Let's consider the changes between years t_1 and t_2 ($t_2 > t_1$) in a mortality indicator estimated for a specific age a. To compute the contribution to changes attributable to different ages/age groups, we use the algorithm this is presented in *Andreev, Shkolnikov and Begun* (2002). Their paper presents a formula for decomposing changes between two periods of time, but in general it compares two different 'experiences' of an indicator – for example, whether the change comes from time, gender, or an ethnic group. Although the underlying principles remain the same, it was convenient for the sake of clarity to adjust slightly the mathematical notation of the paper by Andreev, Shkolnikov, and Begun. For this reason, we will briefly describe the method in the paragraphs below.

If we denote a mortality indicator – life expectancy in this case – for age a as Ind_a, then the attribution of change in the mortality indicator between years t_1 and t_2 at age a attributable to age x is

$$ {}^{a}_{x}\delta^{2-1} = \frac{l^2_x}{l^2_a} \underbrace{(Ind^2_x - Ind^1_x)}_{Variation\ age\ x} - \frac{l^2_{x+1}}{l^2_a} \underbrace{(Ind^2_{x+1} - Ind^1_{x+1})}_{Variation\ age\ x+1}, \quad (1) $$

where l^j_x represents the number of survivors aged x for year t_j, $j = 1, 2$, and Ind^j_x represents the level of the indicator for age x in year t_j.

As has been established by *Andreev – Shkolnikov – Begun* (1982) and *Pressat* (1985), the result of computing ${}^{a}_{x}\delta^{2-1}$ for the decomposition by age does not necessarily have to be the same as that of $-{}^{a}_{x}\delta^{2-1}$, so they suggested replacing ${}^{a}_{x}\delta^{2-1}$ with

$$ {}^{a}_{x}\delta = 0.5({}^{a}_{x}\delta^{2-1} - {}^{a}_{x}\delta^{1-2}) \quad (2) $$

to obtain the attributable contribution coming from age x to the change in the indicator for age a, so that

$$ (Ind^2_a - Ind^1_a) = \sum_{x=a}^{\omega} {}^{a}_{x}\delta\,. \quad (3) $$

In the calculations below, (2) and (3) will be used.

2.2 The decomposition of changes attributable to different causes of death

In this paper we also compute the contribution of the evolution of causes of death for mortality indicators. As in the previous section, consider ${}^{a}_{x}\delta$ as the contribution to the change that is attributable to age x for the mortality indicator at age a between years t_1 and t_2. Assume that the environment is affected by n diseases, so that we denote the change in the indicator at age a between years t_1 and t_2 that is due to disease i ($i = 1, 2, 3, \ldots, n$) as ${}^{i}_{a}\alpha^{2-1}$. Following the reasoning in Arriaga's method, the change associated with disease i is

$$ {}_a^i\alpha^{2-1} = \sum_{x=a}^{\omega} {}_x^a\delta\, {}^i\Lambda_x^{2-1}, \quad {}^i\Lambda_x^{2-1} = \frac{{}^iq_x^2 - {}^iq_x^1}{q_x^2 - q_x^1}, \tag{4} $$

where ${}^iq_x^k$ denotes the mortality rate associated with disease i for age x during year t_k. Similarly, q_x^k represents the total mortality rate for age x (i.e. including all n diseases) during year t_k.

Analysing the formula, it becomes evident that it distributes the changes in the indicator that are attributable to different ages using the changes registered in the mortality rates per cause. In this sense, ${}^i\Lambda_x^{2-1}$ is just the proportion of the overall change in mortality for age x that was registered between times t_1 and t_2 that is attributable to cause i.

The underlying assumption is that the contributions to the changes that can be attributed to a cause are directly proportional to the variations registered in the respective mortality rates. Then, clearly,

$$ \alpha_a^{2-1} = \sum_{i=1}^{n} {}_a^i\alpha^{2-1} = \sum_{i=1}^{n}\sum_{j=a}^{\omega} {}_j^a\delta\, {}^i\Lambda_j^{2-1} \tag{5} $$

is the overall change in the mortality indicator for age a between years t_1 and t_2.

3 LIFE EXPECTANCY AT BIRTH FROM 1970 TO 2013

LE shows a remarkable evolution in France, Czechia, and the United States. In all three countries the values of the indicator have increased as mortality dynamics have evolved at different stages of human life and as the effect of diseases have varied over time. We will present next the decomposition of the changes in LE per age group and the contributions to this that are attributable to the different mortality chapters, which we calculate using equations (2)–(5).

3.1 Life expectancy at birth in France

France experienced a sustained increase in LE during the period we are interested in. LE rose from 68.4 years for males and 75.8 years for females in 1970 to 78.8 years and 85.1 years (respectively) in 2013. This represents a change of 10.4 years for males and 9.3 years for females over the entire period. These changes, however, did not occur in a 'uniform' manner and can be explained in different ways across this time interval.

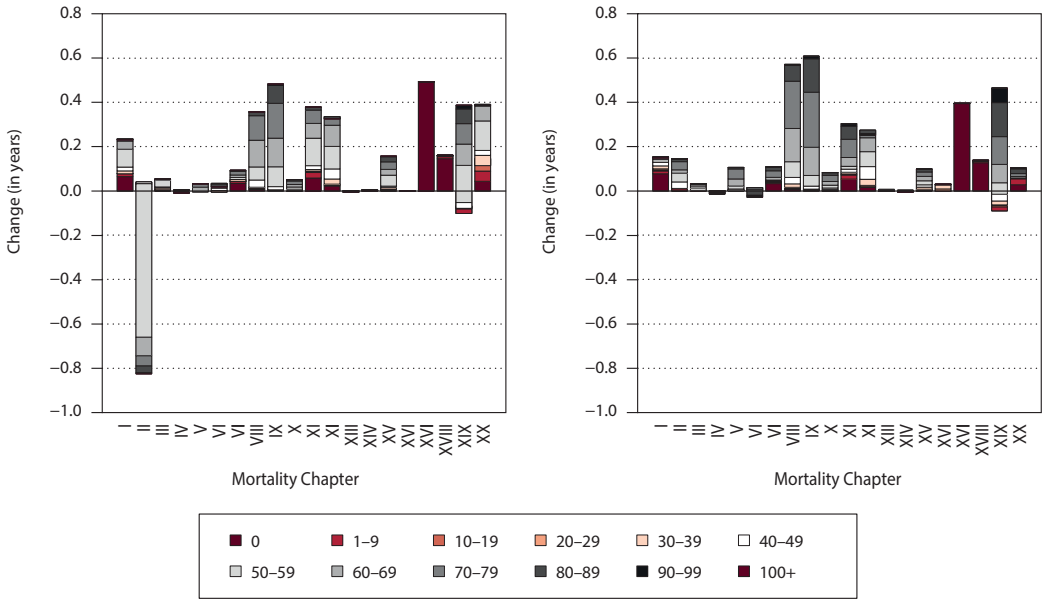
3.1.1 1970–1984

During this period, females experienced a bigger increase in their LE and registered a total change of 3.54 extra years compared to 2.77 extra years for males. By age group, the changes in LE during this period were affected by a very important increase that was caused by mortality changes at very young ages. For example, the contribution to the change that can be attributed to the first year of life alone accounts for around 29% of the total change for males and 19% for females. In general, when we consider the changes that are attributable to ages under 60, the mortality changes in these age groups contributed to almost 54% of the total increase (1.5 years) in the case of males, whereas for females they contributed to 44% (or 1.56 years). In the case of males, estimates show that about 1.3 years (out of the 2.77 years) are attributable to changes in mortality at ages 60 and older, while this increases to 1.98 years when we consider the total change of 3.54 years for females. From this information, it seems that women at older ages saw a much more significant improvement in their mortality prospects than men, who experienced a greater mortality reduction at young ages.

When analysing the results and the estimated changes that can be attributed to the different mortality chapters, the estimates show that some of the most relevant increments in life expectancy, for both genders, occurred as a result of improvements in Cerebrovascular Diseases (Mortality Chapter IX). The changes in mortality between 1970 and 1984 that were due to this group of diseases represented an estimated improvement in LE of about half a year for males and 0.61 years for females. Changes in mortality due to Heart Diseases (Mortality Chapter VIII) also played a central role in improving the indicator for both genders, but the effect is much higher in the case of females since it is estimated that women gained over half a year in LE (in contrast to 0.36 years for males). Similar results are obtained for Mortality Chapter XIX, which is Ill-Defined or Unknown Causes, registering an improvement of 0.46 years for females and 0.38 years for males.

Mortality Chapter XX – External Causes – including death due to accidents, homicides, poisoning, and the like, contributes considerably

Figure 1 Changes in LE by CoD and age, 1970–1984: France, males (left) vs females (right)



Source: HMD, CoDD and MAC.

to the improvement in LE for men (0.39 years), but not for women (0.11 years). Finally, it is worth noting that the results show an important decrease in LE for males due to Chapter II, Malignant Neoplasm, which caused an estimated decrease in life expectancy of 0.82 years for men. Appendix 1 shows all the details of the composition of changes in life expectancy by cause of death.

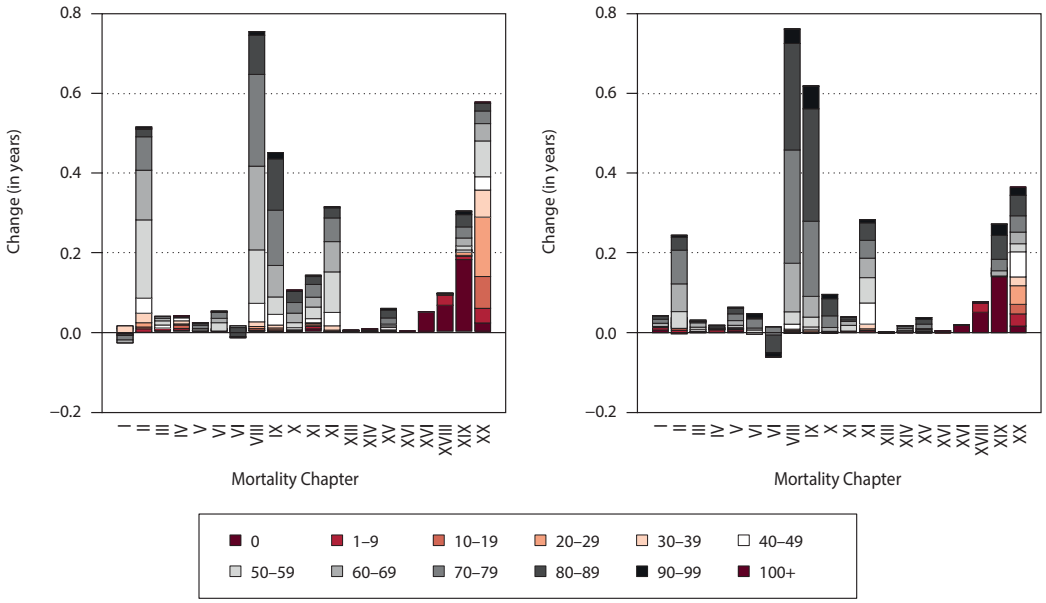
Figure 1 shows the estimated changes in LE by mortality chapter. The overall size of the bars represents the total variations estimated (axis *y*) for the mortality chapters (axis *x*). Every bar is divided into smaller segments with different colours that represent where the overall change comes from in terms of contributing age groups. When parts of a particular bar are in both the positive and negative quadrants, this means that some ages contributed to a decrease in life expectancy for that mortality chapter, whereas other age groups contributed to a gain. An example of this is Mortality Chapter XIX for females (with an overall gain of 0.525 years).

3.1.2 1985–1998

Unlike what happened in the previous period, in the period between 1985 and 1998 LE increased more for males than for females in France (with increments of 3.48 years for men and 2.96 years for women). The variation in LE attributable to each age group underwent several changes in structure: the contribution that is attributable to the first year of life decreased greatly in both absolute and relative numbers and represented about 9% and 8% of the overall change for men and women, respectively. Moreover, the total change in LE for men at ages younger than 60 accounts for 49% (1.72 years) of the total variation, whereas 51% comes from ages older than 60. For women, the difference is more evident, since 29% of the changes (0.87 years) come from age groups younger than 60 and 71% come from seniors.

As regards gains and losses in LE, we can see that France experienced very successful improvements in the treatment of diseases of the Circulatory System, as a result of which Mortality Chapter VIII improved the indicator by 0.76 years for both men and women. This shows that the improvement in this cause of death was much more significant than the one observed in the previous 14-year period. The estimated increases in LE attributable to Cerebrovascular Diseases, which had played a very prominent role in LE increase

Figure 2 Changes in LE by CoD and age, 1985–1998: France, males (left) vs. females (right)



Source: HMD, CoDD and MAC.

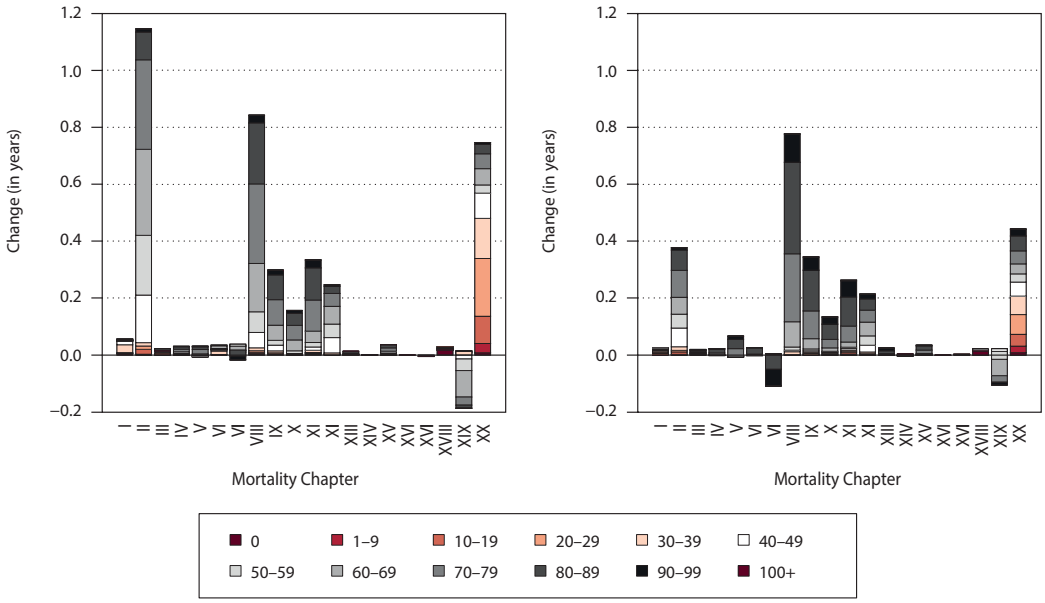
in the previous term for both genders, continue to be relevant, especially for women. In this period, this mortality chapter placed itself as the second and fourth main cause contributing to the enhanced indicator, for women and men. The estimates of the gains that are due to this chapter yield an increment of 0.45 years in LE for males and 0.62 years for females. The mortality experience observed during this period also suggests that there were important improvements in deaths due to external causes, which is the chapter responsible for the second- and third-biggest increments for males and females respectively. In this case, the gain in years of life expectancy is more significant for men than for women. The top three improvements in causes of death are responsible for about 53% and 59% of the overall change in life expectancy during this period. Figure 2 shows this and other results.

3.1.3 1999–2013

From 1999 to 2013, the French population once again saw an important improvement in LE. By the end of this period, like in the previous period, French men experienced a more significant increase than French women – men's LE improved by 3.83 years while women's LE increased by 2.6 years. Not only did men experience a more pronounced improvement in the LE indicator for the second consecutive period, but the difference, when compared with the gains for women, is much more noticeable: 1.23 years greater than that of French women (as opposed to half a year in the previous period). This certainly contributed to a decrease in the gender gap.

The changes in LE during this period confirm a tendency detected earlier: the improvements that are attributable to young ages start to lose their relative importance as mortality improvements start to come from the longevity of the elderly. During this 14-year period, only about 2% of the variation is attributable to changes in the mortality of newborns in both genders, whereas the ages under 60 contributed to 40% of the overall change in the case of males and 25% in the case of females. Moreover, the variations attributable to senior ages (over 60) amount to 2.3 years for males and 1.95 years for females. In this sense, the change in the structure becomes more significant in the case of French men as they seem to keep up better with female mortality at older ages.

Figure 3 Changes in LE by CoD and age, 1999–2013: France, males (left) vs females (right)



Source: HMD, CoDD and MAC.

In this third period (see Figure 3), life expectancy primarily improved as a result of the influence of Mortality Chapter II, Malignant Neoplasms, which generated an improvement of 1.16 years in LE for men. The evolution of mortality caused by Heart Diseases continued to affect positively life expectancy for both genders (with an estimated attribution of an increase of 0.85 years in this indicator for men and 0.78 years for women). Deaths due to external causes (Mortality Chapter XX) also helped to increase LE, with a particularly strong effect in the case of men (0.76 years). Improvements related to Respiratory Diseases started to be more prominent during this term, whereas causes such as Nervous System Disorders (Mortality Chapter VII) caused subtle decreases in life expectancy.

3.2 Life expectancy at birth in Czechia

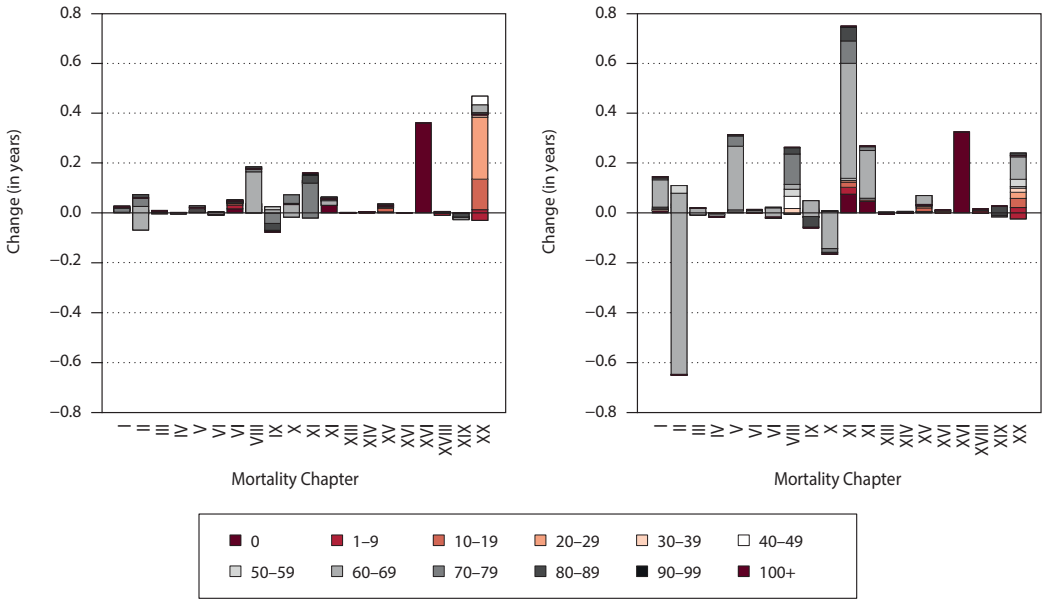
In the case of Czechia, LE increased by 9.11 years for males and 8.16 for females between 1970 and 2013, going from 66.04 years and 72.99 years for males and females, respectively, to 75.15 and 81.15 years. The causes of these variations, as in the case of France, seem to vary in time as mortality evolves by age and cause of death.

3.2.1 1970–1984

The change in LE in Czechia between 1970 and 1984 (see Figure 4) was very similar for both genders and reached 1.3 years in the case of males and 1.51 for females. Around a year of the change is estimated to have been generated by mortality changes in age groups younger than 60, which means that age groups over 60 contribute in a much less significant manner during these years.

The main cause of death contributing to the indicator's improvement is shared by both genders: mortality changes originating in Mortality Chapter XVII, Conditions of the Perinatal Period, improvements in which led to an increase in life expectancy of 0.36 and 0.33 years for males and females. All this variation is attributable to age 0. Improvements related to deaths caused by accidents, homicides, suicides, poisonings, and the like (as defined in Mortality Chapter XX) also contributed significantly. This chapter is estimated to have generated 0.4 extra years of LE in the case of males (as the main cause explaining the increase in this case) and 0.23 extra years for females. In addition, Mortality Chapter XI, Respiratory Diseases, is estimated

Figure 4 Changes in LE by CoD and age, 1970–1984: Czechia, males (left) vs females (right)



Source: HMD, CoDD and MAC.

to be responsible for an increase of 0.76 years in this indicator in the case of females. Some chapters, however, are estimated to have caused decreases in LE during this period. These include Malignant Neoplasms, which are estimated to have contributed to a decrease in LE of 0.66 years for females.

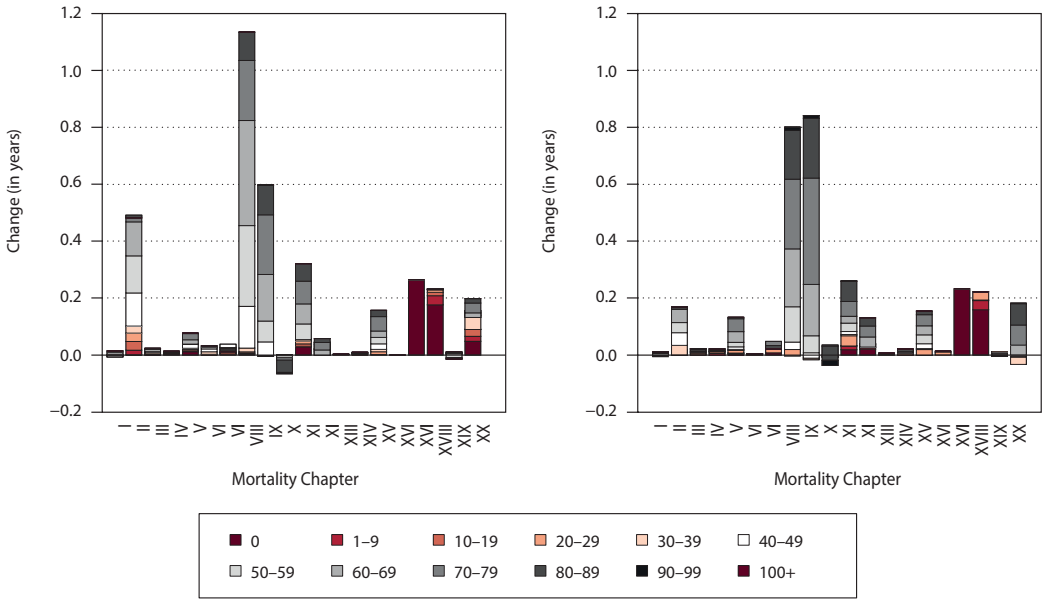
3.2.2 1985–1998

Mortality improvements were much more significant during this 14-year period and led to an increase in life expectancy of 3.56 years for males and 3.23 years for females. Again, mortality improvements among newborns are estimated to be the main driver of these changes, generating an estimated increase in LE of 0.57 years for males and 0.50 years for females. Despite this, age groups under 60 became, in relative terms, less 'important' (for LE changes?) when compared to the previous period. Nevertheless, they continued to be the main driver of change and their absolute contributions increased, generating 1.83 and 1.17 extra years in LE for men and women, respectively. This means that the contributions to changes made by ages 60 and older represented 49% of the variation for men but 64% for women.

When analysing the changes by mortality chapter, the estimated main contributors seem to differ from the ones identified in the previous period. In the case of males, the mortality improvements for causes of death included in Mortality Chapter VIII, Heart Diseases, are the most relevant: they are estimated to have contributed 1.14 years of extra LE. Such improvements are most observed at ages from 40 to 80 years old. The effect of these groups is estimated to explain a year of the overall gains in Mortality Chapter VIII, showing that death rates attributed to these causes mostly improved greatly for adults. Improvements in Cerebrovascular Diseases also seem to be of key importance for the increase in LE. Among men their effect amounts to an increase in LE of 0.60 years. Malignant Neoplasms are also a major contributor in this case, generating 0.48 extra years of LE for males.

In the case of women, mortality improvements in Cerebrovascular Diseases are found to be the main driver of the improvement with an estimated effect of 0.84 extra years in LE. It is worth noting that 0.77 years of the total improvement are due to mortality changes registered at ages over 60. Heart

Figure 5 Changes in LE by CoD and age, 1985–1998: Czechia, males (left) vs females (right)



Source: HMD, CoDD and MAC.

Diseases comes second and generated an estimated 0.80 extra years. Respiratory Diseases also played a central role and caused an estimated increase in LE of over a quarter of a year. Figure 5 presents a detailed picture.

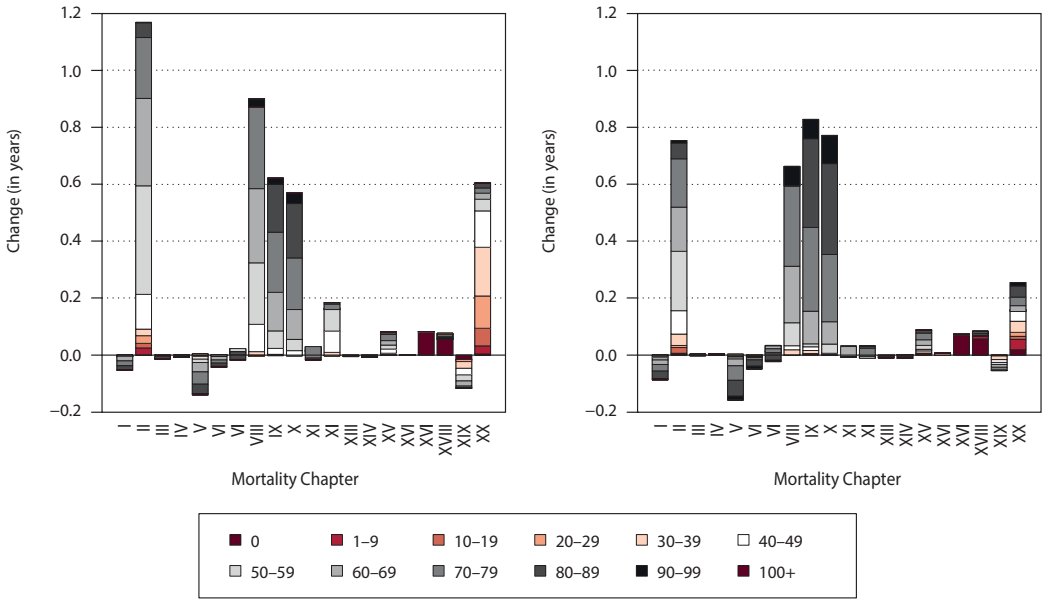
3.2.3 1999–2013

From 1999 to 2013 LE in Czechia took another big leap (in fact for males it was the biggest increase throughout the entire period). The increase in LE during this time was 3.82 years for males and 3.07 years for females. Despite a smaller improvement in mortality at birth during this period, the contributions of age groups under 60 continued to be relevant in the case of males, representing a total gain of 1.85 years or around 48% out of the total change (see Figure 6). In the case of females, the changes attributable to these age groups became less important and amounted to 28% (0.88 years) of the total variation. This shows that women were already experiencing major mortality improvements in senior ages while men were still experiencing very significant changes in younger age groups. In general terms, Czech men seem to be slowly shifting to a pattern that should be more aligned with that of women in the years to come, but this shift seems to be happening at a much slower pace than in the case of French men.

Effects by cause of death show subtle differences based on gender. The increase in men's LE was mostly due to improvements in mortality related to Malignant Neoplasms (generating 1.17 extra years, 50% of which was caused by age groups under 60). Heart Diseases also contributed greatly (0.87 extra years), whereas Cerebrovascular Diseases came third in importance (0.62 extra years).

The chapter contributing most to changes in the LE of women was that of Cerebrovascular Diseases (0.83 additional years), followed closely by Mortality Chapter X, Other Circulatory Diseases (0.77 years). Malignant Neoplasms completes the group of three major contributors, generating an estimated increase in LE of 0.75 years. Together these three Mortality Chapters explain 77% of the overall improvement in the indicator for males and 82% for females. Appendix 2 presents the results in detail.

Figure 6 Changes in LE by CoD and age, 1999–2013: Czechia, males (left) vs females (right)



Source: HMD, CoDD and MAC.

3.3 Life expectancy at birth in the United States

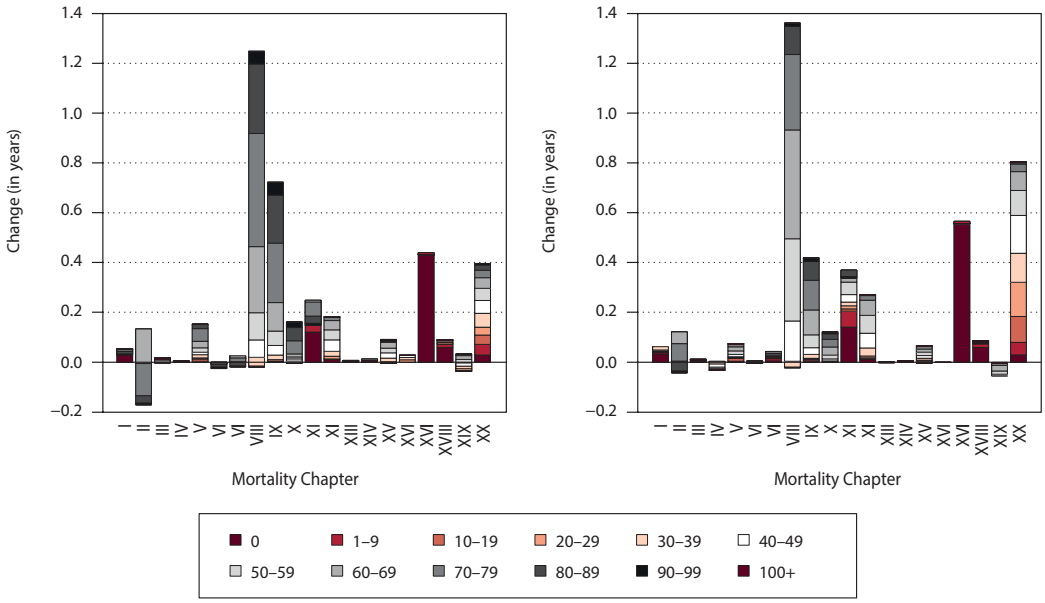
The United States saw LE grow from 67.02 years for males and 74.65 for females in 1970 to 76.6 years and 81.3 years in 2013. One remarkable aspect of these changes is that, out of the three countries being studied, the United States was the country in which the gender gap decreased the most during this period. For now, as in the cases of France and Czechia, the focus will be placed on the sources of changes in LE.

3.3.1 1970–1984

LE improved greatly in the United States between 1970 and 1984. The indicator increased 4.1 years for males and 3.52 years for females. The most relevant change in mortality attributable to a single age group was the change observed at age 0, which was responsible for an estimated increase in LE of 0.8 and 0.66 years for males and females, respectively. Mortality changes at age groups under 60 are responsible for most of the improvement in the indicator for this period in both genders, representing a total increase of 2.74 and 1.95 extra years of LE for men and women. In the case of senior ages, the development was less pronounced during this period and amounted to an improvement in LE of 1.36 and 1.57 years, respectively.

A big part of the positive developments in LE in the United States during this period is estimated to have come from the country's success in fighting Heart Diseases, generating a reduction in deaths high enough to increase LE by 1.36 and 1.25 years for males and females. In the specific case of US women, the mortality reductions in Cerebrovascular Diseases and in Conditions of the Perinatal Period contributed to an increase in LE of 0.72 and 0.43 years, respectively. For males, a very relevant improvement comes from a reduction of deaths resulting from accidents, homicides, suicides, poisonings, and the like, which generated an additional 0.80 years of LE. Changes in mortality from conditions associated with the perinatal period also became a major contributor in the case of men (0.56 years). The estimated decomposition of the changes in LE by Mortality Chapter, for all chapters, is shown in Figure 7.

Figure 7 Changes in LE by CoD and age, 1970–1984: United States, males (right) vs females (left)



Source: HMD, CoDD and MAC.

3.3.2 1985–1998

This period was characterised by more modest increases in LE (an increase of 2.73 years for males and 1.25 extra years for females). According to Figure 8, out of the 2.73 additional years estimated for males, 1.35 years are attributable to mortality improvements at ages below 60. For females, these age groups accounted for 0.66 additional years of LE, out of the total 1.25 years. Because of this, an important part of the improvements in LE during this time period are estimated to be generated by these younger age groups, accounting for 49% and 52% of the overall change among men and women, respectively.

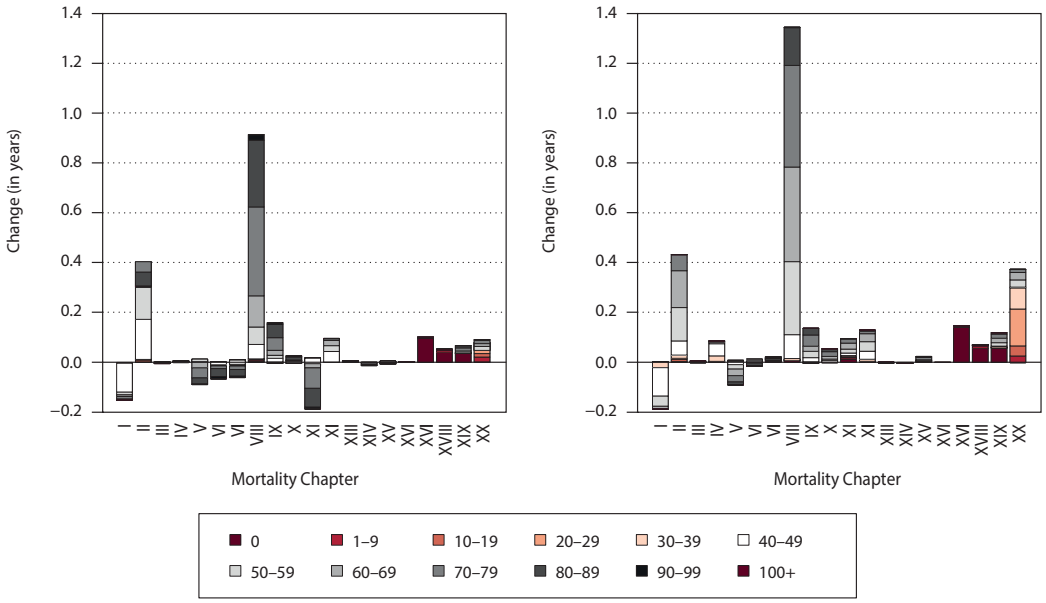
In general terms, the biggest improvement in LE related to a mortality chapter was observed among men, and this was due to the reduction of deaths from Heart Diseases (generating an increase of around 1.35 years). For females, the attributable effect of Mortality Chapter VIII was the most relevant (0.91 years for the period). Another significant increase in LE is estimated to have happened in the case of men, due to a reduction in the death rates associated with Mortality Chapter II.

It is worth noting that Mortality Chapter XI, Respiratory Diseases, was responsible for a decrease in LE for females in the United States, generating a decrease in LE of around 0.19 years. This phenomenon explains a part of the advantage that was observed for males during this period, which, together with the stronger improvement in mortality related to heart disease, explains about 0.70 years of the additional LE gained by US men during this period when compared to women.

3.3.3 1999–2013

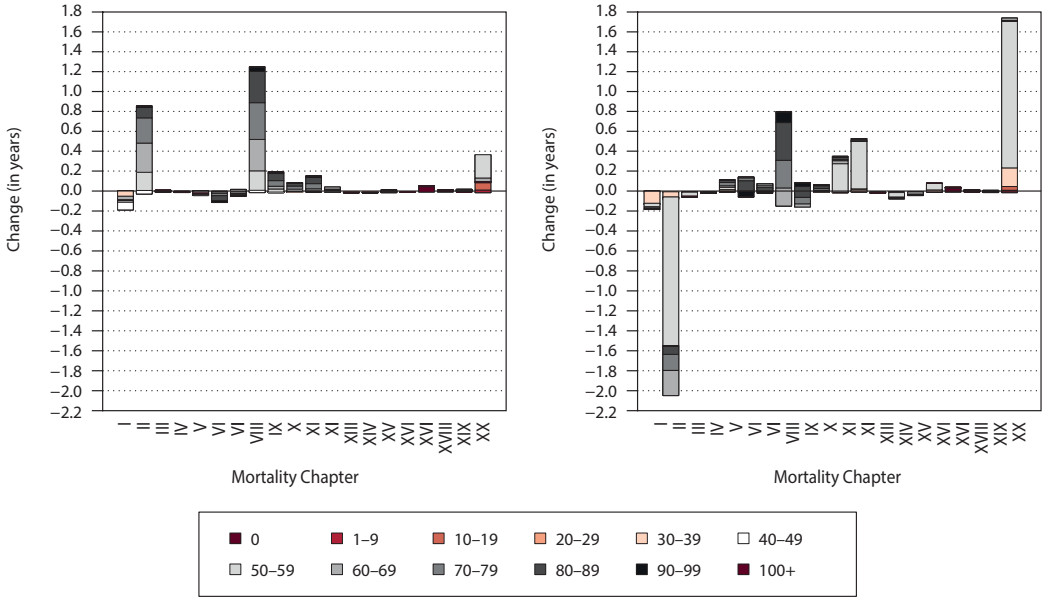
In 1999–2013, increases in LE reached 2.63 and 1.99 years for males and females. These changes are much closer to the ones observed in 1970–1984. However, during these years, the United States seemed to enter a new stage in LE dynamics, one in which LE was driven by mortality improvements in senior ages (cf. Figure 9), as treatments and prevention began to focus more on retirees and older individuals. Mortality improvements in senior age groups (60+) are estimated to have contributed 1.96 years of additional LE for males and 1.62 years for females. This represents 75% and 82% of the overall change and shows a total shift in the pattern previously observed. The fight against Heart Diseases and Malignant Neoplasms

Figure 8 Changes in LE by CoD and age, 1985–1998: USA, males (left) vs females (right)



Source: HMD, CoDD and MAC.

Figure 9 Changes in LE by CoD and age, 1999–2013: United States, males (left) vs females (right)



Source: HMD, CoDD and MAC.

seems to have made these two CoDs the main drivers of the increase in LE for males during this new phase. For females, Heart Diseases and External Causes resulted in the biggest increases. In the case of Heart Diseases, they are estimated to have increased LE by 1.27 for US males and 0.82 years for US females. In the case of Mortality Chapter II, Malignant Neoplasms, the effect is estimated to have caused a gain of 0.88 years for males and a decrease in LE of 1.56 years for females. As noted, the effect of Mortality Chapter XX for females is very relevant in this period, registering a gain of 1.75 years.

The detailed figures for the decomposition of changes in LE in the United States are presented in the Appendix 3.

4 CONCLUSION

We started by pointing out that, when a comparison is possible, our general results are aligned with the results obtained in the existing literature, as expected. Nevertheless, since we cover more than 40 years, 12 age groups, and 20 mortality chapters, this very complete grid of combinations allows us to shed added light on current knowledge, based on the mortality experiences of the three selected countries.

By using the findings in France, Czechia, and the United States, we showed that the development and increases in LE follow a certain tendency: improving mortality at birth is clearly an essential first step towards increasing LE in any country. Once this is achieved, countries tend to see an improvement in survival at younger ages (e.g. ages under 60) so that mortality is reduced for these age groups. Finally, they have just one way to continue to a more 'advanced stage': once they reach a 'high enough' LE, improvements start to derive from extending the life of seniors and reducing the effects of the diseases that affect them the most. It seems that women are the first segment of the population to reach this final stage in a country, but males are keeping up, and are seeing in general terms bigger improvements in LE. France and the United States already appeared to be at this stage for both genders in 2013. In the case of Czechia, women have reached this level, but men have been moving a little more slowly towards increases in LE due to mortality changes at ages older than 60.

At least 50% of the variations in LE in the three countries could be easily explained by focusing just on four mortality chapters. In fact, in the United States these groups of diseases would explain over 70% whereas in France they account for around 60% of LE improvements. Irrespective of geography or gender, the increasing effectiveness at reducing mortality related to Heart Diseases, Malignant Neoplasms, Cerebrovascular Diseases and External Causes seems to have become key to maintaining increasing levels of LE from 1970 to 2013. In the case of French males and US females, the decrease in mortality rates due to Diseases of the Digestive System has also played a major role in this time interval, adding an estimated 0.89 and 0.82 years during the period, respectively.

It is important to note that the United States was the country in which the gender gap in LE decreased the most, as the difference in male and female LE narrowed by 2.84 years between 1970 and 2013. By contrast, the smallest decrease in the gender gap in LE out of all three countries was observed in Czechia, where there was a change of less than a year in the same period. This phenomenon will be analysed in greater depth in future research.

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References

- Actuarial Association of Europe, Social Security Sub-Committee of the Pensions Committee 2019. Meeting the Challenge of Ageing in the EU. *AAE Discussion Paper.* https://actuary.eu/wp-content/uploads/2019/03/Meeting-the-challenge-of-ageing-FINAL.pdf.
- Agyepong, I. A – Sewankambo, N. – Binagwaho, A. – Coll-Seck, A.M. – Corrah, T. – Ezeh, A., … and Piot, P. 2017. The path to longer and healthier lives for all Africans by 2030: the Lancet Commission on the future of health in sub-Saharan Africa. *The Lancet*, 390(10114), pp. 2803–2859. https://doi.org/10.1016/S0140-6736(17)31509-X.

- Al-Ramadhan, M. A. 2008. Contributions of age and cause-specific mortality to gains in life expectancies among the Kuwait population. *Genus*, 64, pp. 155–171.
- Andreev, E. – Shkolnikov, V. – Begun, A. 2002. Algorithm for decomposition of differences between aggregate demographic measures and its application to life expectancies, healthy life expectancies, parity progression ratios and total fertility rates. *Demographic Research*, 7(14), pp. 499–522. https://doi.org/10.4054/DemRes.2002.7.14.
- Arriaga, E. 1984. Measuring and explaining the change in life expectancies. *Demography*, 21(1), pp. 83–96. https://doi.org/10.2307/2061029.
- Arriaga, E. 1989. Changing trends in mortality decline during the last decades. In *Differential mortality: Methodological issues and biosocial factors*, pp. 105–129, Oxford: Clarendon Press.
- Auger, N. – Feuillet, P. – Martel, S. – Lo, E. – Barry, A. D. – Harper, S. 2014. Mortality inequality in populations with equal LE: Arriaga's decomposition method in SAS, Stata, and Excel. *Annals of Epidemiology*, 24, pp. 575–580. https://doi.org/10.1016/j.annepidem.2014.05.006.
- Auger, N. – Harper, S. – Barry, A. D. – Trempe, N. – Daniel, M. 2012. Life expectancy gap between the Francophone majority and Anglophone minority of a Canadian population. *European Journal of Epidemiology*, 27, pp. 27–38. https://doi.org/10.1007/s10654-011-9644-8.
- Bergeron-Boucher, M-P. – Ebeling, M. – Canudas-Romo, V. 2015. Decomposing changes in life expectancy: Compression versus shifting mortality. *Demographic Research*, 33, pp. 391–424. https://doi.org/10.4054/DemRes.2015.33.14.
- Buettner, D. – Skemp, S. 2016. Blue Zones. *American Journal of Lifestyle Medicine,* 10(5), pp. 318–321. https://doi.org/10.1177/1559827616637066.
- Cause of Death Database. https://cod.mortality.org/.
- Das Gupta, P. 1978. A general method of decomposing a difference between two rates into several components. *Demography*, 15, pp. 99–112. https://doi.org/10.2307/2060493.
- Ho, J. Y. – Hendi, A. S. 2018. Recent trends in life expectancy across high income countries: retrospective observational study. *BMJ*, 2018, 362, k2562. https://doi.org/10.1136/bmj.k2562.
- Hosseinpoor, A. R. – Lee, J. H. – Lynch, J. – Mathers, C. – Abou-Zahr, C. 2012. International shortfall inequality in life expectancy in women and men, 1950–2010. *Bulletin of World Health Organisatio*n, 90. https://doi.org/10.2471/BLT.11.097378.
- Hulíková Tesárková, K. – Kašpar, D.– Zimmermann, P. 2015. Convergent and Divergent Trends in the European Mortality: What Is the Position of Czechia? *Geografie*, 120(1), pp. 26–49. https://doi.org/10.37040/geografie2015120010026.
- Human Mortality Database. University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany). Available at www.mortality.org or www.humanmortality.de. Last accessed 12.10.2021.
- Khang, Y.-H. – Yang, S. – Cho, H.-J. – Choi-Jung, K. – Yun, S.-C. 2010. Decomposition of socioeconomic differences in life expectancy at birth by age and cause of death among 4 million South Korean public servants and their dependents. *International Journal of Epidemiology*, 39, pp. 1656–1666. https://doi.org/10.1093/ije/dyq117.
- Le, Y. – Ren, J. – Shen, J. – Li, T. – Zhang, C.-F. 2015. The changing gender differences in life expectancy in Chinese cities 2005–2010. *PLoS ONE*, 10, e0123320. https://doi.org/10.1371/journal.pone.0123320.
- Leon, D. A. 2011. Trends in European life expectancy: a salutary view. *International Journal of Epidemiology*, 40, pp. 271–277. https://doi.org/10.1093/ije/dyr061.
- Liu, L. – Oza, S.– Hogan, D. – Chu Y. – Perin, J. – Zhu, J. – … – Black, R. E. 2016. Global, regional, and national causes of under-5 mortality in 2000–15: an updated systematic analysis with implications for the Sustainable Development Goals. *The Lancet*, 388(10063) pp. 3027–3035. https://doi.org/10.1016/S0140-6736(16)31593-8.
- Martikainen, P. – Makela, P. – Peltonen, R. – Myrskyla, M. 2014. Income differences in life expectancy: The changing contribution of harmful consumption of alcohol and smoking. *Epidemiology*, 25, pp. 182–190. https://doi.org/10.1097/EDE.0000000000000064.
- Martikainen, P. – Valkonen, T. – Martelin, T. 2001. Change in male and female life expectancy by social class: Decomposition by age and cause of death in Finland 1971–95. *Journal of Epidemiology Community Health*, 55, pp. 494–499. https://doi.org/10.1136/jech.55.7.494.
- Meslé, F. Mortality in Central and Eastern Europe: long-term trends and recent upturns. *Demographic Research* – Special Collection 2, pp. 45–70. https://doi.org/10.4054/DemRes.2004.S2.3.

- Meslé, F. – Vallin, J. 2017. The End of East-West Divergence in European Life Expectancies? An Introduction to the Special Issue. *European Journal of Population*, 33, pp. 615–627.
- Meslé, F. – Vallin, J. – Pyrozhkov, S. 2012. Impact of Major Groups of Causes on Life Expectancy Trends. *Mortality and Causes of Death in 20th-Century Ukraine*, pp. 173–195. Springer, Dordrecht. https://doi.org/10.1007/978-94-007-2433-4_11.
- Mondal, N. I. – Shitan, M. 2014. Relative importance of demographic, socioeconomic and health factors on life expectancy in low- and lower-middle-income countries. *Journal of Epidemiology*, 24, pp. 117–124. https://doi.org/10.2188/jea.JE20130059.
- Murwirapachena, G. – Mlambo, C. 2015. Life Expectancy in Zimbabwe: An Analysis of Five Decades. *International Business and Economics Research Journal*, 14(3), pp. 417–430. https://doi.org/10.19030/iber.v14i3.9207.
- Poulant, M.– Buettner, D. – Pes, G. 2019. Blue Zones. Reference Module in *Biomedical Sciences*. Elsevier. https://doi.org/10.1016/B978-0-12-801238-3.11437-0.
- Pressat, R. 1985. Contribution des écarts de mortalité par âge à la différance des vies moyennes. *Population*, 40(4–5), pp. 766–770. https://doi.org/10.2307/1532986.
- Preston, S. H. – Stokes, A. 2012. Sources of Population Aging in More and Less Developed Countries. *Population and Development Review*, 38(2), pp. 221–236. https://doi.org/10.1111/j.1728-4457.2012.00490.x.
- Rosella, L. C. – Calzavara, A. – Frank, J. W. – Fitzpatrick, T. – Donnelly, P. D. – Henry, D. 2016. Narrowing mortality gap between men and women over two decades: a registry-based study in Ontario, Canada. *BMJ Open*, 6(11). [e012564]. https://doi.org/10.1136/bmjopen-2016-012564.
- Simmons, S. 2018. The Gender Gap in Life Expectancy in South Africa from 2000 to 2015: The Role of Age-and Cause-Specific Mortality. *International Journal in Sciences: Basic and Applied Research*, 42(5), pp. 24–36.
- Shkolnikov, V. M. – Andreev, E. M. – McKee, M. – Leon, D. A. 2013. Components and possible determinants of decrease in Russian mortality in 2004–2010. *Demographic Research*, 28, pp. 917–950. https://doi.org/10.4054/DemRes.2013.28.32.
- Tarkiainen, L. – Martikainen, P. – Laaksonen, M. – Valkonen, T. 2012. Trends in life expectancy by income from 1988 to 2007: Decomposition by age and cause of death. *Journal of Epidemiology Community Health*, 66, pp. 573–578. https://doi.org/10.1136/jech.2010.123182.
- Trovato, F. – Heyen, N. B. 2006. A varied pattern of change of sex differential in the G7 countries. *Journal of Biosocial Science*, 38, pp. 391–401. https://doi.org/10.1017/S0021932005007212.
- Trovato, F. – Lalu, N. M. 1997. Changing sex differences in life expectancy in Australia between 1970 and 1990. *Journal of the Australian Population Association*, 14, pp. 187–200. https://doi.org/10.1007/BF03029339.
- Trovato, F. – Odynak, D. 2011. Sex differences in life expectancy in Canada: Immigrant and native-born populations. *Journal of Biosocial Science*, 43, pp. 353–368. https://doi.org/10.1017/S0021932011000010.
- United Nations, Department of Economic and Social Affairs, Population Division 2019. World Population Prospects 2019: Press Release. Available at https://population.un.org/wpp/Publications/Files/ WPP2019_PressRelease_EN.pdf.
- Vaupel, J. W. – Romo, V. C. 2002. Decomposing demographic change into direct vs. compositional components. *Demographic Research*, 7, pp. 1–14. https://doi.org/10.4054/DemRes.2002.7.1.
- Wang, H. – Naghavi, M. – Allen, C. – Barber, R. M. – Bhutta, Z. A – Carter, A. – … – Murray, C. J. L. 2016. Global, regional, and national life expectancy, all-cause mortality, and cause-mortality for 249 causes of death, 1980–2015: a systematic analysis for the Global Burden of Disease Study 2015. *The Lancet*, 388(10053), pp. 1459–1544. https://doi.org/10.1016/S0140-6736(16)31012-1.
- Waldon, I. 1983. Sex differences in human mortality. *Social Science Medicine*, 17, pp. 321–333. https://doi.org/10.1016/0277-9536(83)90234-4.
- Waldon, I. – McCloskey, C. – Earle, I. 2005. Trends in gender differences in accidents mortality: Relationships to changing gender roles and other societal trends. *Demographic Research*, 13, pp. 415–454. https://doi.org/10.4054/DemRes.2005.13.17.
- Woolf, S. H. – Schoomaker, H. 2019. Life Expectancy and Mortality Rates in the United States, 1959–2017. *JAMA*, 322(20), pp.1996–2016. https://doi.org/10.1001/jama.2019.16932.
- World Health Organization 2019. *World health statistics overview 2019: monitoring health for the SDGs, sustainable development goals.* World Health Organization. Available at https://apps.who.int/iris/bitstream/handle/10665/311696/WHO-DAD-2019.1-eng.pdf?sequence=1 andisAllowed=y .
- Yang, S. – Khang, Y.-H. – Chun, H. – Harper, S. – Lynch, J. 2012. The changing gender differences in life expectancy in Korea 1970–2005. *Social Science Medicine*, 75, pp. 1280–1287. https://doi.org/10.1016/j.socscimed.2012.04.026.

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Appendix

Appendix 1 Decomposition of the changes in LE, in years, by mortality chapter – France

	1970–1984		1985–1998		1999–2013		1970–2013	
Mortality Chapter	**Males**	**Females**	**Males**	**Females**	**Males**	**Females**	**Males**	**Females**
I – Infectious Diseases	0.2310	0.1491	-0.0059	0.0426	0.0518	0.0161	0.2769	0.2078
II – Malignant Neoplasms	–0.8237	0.1438	0.5098	0.2439	1.1629	0.3777	0.8489	0.7654
III – Other Neoplasms	0.0525	0.0323	0.0368	0.0273	0.0139	0.0156	0.1031	0.0752
IV – Diseases of the Blood	–0.0088	–0.0130	0.0379	0.0179	0.0310	0.0238	0.0601	0.0287
V – Endocrine/Nutritional	0.0324	0.1056	0.0206	0.0612	0.0315	0.0677	0.0844	0.2345
VI – Mental Disorders	0.0189	–0.0268	0.0481	0.0357	0.0183	0.0254	0.0853	0.0343
VII – Nervous System	0.0935	0.1097	–0.0165	–0.0608	–0.0171	–0.1089	0.0599	–0.0600
VIII – Heart Diseases	0.3559	0.5660	0.7551	0.7605	0.8549	0.7783	1.9660	2.1048
IX – Cerebrovascular Diseases	0.4827	0.6078	0.4503	0.6188	0.3030	0.3457	1.2360	1.5723
X – Other Circulatory Diseases	0.0520	0.0829	0.1034	0.0960	0.1591	0.1350	0.3145	0.3139
XI – Respiratory Diseases	0.3782	0.3034	0.1405	0.0395	0.3393	0.2647	0.8580	0.6076
XII – Diseases of the Digestive System	0.3250	0.2521	0.3130	0.2834	0.2504	0.2150	0.8884	0.7505
XIII – Diseases of the Skin	–0.0058	–0.0008	0.0017	0.0017	0.0138	0.0258	0.0098	0.0267
XIV – Diseases of the Musculoskeletal System	0.0016	–0.0049	0.0047	0.0171	–0.0013	0.0050	0.0050	0.0172
XV – Diseases of the Genitourinary System	0.1577	0.0994	0.0571	0.0379	0.0374	0.0355	0.2522	0.1728
XVI – Complications of Pregnancy/Childbirth	0.0000	0.0308	0.0000	0.0045	0.0000	0.0006	0.0000	0.0359
XVII – Conditions of the Perinatal Period	0.4929	0.3954	0.0489	0.0205	–0.0044	0.0028	0.5374	0.4187
XVIII – Congenital Malformations	0.1611	0.1382	0.0950	0.0748	0.0173	0.0142	0.2734	0.2272
XIX – III–Defined or Unknown	0.3871	0.4645	0.3023	0.2727	–0.1895	–0.0943	0.4999	0.6429
XX – External Causes	0.3859	0.1049	0.5774	0.3648	0.7577	0.4441	1.7209	0.9138
Total increase	**2.7700**	**3.5404**	**3.4800**	**2.9600**	**3.8300**	**2.5898**	**10.0800**	**9.0902**

Source: HMD, CoDD and MAC.

Appendix 2 Decomposition of the changes in LE, in years, by mortality chapter – Czechia

	1970–1984		1985–1998		1999–2013		1970–2013	
Mortality Chapter	**Males**	**Females**	**Males**	**Females**	**Males**	**Females**	**Males**	**Females**
I – Infectious Diseases	0.0238	0.1469	0.0146	0.0120	–0.0532	–0.0869	–0.0149	0.0720
II – Malignant Neoplasms	0.0588	–0.6593	0.4826	0.1678	1.1679	0.7533	1.7093	0.2618
III – Other Neoplasms	0.0072	0.0181	0.0234	0.0229	–0.0135	–0.0022	0.0171	0.0388
IV – Diseases of the Blood	0.0007	–0.0172	0.0133	0.0224	–0.0082	0.0005	0.0058	0.0057
V – Endocrine/Nutritional	0.0202	0.3180	0.0774	0.1325	–0.1396	–0.1575	–0.0420	0.2930
VI – Mental Disorders	–0.0067	0.0136	0.0331	0.0047	–0.0424	–0.0483	–0.0160	–0.0300
VII – Nervous System	0.0487	–0.0180	0.0117	0.0212	–0.0176	–0.0226	0.0428	–0.0194
VIII – Heart Diseases	0.1767	0.2662	1.1366	0.8011	0.8707	0.5936	2.1840	1.6609
IX – Cerebrovascular Diseases	–0.0791	–0.0618	0.5983	0.8420	0.6217	0.8275	1.1409	1.6077
X – Other Circulatory Diseases	0.0334	–0.1683	–0.0612	–0.0186	0.5695	0.7713	0.5417	0.5844
XI – Respiratory Diseases	0.1619	0.7587	0.3211	0.2602	–0.0173	–0.0048	0.4657	1.0141
XII – Diseases of the Digestive System	0.0570	0.2711	0.0580	0.1313	0.1846	0.0324	0.2996	0.4348
XIII – Diseases of the Skin	–0.0014	–0.0050	0.0031	0.0068	–0.0049	–0.0101	–0.0032	–0.0083
XIV – Diseases of the Musculoskeletal System	0.0034	0.0002	0.0098	0.0212	–0.0082	–0.0109	0.0050	0.0105
XV – Diseases of the Genitourinary System	0.0279	0.0306	0.1569	0.1544	0.0815	0.0876	0.2663	0.2726
XVI – Complications of Pregnancy/Childbirth	0.0000	0.0122	0.0000	0.0137	0.0000	0.0071	0.0000	0.0330
XVII – Conditions of the Perinatal Period	0.3644	0.3278	0.2651	0.2331	0.0825	0.0715	0.7120	0.6324
XVIII – Congenital Malformations	0.0048	0.0155	0.2307	0.2220	0.0551	0.0664	0.2906	0.3039
XIX – Ill–Defined or Unknown	0.0007	0.0282	–0.0133	–0.0026	–0.1138	–0.0528	–0.1264	–0.0272
XX – External Causes	0.3975	0.2324	0.1988	0.1819	0.6053	0.2549	1.2016	0.6692
Total increase	**1.3000**	**1.5099**	**3.5600**	**3.2300**	**3.8200**	**3.0700**	**8.6800**	**7.8099**

Source: HMD, CoDD and MAC.

Appendix 3 Decomposition of the changes in LE, in years, by mortality chapter – United States

	1970–1984		1985–1998		1999–2013		1970–2013	
Mortality Chapter	**Males**	**Females**	**Males**	**Females**	**Males**	**Females**	**Males**	**Females**
I – Infectious Diseases	0.0389	0.0309	–0.1876	–0.1514	–0.0851	–0.1764	–0.2338	–0.2969
II – Malignant Neoplasms	–0.0415	–0.1698	0.4333	0.3034	0.8759	–1.5601	1.2677	–1.4265
III – Other Neoplasms	0.0099	0.0139	0.0057	–0.0045	0.0185	–0.0426	0.0340	–0.0332
IV – Diseases of the Blood	–0.0320	0.0009	0.0861	0.0041	–0.0027	–0.0106	0.0514	–0.0056
V – Endocrine/Nutritional	0.0746	0.1528	–0.0899	–0.0889	–0.0111	0.1260	–0.0264	0.1899
VI – Mental Disorders	–0.0044	–0.0243	–0.0142	–0.0661	–0.1060	–0.0502	–0.1246	–0.1406
VII – Nervous System	0.0237	–0.0175	0.0056	–0.0607	–0.0421	–0.0095	–0.0128	–0.0877
VIII – Heart Diseases	1.3615	1.2491	1.3454	0.9152	1.2733	0.8194	3.9802	2.9837
IX – Cerebrovascular Diseases	0.4190	0.7223	0.1371	0.1593	0.2047	0.0960	0.7609	0.9776
X – Other Circulatory Diseases	0.1219	0.1616	0.0547	0.0264	0.0958	0.0757	0.2724	0.2637
XI – Respiratory Diseases	0.3387	0.1490	0.0953	–0.1870	0.1640	0.3647	0.5980	0.3267
XII – Diseases of the Digestive System	0.2718	0.1813	0.1300	0.0959	0.0240	0.5449	0.4258	0.8221
XIII – Diseases of the Skin	–0.0009	0.0022	0.0010	0.0078	–0.0056	–0.0074	–0.0055	0.0026
XIV – Diseases of the Musculoskeletal System	0.0064	0.0059	–0.0036	–0.0126	–0.0034	–0.0522	–0.0006	–0.0589

Appendix 3 **cont.**

	1970–1984		1985–1998		1999–2013		1970–2013	
Mortality Chapter	**Males**	**Females**	**Males**	**Females**	**Males**	**Females**	**Males**	**Females**
XV – Diseases of the Genitourinary System	0.0665	0.0824	0.0240	–0.0040	0.0218	–0.0214	0.1124	0.0570
XVI – Complications of Pregnancy/Childbirth	0.0000	0.0283	0.0000	0.0029	0.0000	0.0905	0.0000	0.1217
XVII – Conditions of the Perinatal Period	0.5565	0.4316	0.1469	0.1013	0.0630	0.0437	0.7664	0.5766
XVIII – Congenital Malformations	0.0857	0.0898	0.0670	0.0503	0.0177	0.0114	0.1705	0.1515
XIX – Ill–Defined or Unknown	–0.0016	0.0329	0.1195	0.0675	0.0234	0.0062	0.1412	0.1066
XX – External Causes	0.8052	0.3968	0.3737	0.0910	0.1038	1.7420	1.2827	2.2298
Total increase	**4.1000**	**3.5201**	**2.7300**	**1.2499**	**2.6300**	**1.9901**	**9.4600**	**6.7601**

Source: HMD, CoDD and MAC.