Mortality and the Provision of Retirement Income

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Foreword

This report provides an overview of trends in mortality and the different approaches to develop mortality tables used in the context of the provision of retirement income, with a view to ensure that they are adequate to protect people's retirement incomes. Mortality assumptions are crucial to ensure the sustainability of lifetime retirement income for pensioners and that there will be sufficient assets for providers to meet their payment obligations. This report looks at the longevity trends and drivers over the last several decades, including the impact of the COVID-19 pandemic. It also explores considerations and traditional approaches for developing mortality tables, and details the standard mortality tables used across OECD member countries. It concludes with guidelines to assist regulators and supervisors in developing mortality tables and assessing whether the assumptions used in the context of retirement income provision are appropriate.

This report is an output from the pension unit in the Consumer Finance, Insurance, and Pensions Division of the OECD Directorate for Financial and Enterprise Affairs. National government delegates reviewed the different chapters, which benefited from their contributions, particularly delegates to the Insurance and Private Pensions Committee, and the Working Party on Private Pensions, as well as members of the International Organisation of Pensions Supervisors. The International Association of Actuaries also reviewed the work and provided useful comments. The views expressed here do not necessarily correspond to those of the national authorities or institutions concerned.

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Table of contents

FIGURES

TABLES

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Executive summary

The aim of this report is to provide guidance to regulators and supervisors of pension systems – as well as other relevant stakeholders – to develop and assess the mortality assumptions used in the context of the provision of retirement income. It looks at trends in mortality over the past several decades, including the impact that the COVID-19 pandemic has had, to provide context and inform future expectations of mortality trends. It also explains the different approaches taken to develop standard mortality tables for pensioners and annuitants, and summarises the tables used across OECD member countries. The report concludes with policy guidelines informed by international good practices.

It is important to understand the historical drivers of mortality to inform future expectations.

Changes in the drivers of historical improvements in mortality can provide insight as to what will happen in the future and help to inform modelling decisions to be in line with those expectations. For example, rapid economic development is often accompanied by accelerated improvements in life expectancy as developing countries catch up to their more economically advanced peers. Political and social drivers can also change the direction of trends, as the collapse of the Soviet Union did in Eastern Europe and the Baltic countries, or as the increase in drug overdoses have in the United States and others. Health policies and medical spending can drive improvements related to medical advances, such as the improvements in mortality from cardiovascular diseases that have driven strong reductions in mortality over several decades, though these gains are now slowing in many countries. Trends in social inequalities can also indicate whether life expectancy inequalities may grow or diminish over time.

The COVID-19 pandemic represented the largest shock to mortality and life expectancy in recent history. While mortality increased as a result of COVID-19 infections, particularly among those with comorbidities, the indirect impacts related to the response to the pandemic also had a significant effect on mortality. Mortality increased in many countries due to a lack of access to health care, either from a reluctance of patients to visit the doctor because of the risk of COVID-19 infection, or because of insufficient medical resources as medical facilities were overwhelmed by COVID-19 patients. Lockdown measures also impacted mortality, taking a toll on mental well-being and at times leading to detrimental behaviour such as substance abuse or physical violence. Some impacts were positive, however, with fewer fatalities from traffic accidents and other infectious diseases such as seasonal influenza. While the consequences of the pandemic are still being felt, its impact on mortality should nevertheless largely be temporary, and mortality levels are expected to normalise in the short term. Mortality assumptions used going forward should therefore reflect this expectation. However, there remains significant uncertainty around the long-term health impacts of COVID-19 and its effect on mortality. These effects will need to continue to be monitored to inform how they should affect mortality assumptions in the future.

Baseline mortality assumptions need to be representative of the population for which they will be used.

Baseline mortality assumptions, or the level of mortality for the base year excluding future mortality improvements, need to be based on data that is as similar as possible to the target population for which they will be used. Mortality levels vary significantly across population groups and the population(s) chosen to calibrate the model should reflect the characteristics of the target population. Populations of pensioners and annuitants tend to be skewed towards higher socio-economic groups, and therefore tend to have higher life expectancies than the population average. This selection effect represents around 2 to 2.5 additional years of life expectancy at age 65 on average in OECD member countries, and is therefore crucial to account for in the development of mortality assumptions.

Mortality improvements are essential to account for the expected increases in life expectancy over time.

Mortality improvements add an additional 1 to 1.5 years of life expectancy at age 65 on average, so are also crucial to take into account when assessing how long lifetime retirement incomes need to be paid. These assumptions should be based on a demographically stable population representative of the population to which they will apply. Mortality improvement assumptions are usually based on general population data, as there are often not sufficient data for pensioner and annuitant populations on which to accurately measure a long-term trend.

The model selected to project future mortality improvements should be compatible with future expectations, taking into account the trade-off between transparency and complexity. A variety of projection models are available, each of which demonstrates a range of advantages and drawbacks. Selection of the appropriate model will need to consider expectations regarding how mortality will evolve in the future and how to best match those expectations while aiming for parsimony.

The guidelines in this report can assist regulators and supervisors to develop and assess the appropriateness of mortality assumptions to ensure the sustainability of lifetime retirement income for pensioners.

The modelling of mortality and development of standard mortality tables involves a considerable amount of complexity and judgement at each step of the process. The guidelines included in this report aim to provide explanations regarding the implications of the different modelling choices available and their appropriateness for use in a particular context.

1 Longevity trends

Jessica Mosher

This chapter discusses recent trends in longevity in order to provide background and context to the discussion around the development of mortality assumptions and the modelling of mortality. It highlights the differences in patterns across population groups and presents evidence of the drivers of the high-level trends observed.

While the global gains in life expectancy over the last century have been impressive across the board, closer inspection reveals patterns that differ across countries, periods, genders, age groups, and socio-economic groups. Identifying these trends and their drivers can not only help to improve the modelling of mortality, but also help to identify circumstances that may shape these trends going forward and change future patterns relative to what has been observed in the past.

This chapter discusses recent trends in longevity in order to provide background and context to the discussion around the development of mortality assumptions and the modelling of mortality. The first section presents the high-level trends in life expectancy across countries and their drivers, and identifies some of the differences across countries, genders, and age groups. The second section looks at the trends in the distribution of life spans, which can provide richer insight into longevity patterns compared to looking only at life expectancy. The third section discusses trends in the inequalities in life expectancy within populations. The final section discusses the implications that these trends have for modelling future improvements in mortality.

1.1. Global trends and drivers of life expectancy improvements

Life expectancies in most OECD countries have been on a continuous upward trend since the mid-twentieth century. Since 1990 alone, males in OECD jurisdictions have gained on average 7.4 years in life expectancy at birth, and females 5.7 years (OECD, 2022[1]).[1] Gains at age 65 have also been impressive, at 4.1 and 3.7 years for males and females, respectively (OECD, 2022[2]). The large relative gain at older ages – upwards of a 20% increase at age 65 compared to less than a 10% increase at birth – are reflective of the acceleration of mortality improvements towards older ages observed in recent decades (OECD, 2014[3]).

OECD jurisdictions that previously lagged behind have gained remarkable ground over the last decades. In 1960, life expectancy at birth in Türkiye was well below 50, while that in South Korea and the current members from Latin America had life expectancies below age 60 (the exception being Costa Rica, where life expectancy was close to 60). This compares to a then-OECD average life expectancy of around 70. In 2019, life expectancy in South Korea exceeded the OECD average of 81, while Chile and Costa Rica fell just under the average.[2] Türkiye, while lower at 78.6, still gained more ground in total. Mexico started off in line with Chile and has also experienced large improvements, but following a stagnation in life expectancy since the 2000s finds itself a bit further behind, with a life expectancy at birth of around 75 (OECD, 2022[1]).

In addition to Mexico, there are a few other exceptions to the continuous upward trend for life expectancy. Denmark experienced a stagnation of life expectancy in the 1980s. The Czech Republic, Hungary, Poland, and the Slovak Republic only saw life expectancy start to improve substantially since the mid-1990s, while the Baltic countries of Estonia, Latvia, and Lithuania actually saw life expectancy decline in the 1970s, and again more substantially in the 1990s. More recently, the United States has also been experiencing a stagnation in life expectancy.

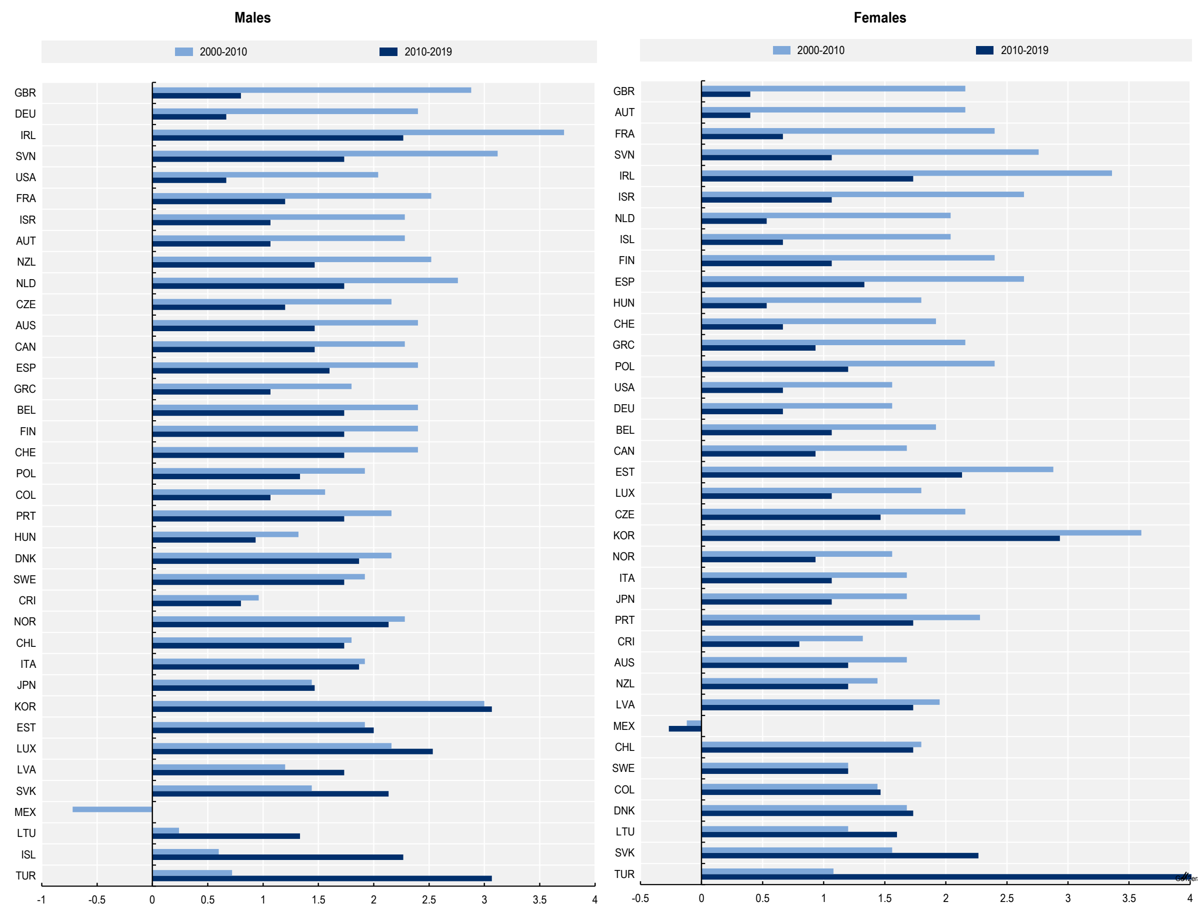
The drivers of these different trends across jurisdictions relate to medical, behavioural and societal factors. For most rich western countries, advances in the treatment of cardiovascular disease have been a main driver of the significant gains in life expectancy over the second half of the twentieth century. Health reforms in Chile contributed to it catching up with other developed countries, as did lower levels of infectious diseases in both Chile and Costa Rica (Alvarez, Aburto and Canudas-Romo, 2019[4]). In Denmark, stagnation in the 80s followed from a high prevalence of smoking (Rosenskjold and Kallestrup-Lamp, 2017[5]; Christensen et al., 2011[6]). Stagnation and decreases in life expectancy in the Central European and Baltic countries were due to these countries not being able to take advantage of the advances in cardiovascular medicine, and also experiencing high rates of deaths linked to accidents as well as smoking, alcohol and drugs (Meslé and Vallin, 2017[7]). Life expectancy significantly improved for these countries following the collapse of the Soviet Union, though in the Baltic States things got worse before they began to improve only in the mid-90s. The stagnation of life expectancy in Mexico is due primarily to high rates of violence and homicide, particularly among mid-life males. This problem contributes to the lack of convergence of life expectancy in Latin America towards that of other developed countries (Alvarez, Aburto and Canudas-Romo, 2019[4]; García and Aburto, 2019[8]). In the United States, the recent stagnation seems to be a result of cumulating trends of reductions in improvements from cardiovascular disease as well as a sharp increase in deaths related to liver disease, suicide and drugs (Chen, Munnell and Sazenbacher, 2017[9]; Case and Deaton, 2015[10]).

Even where life expectancy has not stagnated, smoking prevalence has a large influence on the observed longevity trends. Indeed, smoking can have a dramatic effect on the longevity improvements experienced for smoking cohorts. One study on a cohort of male British doctors showed that improvements in life expectancy accrued only to the non-smokers, with smokers effectively demonstrating zero improvements in mortality. Lifetime smokers had a life expectancy ten years lower than lifetime non-smokers, though this loss of life expectancy could be reduced by stopping smoking at earlier ages (Doll et al., 2004[11]). In the United States, observed cohort effects in mortality are largely attributable to controllable causes linked to lifestyle, and smoking in particular (Lourés and Cairns, 2019[12]). This demonstrates that the ongoing reduction in smoking prevalence can be expected to contribute significantly to improvements in life expectancy for the whole population.

Smoking prevalence has also been a key driver for gender differences in life expectancy. In most countries women took up smoking later than men, and so there is an observed lag in the effects this has had on their mortality. Females in the United States have experienced lower increases in life expectancy at age 50 since the 1980s, which is likely due in part to smoking, as deaths from lung and respiratory diseases have increased since then (Preston, Glei and Wilmoth, 2011[13]). The impact of smoking on mortality for men in the United States began to decline since the 1990s, whereas this occurred for women only a decade later (Chen, Munnell and Sazenbacher, 2017[9]). In addition to Denmark and the United States, smoking has also had a significant impact on female mortality trends in Canada (Preston, Glei and Wilmoth, 2011[13]). Similarly, high smoking rates for female cohorts born around 1925 have led to worse improvements in life expectancy in England and Wales since 1970 relative to 22 high-income countries (Leon, Jdanov and Shkolnikov, 2019[14]). These patterns have led to a reduction in the difference in life expectancy between genders in many countries, particularly at older ages.

More recently, a widespread slowdown in improvements has been observed in many Western countries, most notably since 2010-11. Among OECD jurisdictions, the largest slowdown in improvements in life expectancy at birth comparing the period 2010-19 to 2000-10 occurred in the United States, the United Kingdom, and Ireland for males, and Ireland, Estonia, and Iceland for females. At age 65, the largest slowdown occurred in the United Kingdom, Germany, and Ireland for males and in the United Kingdom, Austria, and France for females (Figure 1.1).[3] The slowdown has generally been stronger for females in absolute terms. A separate analysis by the Office for National Statistics in the United Kingdom looking at mortality experience from 2000 to 2016 showed slightly different results in terms of country ordering, but all results consistently show that the United Kingdom has experienced one of the strongest recent slowdowns observed internationally. In both the United Kingdom and the United States, the slowdown was most significant at ages 65-79, and the United States was the only country of 20 that actually experienced an increase in the age-standardised death rates for ages 40-64 (Office for National Statistics, 2018[15]).[4] For females in the United Kingdom, life expectancy at age 75 has even declined over certain periods (Hiam et al., 2018[16]). Most countries experienced a slowdown in mortality improvement for ages over 80, with the exception of Japan (Office for National Statistics, 2018[15]).

Figure 1.1. Annualised increase in life expectancy at age 65 in OECD jurisdictions (in months)



Note: For Latvia, the increase is shown for 2002-10 rather than 2000-10. The scale is truncated at four months.
Source: Own calculations based on data from OECD (2022[2]), "Life expectancy at 65, https://dx.doi.org/10.1787/0e9a3f00-en.

While the observed slowdown in most countries has occurred in the last decade, the slowdown in the United States began earlier. This seems to be mainly driven by an upward trend in the mortality of middle-aged whites since 1999, particularly ages 49-54 (Case and Deaton, 2015[10]). Total average mortality improvement in the United States was 1% over the period 1999-2018, but was only 0.2% over the period 2013-18 (Holman, MacDonald and Miller, 2020[17]).

Behavioural trends such as obesity are another factor in the slowdown of life expectancy improvement across countries. For example, in the United States the life expectancy gains from reduced smoking have largely already been realised by 2005, so rising obesity is now contributing to slowed improvements (Chen, Munnell and Sazenbacher, 2017[9]). Other countries can expect to follow this pattern as smoking rates have declined and obesity rates continue to grow (OECD, 2019[18]; 2017[19]).

Another key driver in this slowdown in many countries seems to be linked to reduced mortality improvements from cardiovascular disease. Improvements for cardiovascular disease have slowed by over 50% in many OECD countries compared to the previous decade (OECD/The King's Fund, 2020[20]). This is partly linked to the behavioural factors of increased obesity and diabetes, which would also offset some of the ongoing gains linked to reductions in smoking. Reduced improvements in circulatory disease have driven reductions in improvement for age 50-89 in the United Kingdom since 2011 (Office for National Statistics, 2018[21]). In the United States, improvements from heart disease have been falling since 2008 (Holman, MacDonald and Miller, 2020[17]).

At the oldest ages, dementia may be a factor in stalling improvements or even increasing mortality. Mental illness and dementia have contributed to the rising mortality for ages over 90 in the United Kingdom since 2011 (Office for National Statistics, 2018[21]). A 41.8% increase in mortality from dementia from 2001 to 2016 has resulted in a loss of 0.15 years of life expectancy at birth in British Colombia, Canada – a notable decrease at birth particularly as these deaths occur primarily in the oldest ages (Ye et al., 2018[22]).

Another worrisome trend is the increase in deaths due to drugs and suicide, the so-called 'deaths of despair'. This has been a major contributor to the stalling longevity improvement in the United States, and to a lesser extent also in Australia, Canada, Ireland, and the United Kingdom (Case and Deaton, 2017[23]). Through 2015, the mortality attributed to deaths of despair increased the most for Whites aged 45-54, and in particular women (Case and Deaton, 2017[23]). While some have attributed this trend to economic hardship and austerity following the Global Financial Crisis, particularly in Europe, the pattern of these trends has varied across countries and regions, and additional research is still needed to better understand the actual reasons behind them.

Drug overdoses have been a particularly harmful problem. In the United States, deaths from drug overdoses more than doubled between 2000-15, and more specifically deaths from opioid overdoses more than tripled. This has resulted in an overall loss in life expectancy at birth of 0.28 years, of which 0.21 years attributed to opioids (Dowell et al., 2017[24]). But older people are also affected. Ages 64-74 experienced the highest annual increase in opioid deaths in 2018, and this sharp increase extended to males aged 65-84 (Holman, MacDonald and Miller, 2020[17]). In British Colombia, Canada, increased drug overdoses over 2014-17 have reduced overall life expectancy by 0.15 years (Ye et al., 2018[22]). Over the period 2011-16, opioid-related death rates more than tripled in Türkiye, and more than doubled in the Czech Republic and Sweden (OECD, 2019[18]).

Suicides are also experiencing an upward trend in several countries, potentially linked to economic hardship and unemployment. In the United States, suicides have increased annually since 2006, even for older ages (Holman, MacDonald and Miller, 2020[17]). However, several studies demonstrate a link between economic hardship and increased suicides only for those under 65. In Europe, a 1% rise in male unemployment during the recession of 2007-11 implied a 0.94% increase in suicide, and a 1% increase in indebtedness increased suicides by 0.54%. These factors did not have a significant impact on suicides for ages over 65 (Reeves et al., 2014[25]). A longer study showed that a 1% increase in unemployment in the European Union between 1970 and 2007 was associated with a 0.79% increase in suicides below the age of 65. However, the strength of this association varied significantly by country and is even negative in some, and investment in labour market programmes had a mitigating effect (Stuckler et al., 2009[26]).

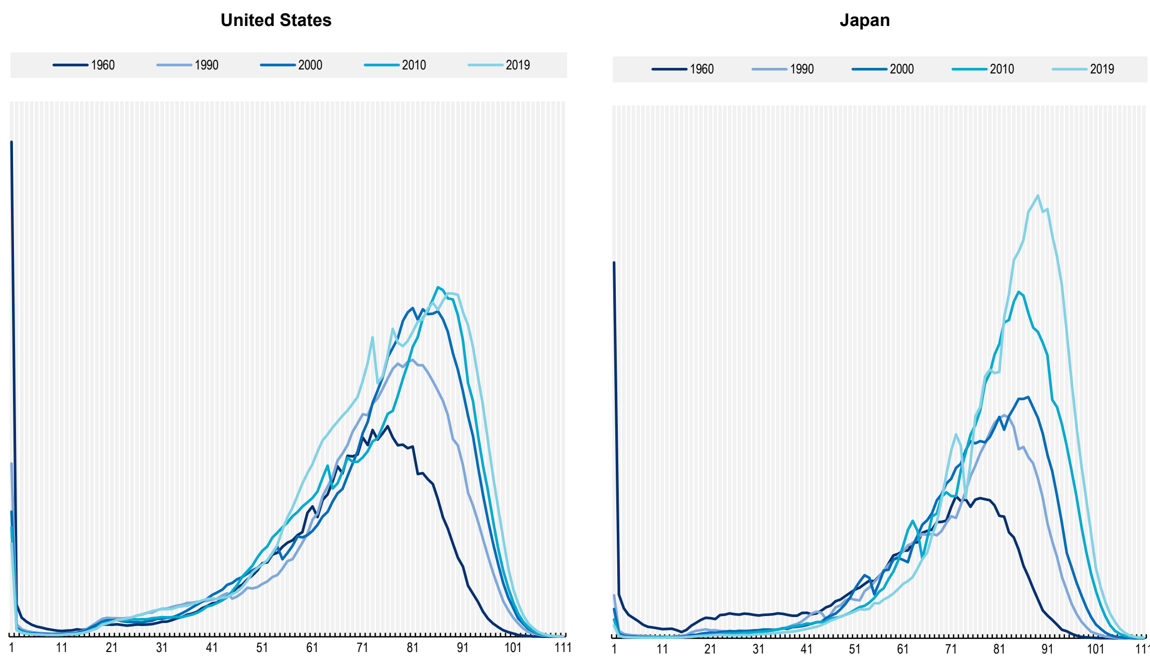
1.2. Patterns in the distribution of lifespans

The patterns of life expectancy and mortality improvements provide only part of the story of the evolution of longevity. The interpretation of changes in life expectancy is difficult, as it remains a summary measure reflecting the average, and is much more sensitive to the mortality at ages nearer to the age at which it is calculated. As such, life expectancy at birth is less sensitive to changes occurring at older ages. Combining life expectancy with analysis of mortality improvement by age can provide further insight as to changes by age, but this still provides an incomplete picture as to the distribution of mortality across ages.

Analysing changes in the distribution of lifespans is useful to complement an analysis of changes in average life expectancy and mortality as it can show how lifespans are converging and/or expanding to older ages for the whole population, not just on average. This can highlight age groups where high mortality may be particularly problematic (which is not observed with an average life expectancy figure), the extent to which people are increasingly living to very old ages in general and not only on average, and any tendency towards a reduction in lifespan inequalities, particularly in old age. A decrease in the variance of the distribution of lifespans indicates a decrease in lifespan inequalities, and a rightward shift of the distribution shows that more people in the whole population are living longer.

To aid in the visualisation of these patterns, Figure 1.2 shows the distribution of lifespans in the United States and Japan in selected years between 1960 and 2019. In both countries, there has been a massive reduction in infant and child mortality since 1960, and a dramatic improvement in adult mortality in Japan. The surprising increase in deaths in the United States for many ages under 70 could potentially be linked to the opioid crisis, but part of this increase is also likely linked with the high numbers of baby boomers that would result in higher deaths regardless, as these distributions do not adjust for population composition. Both countries also demonstrate a shift in the mode of the distribution to higher ages each consecutive year, showing that more and more people are living to older ages. There is also a rightward shift in the distributions themselves, particularly in Japan, showing that the maximum age that people are living to continues to increase.[5] The remarkable difference between these two graphs is that the distribution narrows significantly more in Japan around the modal age at death, whereas the distribution of deaths in the United States demonstrates higher variance, an indication of higher longevity inequalities.

Figure 1.2. Distribution of the age at death, 1960-2019



Note: Distributions are not adjusted for population composition, and the maximum age is capped at 110.
Source: Data from the Human Mortality Database: www.mortality.org.

Demographers have coined several terms for these types of observations. The most notable of these terms are: rectangularisation, or the convergence of lifespans to a single maximal age; compression, or the reduction in the variance around the modal age at death; shifting/delay, or the increase in the modal age at death; and extension, or an increase in the maximal age. Rectangularisation implies a limit to life expectancy, while extension implies that ultimate ages are still being pushed upward. Compression and rectangularisation both imply a reduction in longevity inequalities. Shifting would generally be expected to coincide with increasing life expectancies.

However, these terms can be vague and are at times conflicting definitions of these phenomena. Following this observation, Borger et al. (2018[27]) developed a framework to define and calculate the indicators in a precise manner that allows for the identification and classification of the trends observed over time. These indicators explain more precisely the phenomenon being observed, and allow for any combination of patterns:

- Shift – increase/decrease of the modal age at death
- Extension/Contraction – increase/decrease of the upper bound of the death curve
- Compression/Decompression – increase/decrease in the difference of the area between the actual distribution and a flat distribution (i.e. degree of inequality)
- Concentration/Diffusion – more/fewer deaths around the mode

Application of this framework to 34 countries shows some interesting patterns (Genz, 2017[28]). The modal age at death began its upward trend from the 1970s for the majority of countries, except for several countries in Eastern Europe where this trend only started in the 1990s. Countries have differed more substantially as to when the upper bound of the death curve began to increase. Regional patterns with respect to the upper bounds of the curve are less clear, but most countries have been experiencing an increasing trend since the 1990s. Most countries have also experienced mortality compression since 1920, though there are a number of exceptions, and much of Eastern Europe was neutral or in decompression over the 70s and 80s. Similar patterns are observed for the concentration around the mode. However, when conditioning on survival to age 60, most countries do not experience compression until around the 90s and many Eastern countries demonstrate neutral or decompressing patterns.

Another study looks to analyse more closely the point at which countries transition from a period of compression (decreased variance, in this case) towards a period of mortality delay (i.e. an increase in the modal age at death) (Janssen and de Beer, 2019[29]). It finds that this transformation occurs in stages. The first stage is a compression resulting from reduced mortality at young ages. Compression then slows down because gains at early ages have been largely realised. Delay then becomes the main trend as modal age increases and compression affects different age groups in different ways until delay dominates as adult mortality significantly declines and decompression occurs because of mortality improvements for old ages. The authors find this transition occurred for females nearly a decade earlier than for males, likely due in part to different smoking patterns between genders. The United States was the first to transition from 1950, followed by Northern and Western Europe from the mid-50s through the 60s and Southern Europe in the early 70s. For Eastern Europe, the transition only began in the 90s and is still ongoing.

1.3. Trends in longevity inequalities

The extent to which the distribution of lifespans is compressing or decompressing can also indicate to what extent longevity inequalities exist for a population. If there were no inequalities, everyone would die at the same age. Compression of mortality with more deaths around the modal age implies a reduction in longevity inequalities.[6]

Looking across the entire lifespan, inequalities have decreased in most of the world as life expectancies have increased. This has mainly been driven by the sharp reductions in infant and child mortality, meaning that the left tail of the distribution has been shrinking (Permanyer and Scholl, 2019[30]).

However, this picture changes when truncating the distribution to exclude the younger ages. Reductions in inequality have been much slower when focusing only on adult mortality, and has even increased in Central Asia during the 1990s. When looking only at ages over 65, lifespan inequalities have actually increased in all countries and regions. Latin American countries have among the highest levels of inequalities at older ages by this measure (Permanyer and Scholl, 2019[30]).

Furthermore, the evolution of the distribution of lifespans has not been the same for all groups of the population. Significant inequalities exist across socio-economic groups within countries, and the reduction in the variance of lifespans has occurred primarily for the most advantaged groups. In Finland, the lifespan variation has been stagnant for manual workers while decreasing for non-manual classes (van Raalte, Martikainen and Myrskylä, 2013[31]). In the United States, the lifespan variability has increased for high school educated whites (Sasson, 2016[32]). Higher variation in lifespans for less affluent groups is also observed in Denmark (Alvarez et al., 2020[33]).

The relationship between increasing inequalities and increasing life expectancies is not always intuitive. Improvements in mortality beyond a certain threshold age mechanically increase inequality, as they extend the distribution of lifespans to the right. Indeed, higher mortality improvements at older ages have partly driven the increases in inequality since 1960, particularly in Eastern and Central European as well as Nordic countries, where mortality patterns have differed significantly by age (Aburto et al., 2020[34]). However, the threshold age also increases along with life expectancy, so the age dynamics and link between life expectancy and lifespan equality can change over time.

In order to better understand the implications of longevity inequalities for different population groups, in particular across socio-economic groups, it is necessary to also look at the trends in mortality rates and life expectancy of these groups. Variability in the lifespan can only provide an indication that inequalities may exist, however this cannot explain to what extent inequalities across specific groups translate into differences in average lifespans.

One of the largest challenges in assessing trends in life expectancies across socio-economic groups – apart from a lack of data – is identifying definitions for the groups that correlate strongly with differences in life expectancy. Socioeconomic indicators used include education, occupation, income, wealth, and other economic indicators of relative disadvantage. Box 1.1 discusses the advantages and disadvantages of various definitions to assess longevity differences across socio-economic groups over time.[7]

By many measures, differences in life expectancy across socio-economic groups have widened over time. Those in the higher educational quartile in the United States have experienced higher mortality improvements over the last century (Chen, Munnell and Sazenbacher, 2017[9]). Considering absolute levels of education, mortality rates for the White population without a college degree have actually increased in more recent years, while mortality continues to decrease for those with a college degree and for the Black and Hispanic populations (Case and Deaton, 2017[23]).

Increases in the difference in life expectancy across occupational groups has occurred in England and Wales, in France, and in the Netherlands though there are some differences in this pattern across genders. In England and Wales, differences in life expectancy at birth across occupations has increased over the period 1982-86 to 2007-11 by 1.1 years for males and 1.5 years for females, though the difference has declined for males since 1997-2001 (Office for National Statistics, 2015[39]). In France, a divergence across occupational groups has been observed for males over the period of 1980 to 2011, though the difference across groups remains more stable for females (Insee, 2016[40]). Data for Dutch Olympic athletes over the period 1900-2012 indicates that the differences in life expectancy between low and high socio-economic groups, as measured by their occupations before or after the Olympic Games, has increased for subsequent birth cohorts (Kalwij, 2019[41]).

Box 1.1. Socioeconomic indicators for assessing longevity trends

Educational attainment is the most common indicator available to assess differences in mortality across socio-economic groups. It has the benefit of being a clear measure that is determined early in life, and is also a widely available statistic. Nevertheless, most countries have experienced a large compositional shift in the level of educational attainment of their population, making education a poor measure to assess relative disadvantages over time. As fewer people now have very low levels of education, those who do are likely to be more disadvantaged today than they might have been a few decades ago. Some studies have nevertheless overcome this barrier by assessing changes in life expectancy of different groups based on relative educational attainment rather than absolute measures.

Occupation is another indicator linked to socio-economic groups that statistical agencies commonly collect. This measure has the advantage of having a direct influence on the day-to-day physical environment as well as social and behavioural factors that can be associated with different mortality levels. Nevertheless, categorisation can be a challenge, particularly for intermediate groups. While there tends to be a clear difference in life expectancies between those in manual work and those having managerial roles, the hierarchy of occupation and mortality is less clear, for example, for agricultural workers or small employers. In addition, occupation can change over the lifetime, making classification for assessing trends more difficult.

Income is more directly related to socio-economic status than either education or occupation. Lifetime income is likely to be a better indicator of socio-economic status than income at a single point in time, as it is less affected by temporary changes to an individual's situation.

Wealth is arguably better at capturing the socio-economic status by household, and tends to be a more stable measure. However, it is rather difficult to measure and data on wealth linked to mortality is not widely available. In England, some studies have found wealth to be a better predictor of mortality than other commonly used measures, likely due to the fact that it better reflects an accumulation of disadvantage over time (Demakakos et al., 2015[35]).

Several researchers have sought to overcome the shortcomings of individual measures by using indices combining multiple measures of socio-economic status. Cairns et al. (2019[36]) developed an 'affluence index' combining income and wealth measures for the Danish population. This composite index demonstrated much higher predictive power than either wealth or income measures alone, particularly for higher mortality groups. In England, the regularly published Index of Multiple Deprivation provides an alternative basis for classifying socio-economic status. In addition to income and education, this index includes indicators for employment levels, crime, health, barriers to housing and services, and living environment for small geographic regions. Wen (2019[37]) finds that income, unemployment, average number of bedrooms, housing quality, crowding, education, and rural areas are particularly relevant for assessing differences in mortality.

Note: The OECD Business and Finance Outlook (2016[38]) assesses evidence of the differences in life expectancy for each of these indicators.

Income and wealth measures show increasing disparities for adult and older adult mortality in Canada, Finland, Denmark, and New Zealand. In Canada, inequalities across pension levels over the period 1990-2016 have increased particularly for ages 65-75 (Wen, Kleinow and Cairns, 2020[42]). In Finland, the gap in life expectancy at age 35 between the lowest and highest income quintiles increased by 5.1 years for men and 2.9 years for women over the period 1988-2007 (Tarkiainen et al., 2011[43]). In Denmark, improvements over the period 1985-2012 have been largest for the most affluent and at younger ages, with the gap in life expectancy at age 67 between the highest and lowest affluence deciles increasing by

1.3 years for men. However, the lowest group did improve at a slightly faster rate than the adjacent lower groups (Cairns et al., 2019[36]). Observations were slightly different for females, however, with the decline in life expectancy largest for the low-middle and middle socio-economic groups, who contributed most to the stagnation of life expectancy. The lowest groups actually experienced large positive improvements at ages 80-95 (Rosenskjold and Kallestrup-Lamp, 2017[5]). In New Zealand, the difference in life expectancy at age 65 between highest and lowest tertile of income increased by 1.5 years for males and 1.1 years for females between 1981 and 2001 (Carter, Blakely and Soeberg, 2010[44]).

Consistent with other studies on England and Wales, analysis based on other indicators of disadvantage also show a widening of differences in life expectancies across socio-economic groups. Assessing mortality based on the Index of Multiple Deprivation, which includes among others regional employment and housing indicators, finds that differences in life expectancy across the top and bottom deciles have increased over 2001-17 (Wen, Cairns and Kleinow, 2020[45]).

While relative inequalities have increased over time, there is also some evidence that absolute inequalities in age-standardised mortality rates have decreased. This was the case over the period 1990-2010 for Finland, Norway, Sweden, Scotland, England and Wales, France, Switzerland, Spain (Barcelona), Italy (Turin), Slovenia, and Lithuania based on measures of education and occupation (Mackenbach et al., 2016[46]). In Japan, absolute inequalities have decreased for both genders, while relative inequalities have increased only for specific sectors, such as male service workers (Tanaka et al., 2017[47]). Similarly, in Canada absolute differences between the highest and lowest income quintiles decreased significantly for males over the period 1991-2011, though they seem to have increased since 1996 for women. The difference in relative terms increased significantly for both genders over the period (Marshsall-Catlin, Bushnik and Tjepkema, 2019[48]).

The composition of the population may affect the extent to which differences across socio-economic groups are observed, depending on the socio-economic indicator used. There is some evidence of a ‘healthy immigrant effect’, where the immigrant population tends to be in better overall health relative to the average native population. The typical measures of socio-economic status may not accurately capture these differences. For example, in Canada a study of the mortality in the CPP and QPP based on pension levels shows that the mortality of the lowest group of males eventually becomes lower than the mortality of the middle groups, and the CPP demonstrates lower levels of inequality than the QPP. One reason for this could be the higher levels of immigration outside of Quebec. The pension level of immigrants would not necessarily be reflective of their socio-economic status, as they may be entitled to a lower pension simply because they have contributed for less time (Wen, Kleinow and Cairns, 2020[42]). The healthy migrant effect is also observed in Barcelona, Spain. Despite the stabilised socio-economic inequalities in mortality in the Spanish-born population, one study found no inequalities between neighbourhoods for foreign-born men and women (Rodríguez-Sanz et al., 2019[49]).

1.4. Drivers of longevity inequalities

The drivers of these longevity inequalities are largely the same as the drivers of the observed slowdown in increases in life expectancy in many countries, and are primarily due to deaths that could be avoided. Avoidable deaths can be classified into two overlapping categories of preventable and amenable deaths. Preventable deaths are those that can be linked to controllable factors. These include deaths related to smoking, alcohol, drugs, obesity, and suicide. Amenable deaths are those that could be effectively treated with the appropriate health interventions. The majority of these types of deaths in the OECD and Europe are linked to cardiovascular disease (OECD/European Union, 2018[50]).

Amenable causes of death are one factor increasing longevity inequalities across socio-economic groups. Those with higher education have experienced faster relative mortality declines for amenable causes of death than those with low education in Europe over the period 1980-2010 (Mackenbach et al., 2017[51]).[8]

Increased health expenditure has been successful in stabilising absolute inequalities, however, and improvements in mortality from cerebrovascular disease have actually contributed to reductions in inequalities in Japan (Mackenbach et al., 2017[51]; Tanaka et al., 2017[47]).

The amenable drivers of mortality inequalities tend to also be largely preventable. The slowdown of mortality improvements for cardiovascular diseases is partly due to risk factors such as increased obesity and diabetes, which can have more impact on disadvantaged groups of the population, resulting in large inequalities in cardiovascular deaths (OECD/The King's Fund, 2020[20]).

Indeed, preventable deaths seem to be the largest contributing factor to longevity inequities. Risk factors linked to preventable deaths tend to be correlated with socio-economic position (Chen, Munnell and Sazenbacher, 2017[9]; Demakakos et al., 2015[35]). In England and Wales, excess mortality inequalities linked to causes of death with controllable risk factors has been growing since 2001, linked to a widening gap in the prevalence of factors such as smoking, alcohol, unhealthy diet and low physical activity. Limited inequalities are observed for causes of death with no obvious controllable factors (e.g. breast and prostate cancer) (Cairns, 2019[52]). In Finland, growing inequalities are a result of a stagnation in improvements for the lowest income groups due especially to alcohol-related deaths, but also cancer deaths (particularly lung cancer) and slower declines from heart disease (Tarkiainen et al., 2011[43]). Deaths linked to smoking contributed to the slowdown in life expectancy improvements for less affluent females in Denmark (Rosenskjold and Kallestrup-Lamp, 2017[5]).

Drugs are also a preventable driver in life expectancy inequalities. Drug overdoses are a major contributor to widening inequality among Whites in the United States, with opioids accounting for a significant part of this for ages between 25 and 64 (Geronimus et al., 2019[53]). Deaths due to drug overdoses are three times higher for low socio-economic groups compared to high socio-economic groups in British Colombia, Canada (Ye et al., 2018[22]).

While accidents and suicides have been a driver in the overall slowdown increases in life expectancy, they do not appear to be a major factor for increasing inequalities in all countries. Suicide has been a main driver of widening inequalities in Japan for some groups, but it does not seem to be a big contributor to inequalities in the United States (Geronimus et al., 2019[53]; Tanaka et al., 2017[47]). To the contrary, lower rates of homicide and accidents among Blacks in the United States have contributed to the narrowing of the gap in life expectancy between Whites and Blacks (Geronimus et al., 2019[53]).

1.5. Implications of the observed trends for modelling mortality

Understanding the trends in mortality and life expectancy is important to inform decisions regarding the selection and calibration of the model used to determine mortality improvement assumptions. An analysis of past trends can aid in determining the appropriate period over which to calibrate the model to reflect the current and ongoing patterns, and to what extent these patterns will continue in the near term. An analysis of the drivers of these trends can provide a rationale for longer term expectations regarding an acceleration or deceleration of life expectancy improvement.

Historical patterns in mortality are driven by the political and societal contexts, and large changes can result in breaks in the trend that should not be included for the purpose of modelling current expectations of future mortality. For example, the fall of the Soviet Union had a dramatic impact on the trend in life expectancy of Eastern European and Baltic countries. Including data before the 1990s to calibrate a model would therefore result in a significant underestimation of the potential improvements in life expectancy going forward. Including periods of stagnation, such as that observed in Denmark in the 1980s, can also lead to an underestimation of improvements to the extent that the patterns in the drivers of stagnation change. Life expectancy improvements accelerated again in Denmark as the rates of smoking declined.

Patterns in the distribution of lifespans and the extent to which it continues to move rightward can inform expectations as to whether mortality improvements will continue, in particular at high ages. Observations of continued mortality delay and extension combined with limited compression of mortality at old ages indicates that life expectancy will continue to increase, as will the maximum age of survival. The fact that improvements in life expectancy are accelerating again in Japan – who currently has the highest life expectancy in the world – support this hypothesis, as do the continued higher gains in life expectancy for higher socio-economic groups relative to disadvantaged groups.

The rapid increase in life expectancy of less-wealthy nations demonstrates that those currently behind can be expected to catch up with the right conditions. Reductions in infant mortality and deaths from amenable diseases has been a key driver of the dramatic improvements observed in countries such as Chile, Korea and Türkiye, though violence has in some cases tampered the positive effects from improved health, as it has in Mexico.

Nevertheless, the recent slowdown in mortality improvements observed in many countries raises the question as to whether improvements will be lower in the near and longer term. There are many opposing drivers of this trend that could result in a continued slowdown or a return to the trend observed over the past decades. Continued reductions in smoking will contribute to mortality improvements. However, this may be offset by rising obesity, a large risk factor for cardiovascular disease and a key explanation for slowed improvements for this cause of death. Nevertheless, medical advances in the treatment of cancer, HIV, and hepatitis, among others, could boost improvements from other significant causes of death.

Changes in the behavioural trends that are driving both the slowdown in mortality improvements and the increasing inequalities over time will be a key factor determining whether these patterns continue. Preventable deaths linked to smoking, alcohol, drugs, unhealthy diet and low physical activity seem to be driving the increased inequalities at the heart of the slowdown in life expectancy improvements. Reductions in these harmful behaviours, particularly for low socio-economic groups, could be expected to lead to a reduction of inequalities and a return to the 'normal' trend going forward for all groups of the population.

However, the COVID-19 pandemic does not bode well for an improvement in these controllable risk factors driving inequalities. Lockdown measures have increased economic hardship and exacerbated mental illnesses that could perpetuate 'deaths of despair'. It has also introduced many uncertainties regarding the long-term impact on the mortality of COVID-19 survivors. The next chapter will explore in more detail both the direct and indirect effects that COVID-19 has had on mortality.

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Notes

[1] Through 2019, excluding Latvia for whom the historical data series is not complete over this period.

[2] Average life expectancy is not weighted by populations.

[3] Calculated as an annualised change in life expectancy during the specified periods based on OECD statistics, not standardised for population changes.

[4] The ONS analysis is based on data from the Human Mortality Database (HMD) and compares improvements in life expectancy over the most recent six years compared to the previous six years.

[5] However, this graph caps the age at death to 110, so does not provide a true picture of the maximal ages reached.

[6] Many studies use the Theil index and Gini coefficient to measure lifespan inequalities, but this chapter focuses on the high-level trends and does not enter into the technical discussion of how to measure inequalities.

[7] Previous reports (e.g. OECD (2016[38]) and OECD (2018[54])) have firmly established the existence of differences in life expectancy across socio-economic groups. This chapter focuses only on how these differences may have changed over time.

[8] This study covered Austria, Belgium, the Czech Republic, Denmark, England and Wales, Estonia, Finland, France, Hungary, Italy, Lithuania, Norway, Poland, Slovenia, Spain, Sweden, and Switzerland.

2 The impact of the COVID-19 pandemic on mortality

Jessica Mosher

This chapter focuses specifically on the impact that the COVID-19 pandemic has had on mortality, and how it could affect mortality going forward. The direct impacts on mortality have varied across demographic groups. The response to the pandemic has had indirect effects on mortality relating to health care access, lockdown measures that governments have imposed, and broader social consequences.

The COVID-19 pandemic has been one of the largest shocks to longevity in recent history. The immediate death toll from the virus itself has been significant, but people have also suffered indirect consequences of the pandemic. These have included impacts to health care access and the effects that lockdown measures had on personal well-being and behaviour. Hospitals that were overwhelmed with COVID-19 patients could not always provide needed care for individuals with other illnesses, while the fear of catching COVID-19 may have also led individuals not to seek needed medical care at all. Lockdown measures took a toll on personal well-being, with negative consequences manifesting themselves through substance abuse, declines in mental health, and violence. Nevertheless, it also resulted in some behavioural changes that were positive for mortality, such as less driving and better hygiene. In the long term, the impact on mortality is much more uncertain. There could be additional impacts for those who have been exposed to the virus, or potentially negative consequences on mortality linked to the shifting social and political trends emerging in the wake of the pandemic.

Understanding the broad impact that the COVID-19 pandemic has had on mortality is important in order to inform the setting of mortality assumptions for both current mortality and future mortality improvements. This chapter looks at the wide-ranging impacts that COVID-19 has had on mortality, focusing on the peak years of the pandemic in 2020 and 2021, and considers the effects that we may continue to observe going forward. The first section investigates the short-term impact of the pandemic on mortality. It looks at the direct impact of the COVID-19 virus on mortality and how the impact has varied across different groups of the population. It also considers the indirect effects that the response to the pandemic had, in particular relating to health care and the lockdown measures that governments have imposed. The second section discusses the potential implications for mortality in the longer term. It considers the possible long-term consequences on mortality from the virus itself. It also discusses the potential indirect effects that could be felt from social and political shifts. The chapter concludes with a discussion of the implications that these impacts have for the development of mortality assumptions to be used going forward.

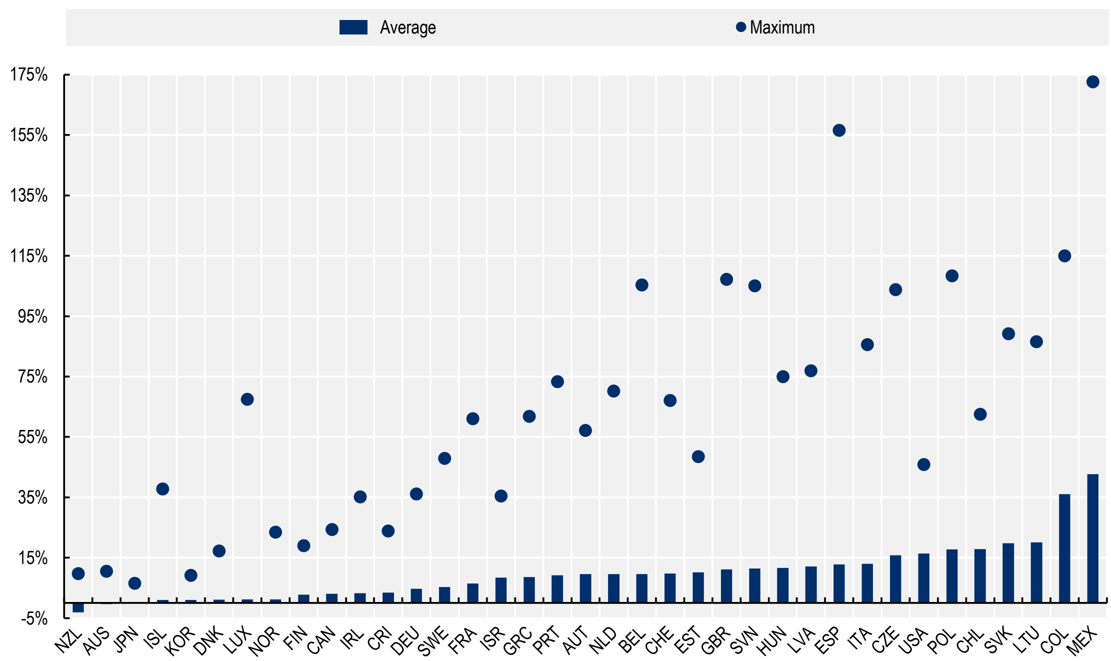
2.1. The short-term impact of COVID-19 on mortality

The first two years of the COVID-19 pandemic cost 5.5 million lives globally (The Economist, 2022[1]).[1] However, this figure does not accurately reflect the total number of lives that the pandemic took during that time. The official count includes only the deaths where the individual tested positive for the virus, or in some countries where the individual demonstrated a probable infection, yet the deaths of many more individuals who were never tested or suspected of being infected can likely be attributed to COVID-19. In addition, this figure ignores the indirect impact that the pandemic has had on mortality, due for example to reduced access to health care or the negative consequences that lockdown measures had on well-being.

To capture the real death toll of the pandemic, a more useful figure is the level of excess mortality experienced. Excess mortality measures the level of mortality experienced compared to what otherwise would have been expected, with expectations normally based on the average experience over recent years. As this figure accounts for all deaths experienced during the pandemic, it captures both the deaths directly related to the virus as well as the indirect effects the pandemic has had on mortality. While many of these indirect effects have likely resulted in additional deaths, there has also been some positive impact, such as the reduction of traffic accidents and improved hygiene, which would serve to offset the total mortality cost of COVID-19.

On a global scale, excess mortality figures present a significantly grimmer picture of the lives lost from COVID-19 than the official numbers indicate. One estimate puts global excess deaths at 19.2 million in 2020 and 2021, more than three times the level of officially reported COVID-19 deaths (The Economist, 2022[1]). Few countries were spared. Figure 2.1 shows the average percentage of weekly excess deaths and the maximum weekly excess deaths experienced in OECD countries over the period from January 2020 to December 2021. The average excess mortality across OECD jurisdictions over the period was just under 10%, with the average maximum excess during any week at 62.5%.[2] Nevertheless, several countries managed to keep excess deaths during the pandemic to a minimum. New Zealand and Australia experienced fewer deaths on average during the pandemic than expected in normal times due to their zero-COVID-19 policies, and Japan, Iceland, Korea, Denmark, Luxembourg, and Norway managed to keep average excess deaths under 1.5%. The relative severity of the pandemic waves differs across countries, with some like Spain experiencing significant spikes, while in others such as Israel the peak in mortality was more moderate. At the right end of the figure, the heavy death toll of the pandemic can be observed in Latin America, particularly in Colombia and Mexico where the average weekly excess mortality exceeded 35%, and the worst wave caused excess mortality of over 160% in Mexico.

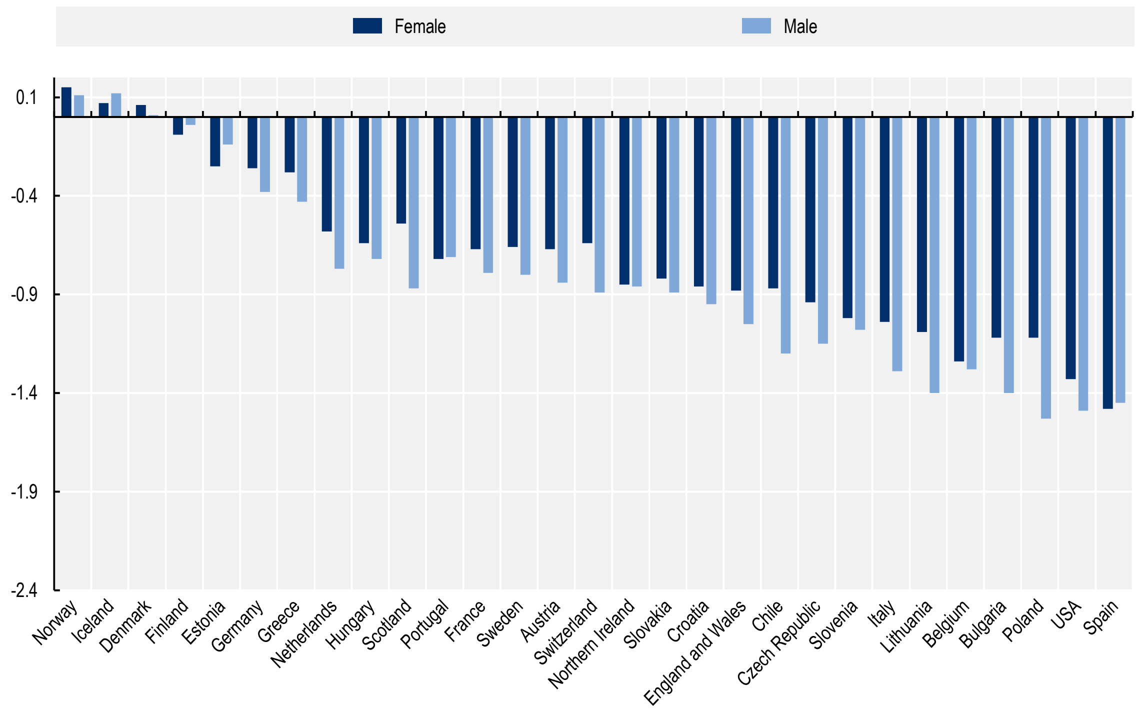
Figure 2.1. Weekly excess mortality during the COVID-19 pandemic, 2020-21



Note: From January 2020 through December 2021 or latest available data. Before 20 September 2021, expected deaths based on the average deaths over 2015-2019. After September 2021, expected deaths calculated based on an extrapolation of a regression over the same period. Average excess mortality calculated as a simple average across weekly reported data for each country.
Source: Adapted from Giattino et al. (2022[2]), *Excess mortality during the Coronavirus pandemic (COVID-19)*, https://ourworldindata.org/excess-mortality-covid.

The excess mortality experienced over 2020 led to a significant reduction in period life expectancy in most jurisdictions. Figure 2.2 shows the change in period life expectancy at age 60 in 2020 compared to 2019 in selected jurisdictions. The results are broadly consistent with the observed total excess mortality, with all jurisdictions shown experiencing a decline in life expectancy except Norway, Iceland, and Denmark, who all experienced very low levels of total excess mortality. In most jurisdictions, males suffered a larger drop in period life expectancy than females, in line with observations that men had a higher mortality risk from COVID-19. Polish males observed the largest decline in period life expectancy in 2020, losing 1.5 years for men, followed by US males and Spaniards of both genders for whom the observed decrease was over 1.4 years.

Figure 2.2. Change in period life expectancy at age 60 in 2020 compared to 2019



Note: Period life expectancy describes the mortality experience of a specific year, and does not take into account future expectations of mortality.
Source: Adapted from Aberto et al. (2021[3]), *Quantifying impacts of the COVID-19 pandemic through life-expectancy losses: a population-level study of 29 countries*, https://doi.org/10.1093/ije/dyab207.

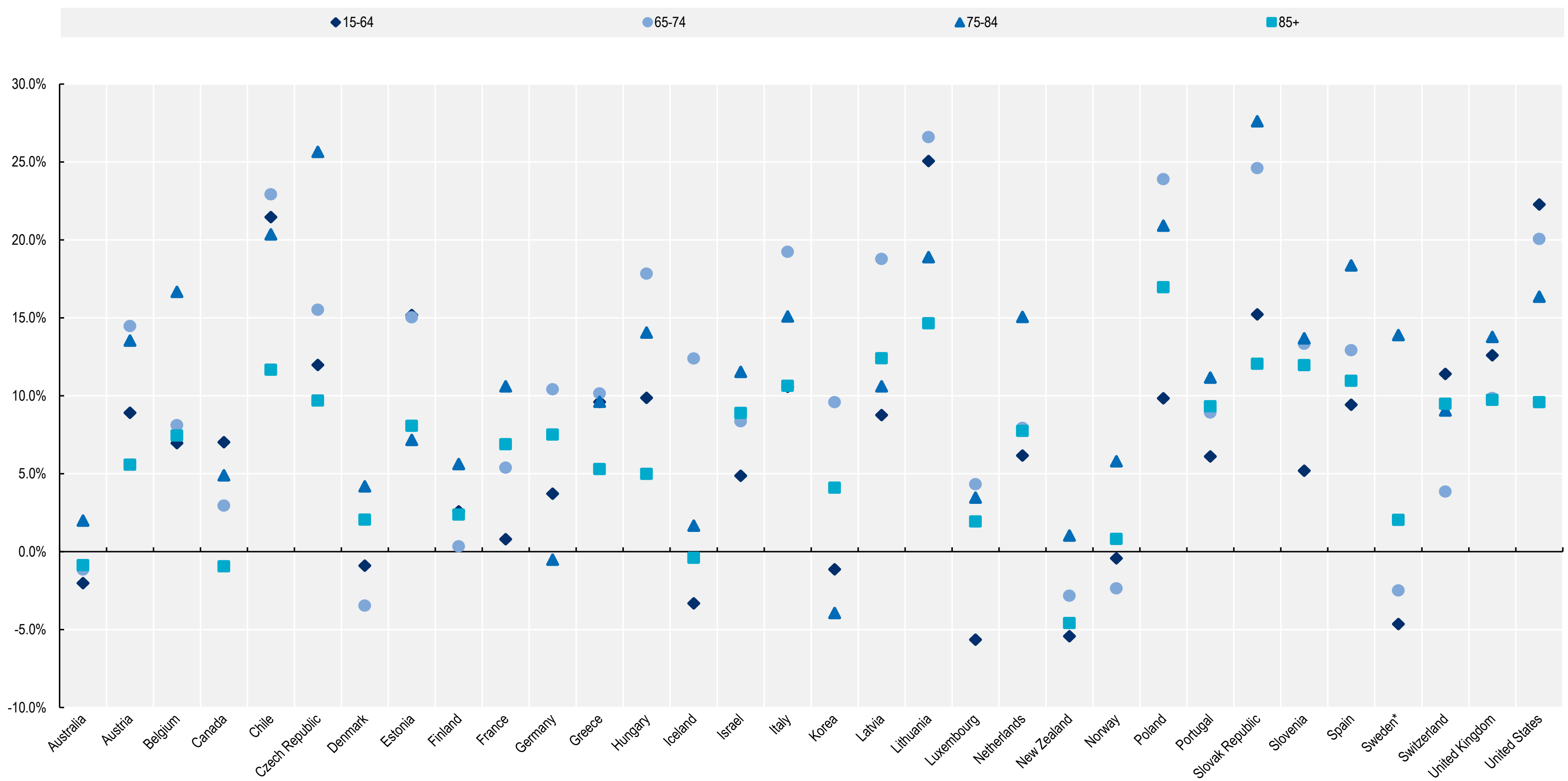
Declines in life expectancy largely continued in 2021, though to a lesser extent. Globally, one study estimates that life expectancy declined by 0.92 years in 2020, and by an additional 0.72 years in 2021, though declines appear to have stabilised towards the end of 2021. Nevertheless, there were differences in trends across countries, with some countries recovering some of the life expectancy lost, and some experiencing even larger declines during the second year of the pandemic (Heuveline, 2022[4]).

Nevertheless, these estimates do not take into account future trends in mortality, and only capture the impact that COVID-19 had on mortality during a single year. The impact on cohort life expectancies – accounting for mortality improvements and a return to 'normal' levels of mortality – would be substantially smaller, even insignificant. For example, Figure 2.2 shows that period life expectancy for Dutch males aged 60 fell by 9.24 months (0.77 years). However, assuming that excess mortality continues only through 2020-2022, the impact on cohort life expectancy is only 15 days (0.5 months).[3]

Within countries, different age groups did not experience the same relative magnitude of excess mortality. The differences observed across age groups may provide an indication as to what extent indirect effects may have had a disproportionate effect on some age groups. For example, the youngest age group may have experienced a net reduction in mortality because of fewer deaths caused by traffic accidents. Other age groups may have modified their behaviour more, such as by being stricter with social distancing. Additional explanations for observed differences across age groups could be differences in access to health care or testing.

Figure 2.3 shows the excess mortality experienced during the pandemic by age group. Those aged 15-64 experienced negative excess deaths in several countries, indicating that positive indirect effects on mortality may have outweighed the negative impact of the COVID-19 virus. Surprisingly, those aged 85 and over did not experience the highest excess mortality in any jurisdiction, and in some countries such as the United States experienced substantially lower excess mortality than other age groups. In the United States, those aged 15-24 actually experienced the highest levels of excess mortality (Leavitt, 2021[5]). The age group 75-84 was the most severely impacted in half of the jurisdictions shown. The relative impact for different age groups has also changed over time. In the United Kingdom, for example, excess deaths for ages 45-64 were somewhat higher in 2021 compared to 2020 (Continuous Mortality Investigation, 2021[6]).

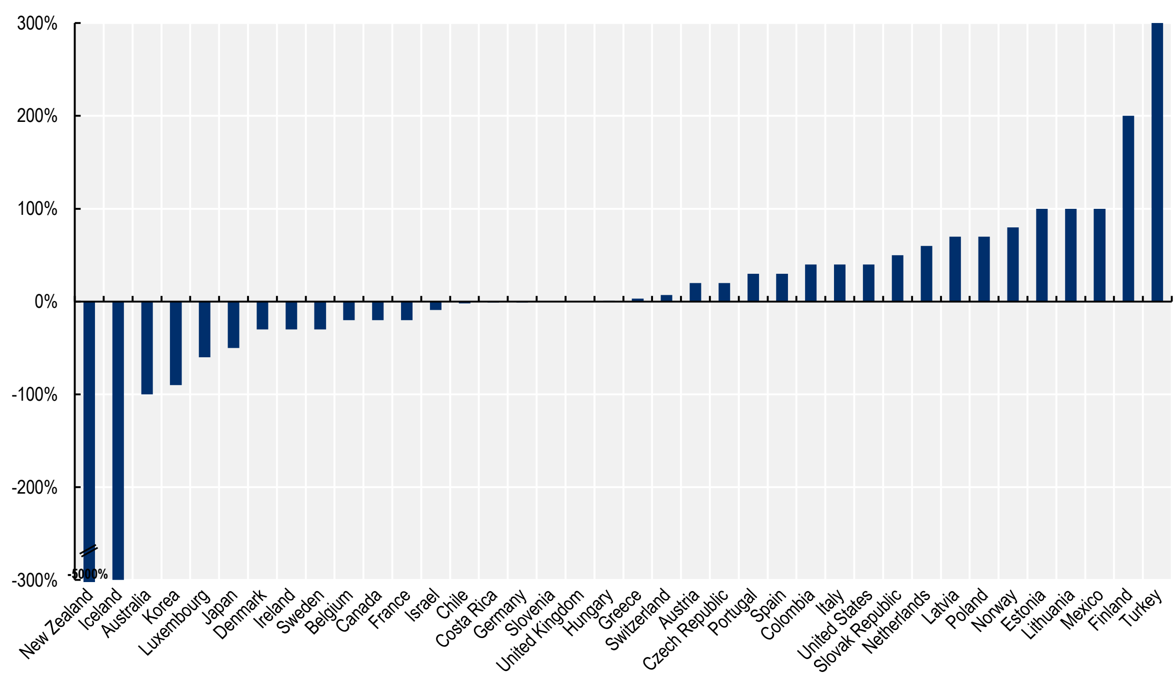
Figure 2.3. Average weekly excess mortality during the COVID-19 pandemic by age group



Note: From January 2020 to December 2021 or latest data available as of 14 January 2022, except Sweden where data is that available as of August 2021. In 2020, Mexico (not shown) experienced 61% excess mortality for ages under 65 compared to 65% for ages over 65 (Gobierno de México, 2021[7]).
Source: Adapted from Giattino et al. (2022[2]), *Excess mortality during the Coronavirus pandemic (COVID-19)*, https://ourworldindata.org/excess-mortality-COVID-19.

It is not easy to distinguish between the deaths caused directly by the COVID-19 virus, and those resulting from the indirect effects of the pandemic. The gap between the COVID-19 deaths officially reported and the observed excess mortality can provide some indication of the indirect cost of lives, as shown in Figure 2.4. Countries on the right side of the figure experienced higher excess mortality than officially reported COVID-19 deaths. While this could indicate that some of the indirect effects of the pandemic have had a negative effect on mortality, this would also capture any of deaths that were from COVID-19 but not reported as such. On the left side of the figure, several countries experienced lower total excess deaths than the number of COVID-19 deaths officially reported. This would capture deaths that were classified as being due to COVID-19 because of a recent positive test result, but were actually due to other causes. This could also indicate that indirect impacts such as behavioural changes may have had a positive impact on mortality.

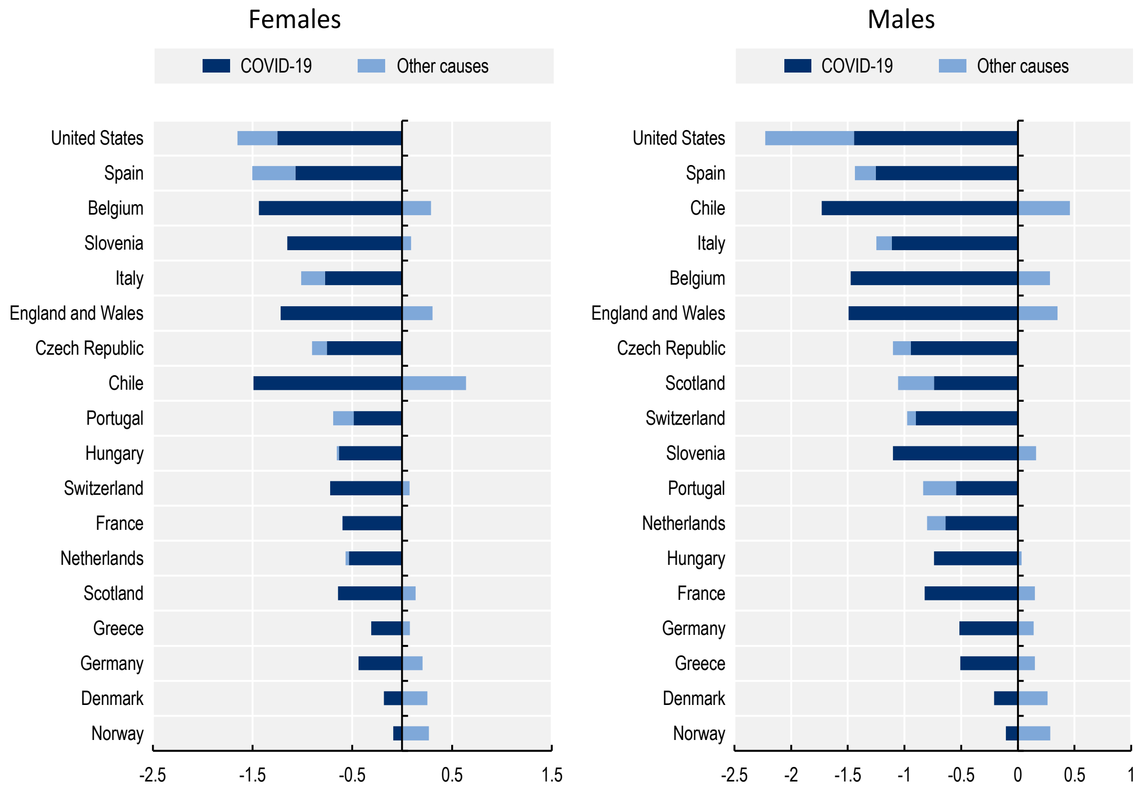
Figure 2.4. Excess mortality relative to officially reported COVID-19 deaths, 2020-21



Note: Data available as of 13 January 2022. Figure truncated at -300%, with the relative excess mortality for New Zealand at -5000%.
Source: Adapted from The Economist (2022[1]), *The pandemic's true death toll*, https://econ.st/3yE7flu.

Another way to understand the direct and indirect impact of COVID-19 on mortality is to look at the decomposition of the change in life expectancy from 2019 to 2020. Figure 2.5 shows the decomposition of this change in life expectancy at birth (contrary to Figure 2.2 that shows life expectancy at age 60) between the direct impact of COVID-19 and the impact from other causes. Chileans experienced the largest reduction in life expectancy attributed directly to COVID-19, whereas those from the United States experienced the largest total reduction in life expectancy. Other causes of mortality actually had a positive impact on life expectancy in Chile, particularly for females.

Figure 2.5. Decomposition of the change in period life expectancy at birth from 2019-20



Note: Period life expectancy describes the mortality experience of a specific year, and does not take into account future expectations of mortality.
Source: Adapted from Aberto et al. (2021[3]), *Quantifying impacts of the COVID-19 pandemic through life-expectancy losses: a population-level study of 29 countries,* https://doi.org/10.1093/ije/dyab207.

Nevertheless, average figures may hide that indirect effects may still have had a net negative impact for many groups of the population, even if they were positive overall. Disadvantaged groups who experienced higher mortality from COVID-19 also experienced higher excess mortality during the pandemic from other causes. One study in the United States estimates that 17% of excess deaths were attributable to causes other than COVID-19, and this figure was substantially higher for counties having lower socio-economic levels, poorer health, and a larger Black population (Stokes et al., 2021[8]).

While official statistics for COVID-19 deaths may not provide an accurate estimate of the total impact it has had on mortality, they do provide important insights regarding relative mortality risk for various groups of the population. The following section describes these differences and their potential drivers.

2.1.1. The direct impact of the COVID-19 virus

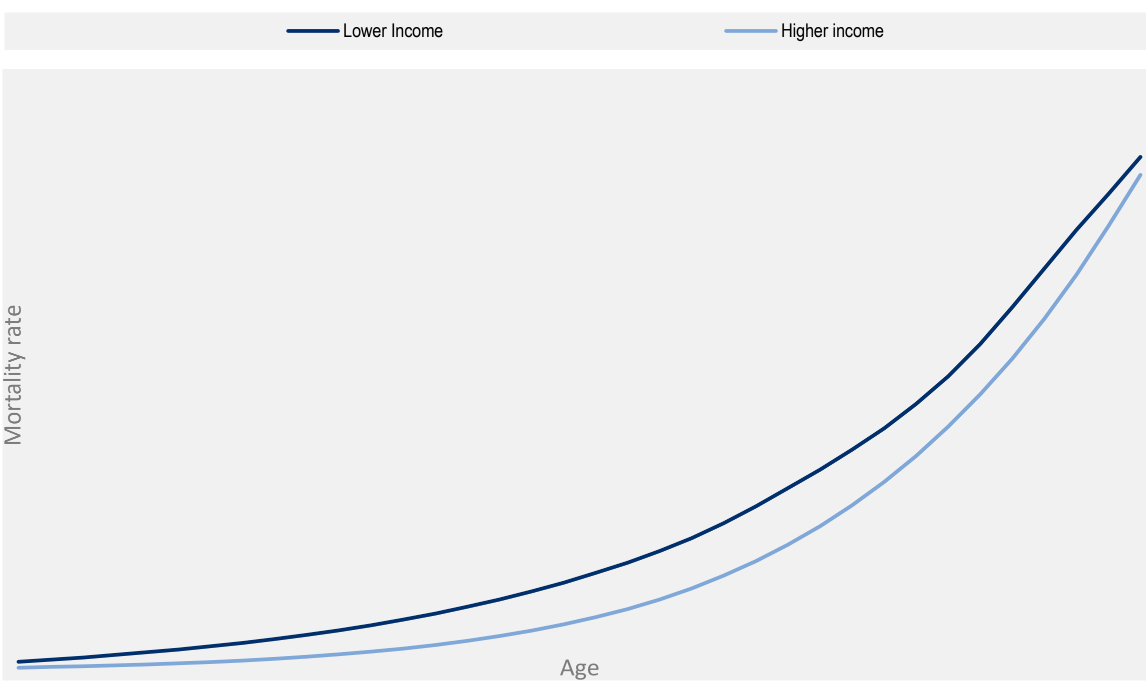
The mortality risk from COVID-19 seems to generally follow a similar pattern to the mortality risk from all causes, so those at higher risk of dying during regular times have also been at higher risk of dying from COVID-19. As with baseline mortality, the mortality risk from COVID-19 differs substantially across ages, genders, baseline health, socio-economic status, and ethnicity.

Differences across ages

The mortality risk from COVID-19 increases exponentially with age, similarly to the normal mortality pattern observed across ages. The Gompertz model, which is commonly used to define mortality rates across ages and assumes that mortality increases exponentially with age, provides an adequate fit for the mortality from COVID-19. Indeed, the pattern of the mortality risk from COVID-19 follows a similar pattern as that for other causes of death related to ageing, including pneumonia and influenza. However, the relative mortality risk for adults from COVID-19 is much higher, at between 2.8 to 8.2 times higher than pneumonia and influenza (Sasson, 2021[9]).

Given the exponential pattern of mortality risk across ages, the age structure of a population is clearly a determinant in the overall mortality for COVID-19 experienced in any given jurisdiction. However, the starting point of mortality also matters. Older people are at higher relative risk in high-income countries, who have lower baseline mortality at adult ages, than in low and middle-income countries. This is because high-income countries have experienced more significant longevity gains at younger to middle ages, so the mortality curve for high-income countries is much steeper (see Figure 2.6 for an illustration). This means that individuals 'age' more quickly than in low and middle-income countries where the mortality curve is flatter. As such, the mortality risk from COVID-19 increases on average by 12.6% with each year of age in high-income countries, compared to only 7.1% in low and middle-income countries (Demombynes, 2020[10]). Younger individuals in the latter countries are therefore at higher relative risk of dying from COVID-19.

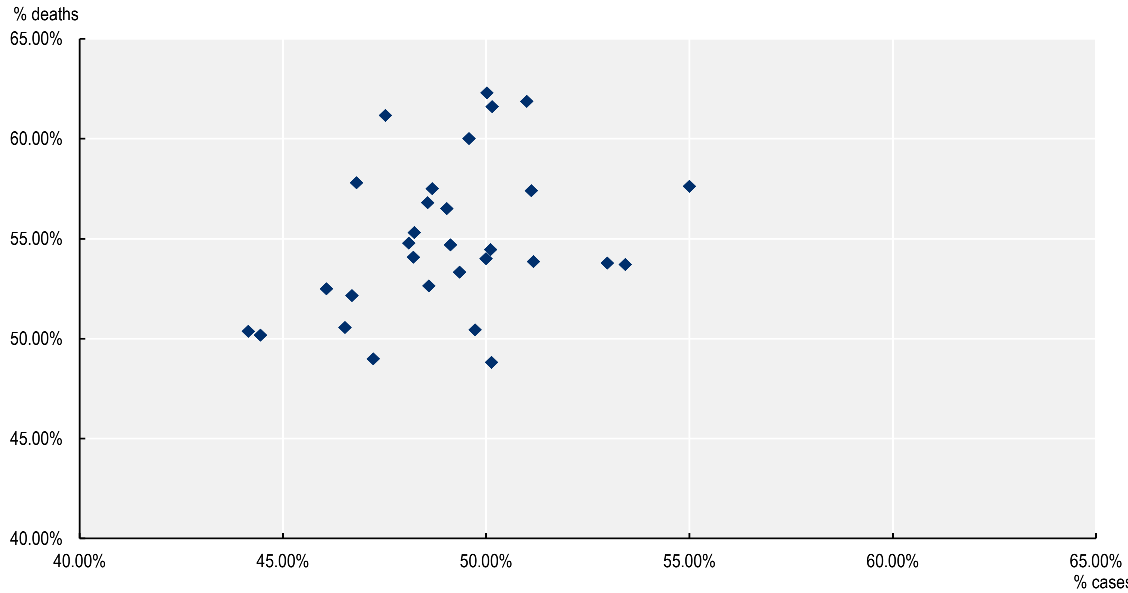
Figure 2.6. Illustration of slope of mortality curves for higher and lower income countries



Differences between genders

Males are on average at a higher risk of dying from COVID-19 than females. Males represent slightly less than half of confirmed positive cases – though they are also less likely to get tested – but make up a higher proportion of confirmed deaths (The Sex, Gender, and COVID-19 Project, 2021[11]). Figure 2.7 shows that this is generally true in a sample of 30 OECD countries where sex-disaggregated data is available. While men represented on average 48.3% of confirmed COVID-19 cases, weighted by the number of cases, they made up 55% of the deaths (The Sex, Gender, and COVID-19 Project, 2021[11]).

Figure 2.7. Percent of male confirmed COVID-19 cases and deaths in OECD countries



Note: Data from 30 OECD countries available as of 24 August 2021.
Source: Adapted from The Sex, Gender, and COVID-19 Project (2021[11]), *The COVID-19 Sex-Disaggregated Data Tracker*, https://globalhealth5050.org/the-sex-gender-and-COVID-19-project/the-data-tracker.

Nevertheless, the difference between genders of mortality risk from COVID-19 are largely in line with differences in baseline mortality. One global study concluded that males were nearly 40% more likely to die of COVID-19 than females, and nearly three times more likely to require intensive care, even though there was no difference between genders with respect to the proportion of confirmed positive cases of COVID-19 (Peckham et al., 2020[12]). A study on European data estimated the increased risk of males to range from 11% to 54% (Ahrenfeldt et al., 2020[13]). Another estimate based on a review of existing studies, however, puts the relative risk to males higher at 86% (Biswas et al., 2020[14]). Nevertheless, these observations are mostly in line with the generally observed increased risk of mortality of males. To put this into perspective, males in the United States between the ages 55 and 80 have a higher risk of mortality than females between around 35% and 70%.[4] Differences between genders by age also demonstrate a pattern consistent with baseline mortality, tending to increase until ages in the 60s and decreasing thereafter (Ahrenfeldt et al., 2020[13]).

There are some exceptions, however, with a handful of countries experiencing a higher case fatality rate for females. In India, for example, the case fatality rate at the end of September 2020, was 3.3% for women compared to 2.9% for men. Nepal, Slovenia, and Vietnam have also demonstrated higher case fatality rates for females. Nevertheless, it is difficult to determine whether these are the true differences in mortality or whether they may be caused by biases in reporting, testing or access to health care (Dehingia and Raj, 2021[15]).

Differences by underlying health conditions

Having an underlying comorbidity significantly increases the mortality risk of COVID-19. Kidney disease is among the most deadly, increasing the risk of death by nearly five times. Other comorbidities identified as significant risk factors include, in order of descending risk, cardiovascular disease (~3x), respiratory disease (2-3x), diabetes (~2x), hypertension (~2x), dementia (~2x), cancer (~2x), and liver disease (1.5x) (Biswas et al., 2020[14]; Cho, Yoon and Lee, 2021[16]).

Indeed, the vast majority of people who die from COVID-19 have at least one comorbidity, and multiple comorbidities are common. Among those who died of COVID-19 in Canada, for example, 90% had at least one other underlying condition, nearly two-thirds had at least two comorbidities and nearly half had three or more (Statistics Canada, 2021[17]). One study on a care home in Sweden showed that deaths during the first wave of the pandemic were mainly the frailest of the population having multiple comorbidities, with 92% of deaths having three or more comorbidities (Nilsson, Andersson and Sjödahl, 2021[18]).

Death among the population under 65 with no comorbidities remains rare. Less than 3.6% of COVID-19 fatalities under age 65 in France, Italy, the Netherlands, Sweden, Georgia (USA), and New York City (USA) had no comorbidities, though Mexico presents an exception to this with nearly 18% of those dying under 65 having no comorbidity (Ioannidis, Axfors and Contopoulos-Ioannidis, 2020[19]). However, this could be at least partially driven by lower levels of reporting or diagnosis of comorbidities in Mexico.

Frail populations are clearly more at risk of dying from COVID-19. This leads to the somewhat counterintuitive observation that countries having better health care systems also have higher COVID-19 death rates. This is because in these countries people are more likely to survive life-threatening events such as heart attacks and strokes, making the overall population frailer on average. One study found that for every 1% increase in the size of a country's population surviving heart conditions or stroke, the death rate from COVID-19 increased by 19% (Botly et al., 2020[20]).

That frailer populations are more at risk supports the hypothesis that many of the deaths from COVID-19 are accelerated deaths that may well have occurred in the short term regardless. This phenomenon has been observed in past pandemics as well. Following the Spanish Flu of 1918-1919, the gap in life expectancy between males and females significantly decreased. This is likely because many of those dying during that pandemic also had tuberculosis. Indeed, tuberculosis rates dropped in the years following the Spanish Flu, and disproportionately so for males (Noymer and Garenne, 2000[21]).

Differences by socio-economic status

There is mixed evidence as to whether more disadvantaged groups are at higher risk of dying from COVID-19. The link between socio-economic status and COVID-19 mortality risk varies from one country to the next, therefore local context seems to play an important role in the difference in outcomes.

Higher levels of deprivation have been associated with higher COVID-19 mortality in several jurisdictions. In England, a 1 percentage point increase in the proportion of the population experiencing income deprivation was found to lead to a 2% increase in COVID-19 mortality rates (Rose et al., 2020[22]). In Scotland as well, mortality rates were two times higher for those from the most deprived areas, controlling for age and sex (Lone et al., 2021[23]). A strong gradient of excess mortality and socio-economic status was also found in Chile (Mena et al., 2021[24]). Those in greater poverty and living in urban areas experienced larger decreases in life expectancy during 2020 (Mena and Aburto, 2022[25]).

Nevertheless, other studies have not shown a conclusive link between socio-economic status and COVID-19 mortality. In Germany, one study found no evidence of a link between poverty and COVID-19 mortality during the first wave of the pandemic (Ettensperger, 2021[26]). In Wisconsin, USA, poverty was found to be associated with higher rates of admission to the Intensive Care Unit, but not higher rates of death (Muñoz-Price et al., 2020[27]). Supporting these results, a study using US Census data did not show income or poverty to be a significant factor in predicting mortality (McLaren, 2020[28]).

The drivers of these disparities and the potential increased mortality risk for lower socio-economic groups varies across countries. A common explanation put forward is that lower socio-economic groups have a higher incidence of comorbidities that increase the mortality risk from COVID-19. In the United States, those with either lower education or lower incomes have higher rates of every medical risk factor (Wiemers et al., 2020[29]). In Chile, people living in lower socio-economic areas are more likely to be overweight and live in crowded conditions (Mena et al., 2021[24]). However, in England, the higher mortality risk for more deprived groups was not significantly explained by medical risk factors (Williamson et al., 2020[30]).

Access to medical care and health services is another potential driver of observed differences. In Chile, lower socio-economic neighbourhoods experienced more testing delays (Mena et al., 2021[24]).

Higher rates of infection may also play a role. Lower socio-economic groups may be more likely to have occupations that do not allow for teleworking, increasing their risk of infection. In Chile, lockdown measures were less effective at reducing people's mobility in more disadvantaged areas (Mena et al., 2021[24]). Lower socio-economic groups in South Korea were also shown to be at higher risk of contracting COVID-19, particularly for those over the age of 60 (Oh, Choi and Song, 2021[31]).

Difference by ethnicity

Large disparities of mortality rates due to COVID-19 across ethnic groups have been observed in some jurisdictions. In the United States, Black, Hispanic, and Native populations have been at least twice as likely to die of COVID-19 compared to the White population (Center for Disaease Control and Prevention, 2021[32]). This led to a reduction in life expectancy in 2020 for Black people and Hispanic people that was two to three times greater than for white people (Woolf, Masters and Aron, 2021[33]). In England, the Black male population's mortality risk was 3.7 times that of the White population during the first wave of the pandemic, and nearly all ethnic minorities were at higher risk of death than white people. During the second wave, the mortality risk for the Bangladeshi population increased substantially to 4-5 times that of the White population (Office for National Statistics, 2021[34]).

The higher risk to ethnic minorities is clear, though factors other than ethnicity are likely driving these results. One study in Louisiana confirmed that while Black people had a much higher rate of hospitalisation and deaths than white people, race itself was not an explanatory factor in the conditional survivor probability when controlling for other factors (Price-Haywood et al., 2020[35]).

There are several explanations put forward to explain observed differences across ethnic groups, including that they tend to be from more disadvantaged backgrounds, have higher rates of comorbidities, or have higher rates of infection. However, there is not strong evidence supporting the explanation that these populations tend to more often be from lower socio-economic backgrounds. One study in England showed that only a small part of the excess risk could be attributed to higher levels of deprivation (Williamson et al., 2020[30]). Another study in Wisconsin, USA, found no strong relationship between socio-economic status and race (Muñoz-Price et al., 2020[27]). An analysis using US Census data also found no evidence that income, poverty rates, or educational differences were driving the racial disparities for Black and Native populations, though education did seem to be a factor for differences observed for the Hispanic and Asian populations (McLaren, 2020[28]).

That minority populations suffer from higher rates of comorbidities seems to be a more plausible explanation for their increased mortality risk. In the United States, Black people have a higher prevalence of most of the COVID-19 risk factors than whites people (Wiemers et al., 2020[29]). In one study in Louisiana, USA, Black patients had a higher prevalence of obesity, diabetes, hypertension, and chronic kidney disease (Price-Haywood et al., 2020[35]). In contrast, another study in England showed that a higher prevalence of medical problems did not fully explain observed disparities (Williamson et al., 2020[30]).

Higher infection rates may be another explanatory factor for observed ethnic disparities. In the Wisconsin study, Black people were more likely to test positive for COVID-19, even when controlling for demographics, health and geography (Muñoz-Price et al., 2020[27]). Another study linked the increased risk to the use of public transportation and to the prevalence of heath support workers in the population (e.g. home aids, nursing assistants), in line with the theory of increased exposure leading to higher rates of infection (McLaren, 2020[28]).

2.1.2. The indirect impacts of responses to the COVID-19 pandemic

The indirect consequences of the COVID-19 pandemic on mortality have potentially been large. The gap between officially reported COVID-19 deaths and the number of excess deaths presented in Figure 2.4 and Figure 2.5 provided some indication of the magnitude of this impact. This section aims to better understand the drivers of excess deaths not directly related to the COVID-19 virus itself. Drivers identified include reduced health care access, the impact of lockdown measures on well-being and behaviour, and the broader economic impact that the response to the pandemic has had.

Healthcare access

The COVID-19 pandemic caused significant disruptions to health services, including essential and emergency care that could have led to excess mortality from health problems other than COVID-19. A survey by the World Health Organization (WHO) found that 94% of the 135 responding countries experienced some disruption to essential health services, and over a third of the countries experienced disruptions to over half of their services. This included potentially lifesaving emergency, critical and operative interventions, which were disrupted in 20% of the countries. Over 40% of countries had disruptions to mental, neurological and substance abuse services, and a third experienced disruptions related to pre- and post-natal care. While less impacted, 26% of high-income countries still experienced disruptions (World Health Organization, 2021[36]).

Disruptions to health services, in particularly urgent care services, likely led to an increase in mortality for those unable to obtain needed treatment. One survey in the United States indicated that 1-2% of individuals surveyed were not able to access needed urgent care in the prior two months specifically because of the pandemic (Center for Disease Control and Prevention, 2021[37]). Deaths from Alzheimer's and heart disease significantly increased in the United States during the peaks of the pandemic (Woolf et al., 2021[38]). The United Kingdom estimated that 6 000 of the excess non-COVID-19 deaths in March and April 2020 were due to changes in emergency care, compared to 42 000 deaths attributed directly to COVID-19. Another 10 000 are estimated to have died as a result of changes to adult social care, including early discharge, lack of emergency health care, and changes in the quality of care (Office for National Statistics, 2020[39]).

Avoidance of health care facilities because of a fear of being infected also likely played a significant role in the increased deaths among those not receiving needed care. In Northern Italy, emergency visits and hospitalisations decreased across all age groups and all types of diagnoses shortly after the first confirmed COVID-19 case in Italy. However, out-of-hospital mortality from neoplasms, cardiovascular and endocrine diseases significantly increased during lockdown, indicating that these individuals were not seeking needed care at the hospital (Santi et al., 2021[40]). Similarly, in Denmark, non-COVID-19 hospital admissions decreased by 30% after the first lockdown, and by 22% following the second lockdown after trends had returned to baseline levels. Despite this, mortality rates for non-COVID-19 diseases increased by over 20% during the lockdowns, and mortality rates from respiratory diseases, cancer, pneumonia, and sepsis remained higher over the entire period (Bodilsen et al., 2021[41]). In England and Wales, deaths from ischaemic heart disease, asthma, and diabetes increased, despite a reduction of these deaths in hospitals, indicating that many of these deaths were due to not receiving care (Kraindler, Barclay and Tallack, 2020[42]).

Disadvantaged groups of the population were in many cases more likely to experience reduced access to health care services. In Europe, a strong socio-economic gradient was observed by socio-economic status and previous health conditions for those experiencing foregone, postponed, or unavailable care, meaning that those who were more economically vulnerable and in poor health had less access to the health system (Börsch-Supan, 2021[43]). In the United States, the proportion of individuals not having access to urgent care because of the pandemic was negatively correlated with education level (Center for Disease Control and Prevention, 2021[37]). In addition, Black, Hispanic, and disabled populations were more likely to avoid urgent or emergency care during the first wave of the pandemic (Czeisler et al., 2020[44]). Hospital restrictions also seem to have been unbalanced in some cases, with sites caring more for Black populations being more impacted by lockdown measures. In a study on US patients with prostate cancer, prostatectomies decreased by over 90% for Black people compared to only 17% for white people, a difference not explained by the clinical parameters such as risk factors and age. While surgical treatments were restricted during lockdowns to prioritise those needing emergency care, some sites experienced increased surgical volume while those treating a higher proportion of Black patients paused surgeries completely (Vince, 2021[45]).

Capacity constraints and diminished resources potentially also put developing countries at increased mortality risk, especially children. Vaccination programmes against diseases other than COVID-19 in particular have been significantly disrupted. In April 2021, vaccination programmes in 50 countries were still postponed, meaning that 228 million people faced an additional risk of contracting life threatening diseases such as measles, polio, and yellow fever (WHO, 2021[46]). Missed vaccinations may also reduce herd immunity, presenting a larger risk to these populations as a whole. This is not without precedent. During the Ebola outbreak in 2014, vaccinations for infants under one year fell by 75%, vaccinations for measles fell by 20%, and around half of the children in the three most affected countries did not receive all of their routine vaccinations (Elston et al., 2017[47]).

Past experience has shown that the unavailability of health care or the reluctance to seek health care during health crises can be particularly detrimental to pregnant women and children, especially in developing countries. At the height of the Ebola outbreak in 2014 in Sierra Leone, maternal mortality increased by 170%, and still births increased by 40%. Over that year, reduced access to routine health services increased maternal and child mortality by 22% and 25%, respectively, with preventable and treatable infectious diseases being a major contributor to the latter (Elston et al., 2017[47]). Applying this experience to the COVID-19 pandemic, one theoretical model estimated that child mortality could increase by up to 45%, and maternal mortality by up to 39%, in low-income and middle-income countries. 60% of the increase in maternal deaths were due to reduced access to key childbirth interventions, while 40% of the increase in child deaths were due to reduced access to treatments for pneumonia, sepsis, and diarrhea (Roberton et al., 2020[48]).

Lockdown measures

The strict lockdown measures that many governments implemented during the peak waves of the COVID-19 pandemic had a significant toll on the mental health and well-being of the populations impacted. In the United Kingdom, the proportion of adults experiencing some form of depression in early 2021 doubled from pre-pandemic levels, with young adults and women more impacted (Office of National Statistics, 2021[49]). Similarly, the proportion of adults having symptoms of anxiety or depression increased by 5 percentage points over the period from August 2020 to February 2021, with young adults being particularly impacted (Vahratian et al., 2021[50]). Such declines in well-being can lead to potentially fatal detrimental behaviour linked to substance abuse or even suicide. Declines in well-being at home may also pose a threat to those in abusive relationships. On the positive side, in some jurisdictions social distancing may have reduced the number of homicides during lockdown periods, reduced traffic fatalities, and reduced fatalities from other contagious diseases such as seasonal influenza.

Substance abuse

The boredom and reductions in well-being that accompanied lockdown measures exacerbated existing negative trends with respect to substance abuse and fatalities from drug overdoses. In the United States, deaths from drug overdoses increased by 29% in 2020 compared to 2019. That amounted to 93 000 people, or to put this into perspective, about 25% of the number of deaths due directly to COVID-19 (OSF Healthcare, 2021[51]). In 2020, more than twice the number of people in San Francisco, California died of overdoses than of COVID-19 (The Economist, 2021[52]). Ontario, Canada experienced an increase of 75% in deaths from opioid overdoses in 2020 compared to 2019, with an 82% increase for the 25 to 44 age group (Gomes et al., 2021[53]). Alcohol-related deaths also increased substantially in Canada in 2020, increasing by more than 20% for those under the age of 65, and by nearly 50% for those under the age of 45 (Statistics Canada, 2021[54]).

The alarming increase in overdoses has been directly linked with the lockdown orders imposed in certain areas. Weekly median death rates from overdoses in San Francisco, California increased by 50% following the shelter in place order (Appa et al., 2021[55]). Overdose deaths in Ohio, USA, increased by over 70% within two months following the declaration of a national emergency before decreasing again by August 2020. The largest increase was for ages under 25, whose death rates more than doubled compared to 2018-2019, and ages over 65 where the increase was just under 90% (Currie et al., 2021[56]).

However, the impact of lockdowns on substance abuse varies across countries. While the data is less conclusive, some evidence indicates that drug use declined during the strict lockdown periods in Europe, largely due to disruptions in the supply chain and less opportunity to use. Overdose deaths seem to have been lower in Italy and Portugal. However, they may have been higher in Finland, and they increased in Spain once lockdown restrictions eased. Other worrisome trends indicate that there could be an increase in problems linked to substance abuse in the coming years. Cocaine shipments seem to have increased substantially in Europe, and the product has also become more potent (UNODC, 2021[57]).

Suicide

While depression and anxiety rose during the pandemic, this did not seem to lead to an immediate increase in suicide mortality in most countries. In one study of 21 high- and upper-middle-income countries, no significant increase in suicides was observed through the end of July, 2020 (Pirkis et al., 2021[58]). Suicides even declined in some jurisdictions, such as the United States where suicides in 2020 were 6% lower than in 2019 (Ahmad and Anderson, 2021[59]). One explanation for this could be that significant efforts were put into offering support to those at risk, in recognition of the impact that lockdown could have on mental health. Another, observed in previous epidemics, is the feeling of community and everyone going through hard times together. The economic assistance that many governments provided in high-income countries could have also mitigated any increase in the short term (John et al., 2020[60]).

Indeed, there is some evidence that the impact of the pandemic on suicide rates could come later. Japan, Puerto Rico and Vienna, Austria all showed signs of an increase in suicides following the initial wave (Pirkis et al., 2021[58]). Following an initial decline of 14% in Japan during the first five months of the pandemic, suicides increased by 16% during the second wave, particularly for females and adolescents (Tanaka and Okamoto, 2021[61]). In Peru, the downward trend in suicides seemed to reverse in the post-lockdown period (Calderon-Anyosa and Kaufman, 2021[62]).

In addition, suicide rates may have increased for certain groups of the population. There were some signs that child suicide rates increased in the United Kingdom during the first lockdown period (Odd et al., 2021[63]). During the first wave of the pandemic, suicides among the Black population in Maryland, USA, appeared to have doubled compared to previous years, while among the White population suicides nearly halved (Bray et al., 2021[64]). In the United States, emergency room visits due to suicide attempts by adolescent girls increased by 51% in early 2021 compared to 2019, while rising only 4% for boys (U. S. Surgeon General, 2021[65]).

Femicide

Lockdown measures may have increased violence against women, as those in abusive relationships became trapped at home with their abusers. Data early in the pandemic showed a worrying increase in the reports of domestic violence and calls to emergency and helplines, with observed increases between

25% to 33% in Argentina, France and Singapore (UN Women, 2020[66]). In Peru, calls to helplines for domestic violence increased by 48% (Calderon-Anyosa and Kaufman, 2021[62]). In South Africa, gender-based violence cases increased by 37% during the first week of lockdown in April 2020 (Warah, 2021[67]).

This increase in domestic violence has not necessarily translated into increased femicides, however. Femicides decreased slightly in Mexico after remaining constant during the lockdown period, and also decreased in Argentina, France, Peru, and Portugal, though in the latter the number of attempted femicides did not decrease (Hoehn-Velasco, Silverio-Murillo and de la Miyar, 2021[68]; Statistica, 2021[69]; Le Monde, 2021[70]; Calderon-Anyosa and Kaufman, 2021[62]; OMA-UMAR, 2020[71]).

Nevertheless, femicides increased in some jurisdictions, and for others there were signs that an increase could be yet to come. Femicide rates nearly doubled in the United Kingdom during the first weeks of the pandemic (Guerra Lund, Manica and Mânica, 2020[72]). A significant increase was also observed in Quebec, Canada (Laou, 2021[73]). Femicides followed a steady increasing trend between March and August, 2020 in Colombia (Statistica, 2021[74]). In Peru, over 900 women, of which two-thirds were children, were reported missing during the three and a half months of lockdown, and many missing person reports later end up being femicides (Charrier, 2020[75]). In addition, a significant portion of femicides occur at the moment of separation from the partner, whereas women were not able to leave during lockdown periods (Shiloh Vidon, 2021[76]). Lockdown measures may also have reduced the opportunity for femicide. In Peru, for example, bodies are most frequently found outside of the home (Casana-Jara, 2020[77]).

Homicide

While lockdown measures had a significant positive influence on crime rates, which experienced sharp reductions, homicide rates seem to have been less impacted. While overall crime reduced by 37% in European cities, the reduction was lowest for homicides, which went down by only 14% (Nivette et al., 2021[78]). Homicides in Mexico did not experience a big change, even though other types of crime reduced during lockdown before returning to pre-pandemic levels (Balmori de la Miyar, Hoehn-Velasco and Silverio-Murillo, 2021[79]). Other areas in Latin America experienced a more significant drop, with homicides reducing by 24%, 29% and 76% in large cities in Brazil, Colombia and Peru, respectively, though in Peru rates started to pick back up following the lockdown period (Nivette et al., 2021[78]; Calderon-Anyosa and Kaufman, 2021[62]). Despite a significant drop in crime in large cities in the United States during lockdown orders, homicides actually increased in the summer of 2020 (Abrams, 2021[80]).

Traffic accidents

Lockdown measures led to a significant drop in traffic, though this did not always translate into a reduction in traffic fatalities. Nevertheless, many countries did experience a substantial drop in traffic deaths. Peru experienced a larger drop in fatalities related to traffic accidents than the reduction in suicides and homicides (Calderon-Anyosa and Kaufman, 2021[62]). Stay-at-home orders in March and April, 2020, reduced traffic deaths in Türkiye by 72% (Oguzoglu, 2020[81]). Across Europe, traffic fatalities decreased by 17% on average, although fatalities actually increased in Finland, Ireland, Latvia, Estonia, Luxembourg, Switzerland, and Iceland (European Commission, 2021[82]). Only a slight decrease was observed in Japan, and fatalities increased in certain prefectures such as in Tokyo (Tauchi, 2021[83]).

Globally, the change in traffic fatalities was not proportional with the change in traffic. In April 2020 the International Transport Forum found a decrease in road deaths by only a third, even though traffic was halved (ITF, 2020[84]). Other jurisdictions experienced an increase in traffic fatalities, despite less driving. In Ontario, Canada, traffic fatalities increased by 22% despite a reduction in accidents of 26% (The Canadian Press, 2021[85]). In the United States, traffic deaths increased by 7.2% compared to 2019 despite a 13.2% decrease in miles driven (NHTSA, 2021[86]). The increase in fatalities in both jurisdictions was attributed to an increase in reckless driving practices.

Contagious disease

Improved hygiene and social distancing measures, including the use of masks, have not only helped in preventing the spread of COVID-19, but have also led to a significant reduction in the transmission of contagious diseases, in particular seasonal influenza. In normal years, seasonal influenza is a significant cause of mortality globally, with around 300 000 to 500 000 deaths each year associated with influenza (Paget et al., 2019[87]). During the 2020-2021 influenza season, samples testing positive for influenza fell to practically zero in the WHO European Region (the European Influenza Surveillance Network, 2021[88]). It has also reached historical lows in the United States, Australia, Chile, and South Africa during 2020 (Olsen et al., 2020[89]).

While fewer people certainly lost their lives to influenza, the net benefits are less clear. The elderly more susceptible to seasonal influenza would be also more at risk for COVID-19. In addition, the absence of the seasonal influenza epidemic could lead to a reduction in herd immunity, leading to more severe and longer epidemics in coming flu seasons (Sanz-Muñoz et al., 2021[90]).

2.2. Potential long-term consequences of the COVID-19 pandemic on mortality

While the short-term impacts of COVID-19 on mortality continue to emerge, most of these impacts should be temporary as the drivers of excess mortality subside. Nevertheless, COVID-19 could also have some effects on mortality that could emerge over time. The COVID-19 virus itself may have a long-term impact on health or immunity. The pandemic situation may also have exacerbated political and societal trends that could have long-term implications for future trends in life expectancy.

2.2.1. Long-term effects of the COVID-19 virus

COVID-19 may have long-term health implications that could increase the mortality risk of survivors. Many people who contracted and survived COVID-19 have experienced symptoms for weeks or even months, even if their initial symptoms were mild to moderate, a situation which has now commonly become known as “Long COVID-19”. Generally, long-term medical problems reported following COVID-19 infections are not necessarily the same symptoms as for the acute infection, and can include respiratory issues, neurological problems, gastrointestinal disorders, cardiovascular disorders, and a higher risk of having mental health issues (Al-Aly, Xie and Bowe, 2021[91]).

Estimates of the prevalence of Long COVID-19 vary widely. While many studies may be biased towards hospitalised patients, one review of current literature estimates that 56% of confirmed COVID-19 cases experience symptoms beyond 12 weeks, and that 10% of these were not able to return to work (Domingo et al., 2021[92]). A broader and ongoing study in the United Kingdom indicates that up to 12% of infected individuals report to have symptoms lasting beyond 12 weeks, and up to 18% for those having symptomatic acute infections (Office for National Statistics, 2021[93]). A more recent review of evidence suggests a prevalence of the most prevalent post-COVID-19 symptoms within the community at over 50%, though this is also based on data from the early waves of the pandemic (ECDC, 2022[94]).

There is evidence that COVID-19 can cause lasting damage to the kidneys, lungs, heart, and brain, which could potentially lead to increased mortality risk. Severe illness from COVID-19 can lead to a long-term reduction in kidney function, and even patients experiencing moderate illness were shown to be at increased risk of death over the next six months (Bowe et al., 2021[95]). In another study, a third of a sample of hospitalised patients experienced lung tissue death (Marshall, 2020[96]). Heart injury has been in a quarter of hospitalised patients, and 60% of patients having recovered from COVID-19 had lasting heart inflammation (Giustino et al., 2020[97]; Puntmann et al., 2020[98]). There is also evidence that COVID-19 blocks blood flow to the brain (Hirunpattarasilp et al., 2021[99]). Long-term health impacts of these clinical observations could include kidney or heart failure, chronic respiratory problems, strokes, or even an increased risk of Parkinson's and Alzheimer's disease (Mayo Clinic, 2021[100]). A nationwide study in Estonia demonstrated that those infected with COVID-19 tripled their mortality risk over the next year, particularly for those aged 60 and over. The increased risk was linked to cardiovascular and respiratory diseases as well as to cancer (Uusküla et al., 2022[101]).

Evidence of longer-term complications can be found in patients recovering from the related diseases of severe acute respiratory syndrome (SARS) and the Middle East respiratory syndrome (MERS). Abnormalities in lung functioning, reduced exercise capacity, and psychological problems are common in survivors of SARS and MERS even 12 months after they have been discharged from the hospital (Ahmed et al., 2020[102]). After 15 years, 4.6% of SARS patients still had visible scarring on their lungs, and 38% had diminished lung functioning (Zhang et al., 2018[103]).

Studies on the Spanish Flu of 1918 have shown that there may be lasting health impacts to individuals exposed to viruses around birth. Children born in Sweden in 1919 are estimated to have had three months shorter life expectancy than proximate cohorts. The 1919 cohort ultimately had worse health and socio-economic outcomes in old age, and males exposed to the virus during the second trimester experienced higher rates of heart disease and cancer (Helgertz and Bengtsson, 2019[104]). Similarly, in the United States, cohorts exposed in late gestation and at birth experienced 8-9% higher mortality from all causes, translating into at least seven months lower life expectancy at age 70 compared to surrounding cohorts. Those born during the peaks of the pandemic had higher mortality in particular from respiratory and cardiovascular disease, but also fewer cancer deaths (Myrskylä, Mehta and Chang, 2013[105]). These outcomes could mean that the 2020-2022 cohorts born during the COVID-19 pandemic could experience specific patterns of future mortality improvements and lower life expectancies compared to surrounding cohorts.

There is also evidence that any immunity acquired during a flu pandemic can affect future immune responses to other viruses, especially immunity acquired in childhood. One recent and plausible explanation put forward for the high fatality rate for young adults during the Spanish flu is the concept of antigenic imprinting, where the body's antibody response is significantly influenced by the influenza strains exposed to in childhood. The ages experiencing the highest fatality during the Spanish flu would have been young children during the H3N8 Russian influenza in 1889-1890. The Spanish flu was caused by another type of influenza strain, the H1N1 strain. The antigenic imprinting theory proposes that the immune response of this cohort was dominated by antibodies responding to the earlier strain, and therefore not effective against the H1N1 strain (Gagnon et al., 2013[106]). This theory could also explain differences in the prevalence of infection from different flu strains for cohorts born before and after the Hong Kong flu of 1968 (Woo, 2019[107]).

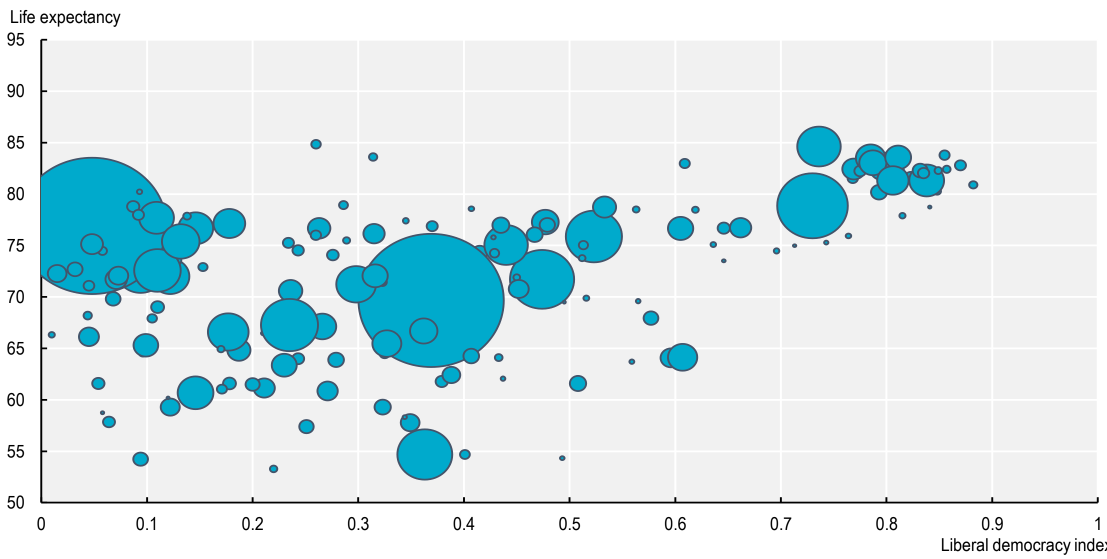
Immune responses to coronaviruses may also be influenced by past exposure, which can have implications for future immunity. One study found that while the antibodies found in patients who had recovered from SARS were not effective against COVID-19 by themselves, these patients had a very strong immune response to the Pfizer vaccine, even after just one dose. The antibodies they developed were also effective against a broader range of coronavirus variants, which was not the case for others vaccinated for COVID-19 (Tan et al., 2021[108]). Other researchers have speculated that there may be some level of protection offered from T cells developed in response to other types of coronavirus, which seem to also be more effective than antibodies against different variants (Redd et al., 2021[109]; Tarke et al., 2021[110]; Geers et al., 2021[111]; Doshi, 2020[112]). Nevertheless, more research is needed to investigate the implications of the immune response to different strains of coronavirus.

2.2.2. Potential long-term political shifts

In addition to the impacts to health and well-being, COVID-19 has also impacted political discourse and preferences more broadly in societies. Political trends can have an impact on the mortality and life expectancy of populations. Populations in democratic countries generally have higher life expectancies.

Countries scoring at least 0.7 on the Liberal Democracy Index all had life expectancies over 74, while those countries having life expectancies under 60 all score below 0.5 on the Index (Figure 2.8).

Figure 2.8. Life expectancy at birth vs. Liberal Democracy Index, 2019



Source: Source: Adapted from Ortiz-Ospina (2019[113]), *Does democracy lead to better health?*, https://ourworldindata.org/democracy-health.

Indeed, democracy seems to matter more than economic measures for measures of health of a population. Democracy is more strongly associated with higher life expectancy than a country's GNP, level of inequality, and public expenditure (Franco, Álvarez-Dardet and Ruiz, 2004[114]). Democratic experience also explains more of the variation in mortality from cardiovascular disease, transport injury, cancer, cirrhosis, and other non-communicable diseases than GDP does (Bollyky et al., 2019[115]).

Political shifts have led to significant changes in life expectancy in the past. Life expectancies in the Central and Eastern European and Baltic countries started improving in the 1990s following the collapse of the Soviet Union, after years of stagnation and even decreases in life expectancy. Following the German reunification of 1990, the life expectancy of East Germans rapidly caught up to that of West Germans. One estimate is that East German men and women would have had 5.7 years and 4 years lower life expectancy, respectively, if reunification had not occurred (Vogt, 2013[116]).

Over recent decades there have been trends in the opposite direction, indicating some reversal in trends towards democracy, even in established democracies. Since 2005, the number of countries classified as "Free" by Freedom House has gone from 89 to 82, while the number of "Not Free" countries has increased by 9 over the same period. The "Democracy Gap", or the number of countries whose aggregate Freedom score declined compared to those where it has increased, has been negative over the last 15 years and reached its highest level over that period in 2020 (Repucci and Slipowitz, 2021[117]). At an international level, some researchers have observed a decline in overt efforts to promote democracy, which has contributed to an increased willingness by some governments in developing democracies to violently oppose pro-democracy demonstrations and political opponents (Hyde, 2020[118]). Societal preferences have also moved away from democratic values in some areas. For example, in 2018, for the first time less than half of Latin Americans expressed full support for democracy, and nearly a third expressed indifference between a democratic or authoritarian regime, twice the proportion expressing an indifference two decades ago (UNDP, 2020[119]).

The COVID-19 pandemic has exacerbated these trends. From January to August 2020, measures assessing the condition of human rights and democracy decreased in 80 out of 192 countries, or over 40% of the countries assessed, with struggling democracies and highly repressive states being the most impacted (Repucci and Slipowitz, 2020[120]). There is also evidence that the pandemic may have influenced public preferences for democracy, at least in the short term. At the beginning of the pandemic, Spaniards expressed higher preferences for strong leadership, technocracy, and authoritarian government, as well as more willingness to give up individual freedoms (Amat et al., 2020[121]).

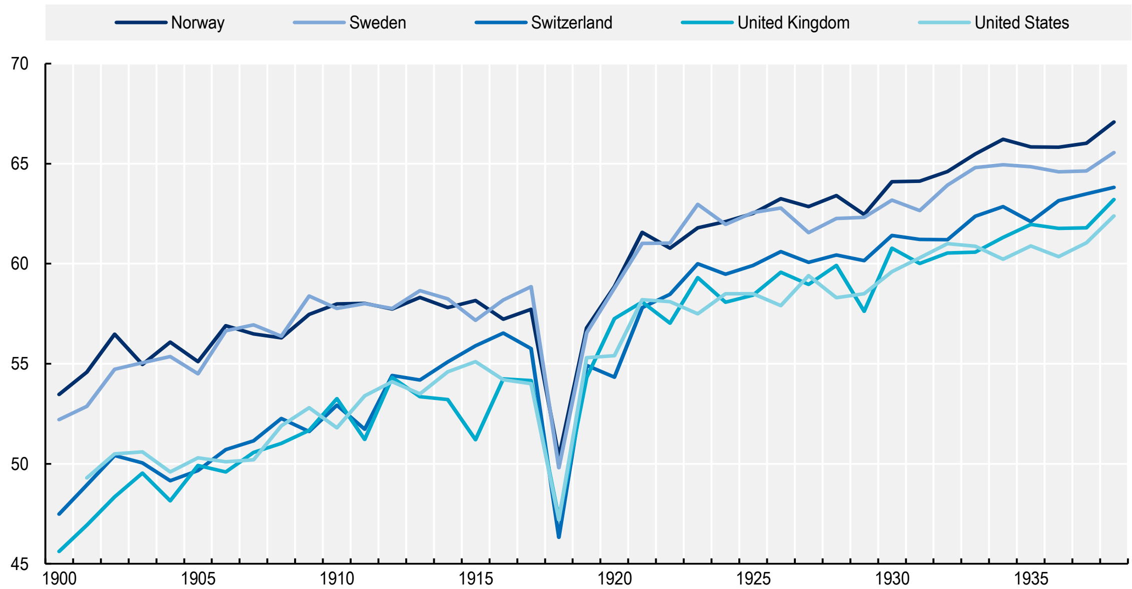
Nevertheless, COVID-19 is unlikely to have an enduring negative impact on established democracies. To the contrary, public opinion may push these countries to place more weight on public health issues and the opinions of experts (Rapeli and Saikkonen, 2020[122]). However, social media has still facilitated the spread of misinformation that reinforces some groups' beliefs in the effectiveness of unproven treatments or the dangers of vaccination against COVID-19. This type of polarisation is likely to endure.

2.3. The implications of COVID-19 for the development of mortality assumptions

COVID-19 has had a significant impact on mortality and life expectancy in the short term, but the impact on mortality assumptions used going forward should be much lower. Many of the mortality shocks will be temporary, and mortality rates can be expected to return to their prior trajectories. Longer-term impacts are significantly less certain, however, thereby increasing the potential risk that experience will deviate from best estimate assumptions. This calls for the ongoing monitoring of longevity experience. Impacts will also vary widely from one country to the next, depending on factors such as the level of development, baseline health, and conditions during lockdown. These differences will need to be considered when assessing the impact of the COVID-19 pandemic on mortality assumptions.

The immediate impact of the COVID-19 virus itself will be a temporary shock to mortality. The evidence shows that across ages and genders, the shock to mortality seems to have been broadly parallel to the baseline curve. That is, the pattern of mortality across ages and genders was similar to a normal year, albeit at a higher level. Once the pandemic subsides, mortality rates should return to their baseline levels. This was the case following the Spanish Flu pandemic of 1918-1919. Figure 2.9 shows that life expectancy returned to its previous trend within three to four years, even exceeding the level observed prior to the pandemic.

Figure 2.9. Life expectancy at birth around the Spanish Flu of 1918-19 for selected countries



Source: Adapted from Roser, Ortiz-Ospina and Ritchie (2019[123]), *Life Expectancy*, https://ourworldindata.org/life-expectancy.

Indeed, the frailest of the population are more likely to have died during the COVID-19 pandemic, and survivors should be relatively stronger on average, resulting in lower mortality in the years following the pandemic. Many of the deaths due to COVID-19 were likely accelerated deaths that would have occurred anyway over the next several years. This is supported by evidence that the specific groups experiencing higher mortality were also the ones having a higher mortality risk generally, in particular those with higher rates of comorbidities. This selection effect will likely be short-lived, however, with mortality levels returning to their previous trajectory within a few years, as they did following the Spanish Flu pandemic of 1918-1919 (Figure 2.9).

Nevertheless, the impact of COVID-19 on mortality will likely still be felt over the coming year or two, as new variants emerge that may be more contagious and able to evade vaccines. Indeed, elevated excess mortality continues, at least in cycles, in many jurisdictions. Nevertheless, while variants of the virus continue to infect even vaccinated individuals, increased immunity has led to lower rates of health complications and deaths.

Viruses causing past pandemics have eventually become endemic, as more people become exposed to the virus and it mutates and becomes less fatal, even if it manages to at least partially evade immunity (Callaway, 2021[124]; Branswell, 2021[125]). If this trend continues with COVID-19, the virus should eventually become endemic and continue to circulate among the population, likely causing milder symptoms like a seasonal cold, as with the other four coronavirus strains that currently circulate endemically among the human population. As such, it can be expected that the pandemic will eventually dissipate and excess mortality levels will return to normal, though uncertainty remains around the virulence of future variants and how long this process will take.

The indirect impacts of the pandemic on mortality should also largely be temporary. Disruptions to health care service should lessen as increased COVID-19 vaccination rates improve hospital capacity to care for other patients. Reductions in infections should also help assuage people's fear to seek needed medical attention, and health care provision should return to its normal levels. Nevertheless, delayed diagnosis of serious illness, such as cancer, may increase mortality in the short term to the extent that early preventative measures were not taken. In addition, high levels of stress and burnout among medical staff could present a challenge to maintaining the same levels of health care, as many individuals could exit the profession.

Lockdown measures have also been lifted, though some of the impacts that these will have on mortality may still emerge over the next year or two. Lingering mental health issues from the lockdown situation may endure, potentially increasing suicide rates, particularly if the widespread awareness and support offered during lockdown is eased during the post-lockdown period. While lockdown exacerbated the existing trends in drug overdoses in some cases, the change in trends generally seemed to be linked directly to lockdown. Nevertheless, the increasing trend in overdoses can certainly be expected to continue barring major changes in the facility to access drugs, and may even accelerate. The reduction in herd immunity from seasonal influenza will likely mean that the flu epidemics of the coming years will be more severe, and potentially have a larger impact on mortality than recent epidemics. Thus any short-term gain from reduced influenza deaths are likely to be neutralised, or even net out to be negative.

Longer-term health impacts of the COVID-19 virus cannot be known in advance, and will only emerge in the decades to come. Ultimately, a cohort effect may emerge in the data for survivors or for those born during the COVID-19 pandemic. Disadvantaged populations that experienced higher infection rates could be more impacted. These trends will need to be monitored over time.

Political shifts will also need to be monitored, though there does not seem to be an immediate threat to mortality from changing political actions and public preferences for established democracies. There may nevertheless be a negative shift in the long-term trend in life expectancy for newer or less stable democracies if the current trends with respect to the support for democracy continue.

Given that the impact of COVID-19 on mortality can be expected to be limited, the mortality experience during the peak of the pandemic should be adjusted or excluded from any calibration of mortality assumptions, as their inclusion would significantly increase the current level of mortality and distort the expected trend going forward. Nevertheless, while mortality should return to its prior trajectory over the next few years, it will likely be rather volatile in the near- and long-term uncertainty in the trend remains. Mortality rates may initially decrease beyond what their prior trend implied, as the surviving population is likely to be stronger and healthier on average. This decrease could potentially be partially offset, however, by higher mortality from the indirect effects of the pandemic – such as health care interruptions and more severe flu seasons – that should gradually subside.

However, the potential long-term effects of the COVID-19 virus on mortality remain highly uncertain and cannot yet be reflected in best estimate mortality assumptions. Assumptions will need to be regularly monitored and updated to adjust to any continued excess mortality in the short term. It will also be important that risk assessments reflect and account for the increased uncertainty in the long term. Stress testing of the assumptions can help to ensure that the potential impact of higher long-term mortality is understood and accounted for in the risk management strategy.

The COVID-19 pandemic will eventually come to an end, and the mortality assumptions used in the context of asset-backed pension arrangements must reflect the best estimate view of what is most likely to happen going forward. At this point in time, the most likely scenario seems to be that mortality levels will return to their previous trajectory.

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Notes

[1] This compares to 8.9 million deaths from ischaemic heart disease in 2019, the world's biggest cause of death (World Health Organisation, 2020[126]).

[2] Simple average across countries and weeks.

[3] Calculations based on male mortality with improvements from the AG2020 mortality table, assuming excess mortality of 8.7% in 2020, 10.4% in 2021 (the actual average weekly excess mortality observed each year in the Netherlands), and 5% in 2022.

[4] Based on the 2019 general population life tables from the Human Mortality Database.

3 Modelling choices for the development of standard mortality tables

Jessica Mosher

This chapter describes the various modelling decisions required for the development of mortality tables for pensioner and annuitant populations. It explains why one approach may be selected over another, along with any potential advantages or disadvantages. As such, it should help regulators and supervisors to have a better sense of the implications and appropriateness of the modelling choices in a particular context.

The development of mortality tables requires numerous modelling decisions. Each aspect of modelling involves a certain level of judgement to determine whether one model could be more suitable than another, and therefore it is useful to have an understanding of the implications that different choices can have.

This chapter aims to describe the different options in an intuitive manner, and to explain why one approach may be selected over another, along with any potential advantages or disadvantages. As such, it should help regulators and supervisors to have a better sense of the implications and appropriateness of the modelling choices in a particular context. Its objective is not to enter into the mathematical details and the technical aspects of model implementation, though it does include some details where they might be relevant.

The chapter is organised around the main steps followed in the development of mortality tables. The first section discusses the graduation techniques used to smooth raw mortality rates. The second section looks at ways that the mortality curve can be extended to both younger and older ages. The third section considers how mortality tables account for selection effects and adjust the mortality rates to reflect the lower expected mortality for pensioner and annuitant populations. The fourth section discusses the different options available to model future mortality improvements. The final section provides some insights as to how innovations in data analysis are starting to be used to inform the development of mortality assumptions.

3.1. Graduating central mortality rates

The graduation of mortality rates involves fitting a function to the observed raw mortality rates to result in a smooth pattern of mortality across ages. Due to normal variability, raw mortality rates do not necessarily follow a smooth pattern across ages, particularly for smaller pensioner and annuitant populations. As such, graduation techniques are usually employed to smooth the raw rates and obtain a mortality curve that reflects the expected biological pattern of mortality, that is generally increasing monotonically with age.

For pensioner and annuitant populations, graduation is more commonly performed over a range of central ages (e.g. 50-95) where observations are sufficient to calculate a robust estimate of mortality. For larger populations, such as the general population of a country, the graduation can potentially be done over a larger range of ages.

Mortality rates are calculated taking the ratio of observed deaths to the number of individuals alive in the year.[1] Box 3.1 provides a more precise explanation. This ratio can also be calculated based on pension amounts rather than individual lives. The latter approach is intended to capture the economic gradient of mortality, where lower mortality rates are observed for those with higher pensions. It is therefore often the preferred approach for mortality tables used to value liabilities. Nevertheless, to limit the cross-subsidisation across members, different mortality assumptions are also commonly generated for different segments (e.g. high and low income, as in the United Kingdom, or White and Blue collar, as in the United States).

Box 3.1. Mortality rates

'Mortality rate' is a general term, and it is not always clear to which mathematical concept it refers. There are a few key concepts to understand when discussing mortality rates.

The probability of death, often written as q_x, refers to the probability that someone aged x at the beginning of the year will die during the year. This is therefore calculated as the ratio of the number of deaths at age x during the year over the number of individuals at age x alive at the beginning of the year. This is the probability that standard mortality tables normally provide.

In contrast, the force of mortality, μ_x, is the instantaneous rate of mortality for someone at an exact age x. This concept is related to the central mortality rate, m_x, which is calculated as the number of individuals aged x that died during the year divided by the average number of individuals aged x during the year. This is the quantity often calculated as the 'raw mortality rate' because data for central exposures tends to be more commonly available, particularly for the general population.

Under the assumption that the force of mortality is relatively constant over the year and that deaths follow a Poisson distribution, since deaths are random and independent, the probability of death can be approximated with the central mortality rate as follows, though this approximation is less accurate at high ages:

$$qx = 1 - \exp(-mx)$$

The force of mortality and central mortality rate are often used interchangeably.

This chapter tends to use the generic term of mortality rate to avoid specifying which quantity is being modelled. Graduations and projections of mortality rates can reference either term, q_x or m_x, depending on the particular model chosen.

The most well-known model to capture the pattern of human mortality across ages is the Gompertz model. This model essentially assumes that mortality increases exponentially with age, or equivalently that the log of the mortality rates is linear. It provides a good fit for the ages that are most relevant for pensioners and annuitants, that is, older ages above around age 65.

There are several variations of the Gompertz model which aim to take into account varying patterns for different age groups. Makeham extended the Gompertz model to include a positive constant that better reflects the pattern of mortality for the middle ages, as it captures the excess mortality due to drivers such as accidents and infections that affect all ages (Ramonat and Kaufhold, 2018[1]; CMI, 2015[2]). Heligman-Pollard further extended the model to better capture the pattern of mortality at the youngest ages, in particular the declines in infant mortality and the "accident hump" reflecting the higher mortality of those in their late teens and twenties (CMI, 2015[2]). Beard adapted the model to improve the fit at the oldest ages, in line with the argument that the most frail of the population die sooner, and therefore the mortality at the oldest ages does not increase as quickly because the individuals surviving to these ages tend to be the strongest and healthiest (Ramonat and Kaufhold, 2018[1]).

The appropriate variation of the Gompertz model to use will depend in part on the ages for which experience is available. Often, for pensioner and annuitant populations mortality experience is only sufficient at the middle to older ages, in which case the Gompertz or Gompertz-Makeham model are likely to provide an adequate fit. If smoothing across a larger range of ages, alternative models may be more appropriate.

Another type of model that is commonly used to graduate mortality for pensioners and annuitants is the Whittaker-Henderson model. The Whittaker-Henderson model is a special case of p-spline model, which splices together cubic polynomials at specified intervals (b-splines) and applies a penalty function to increase the level of smoothness and avoid over-fitting. For the Whittaker-Henderson model, the intervals are specified over single years (Ramonat and Kaufhold, 2018[1]).

The Whittaker-Henderson model has some advantages over Gompertz-type models. First, the model can fit the particular pattern of mortality observed across all age groups. Secondly, the graduations can also be done over two dimensions to obtain consistent mortality curves across both ages and years. However, it involves significantly more parameters, and requires more judgement by the modeller. At a minimum, it requires assumptions to set the desired balance between smoothness and fit and the order of the difference equation used to express smoothness.

The modeller can use statistical tests to aid in the selection of the best-fitting model. There are several tests and metrics commonly used in this regard. One is the Pearson's chi-squared test, which indicates the likelihood that the observed distribution was due to chance. The sign test shows whether the fitted curve is equally likely to fall above or below the observed curve, and the runs test extends this to show how often the sign of this difference changes to ensure that the fitted curve is capturing the observed shape. Information criteria are also commonly used to balance goodness of fit with the desire to have a parsimonious model with fewer parameters.

3.2. Extrapolating mortality to low and high ages

Where the observed mortality is only sufficient to be calculated for central ages, as is usually the case for pensioner and annuitant populations, it is necessary to make assumptions regarding the mortality rates at younger and older ages. This is normally done by extrapolating or interpolating the graduated mortality rates from the central age range to the extreme age ranges.

3.2.1. Modelling mortality for younger ages

Simple approximations are usually favoured for the extrapolation of mortality rates to younger ages below the central age range on which mortality experience was directly graduated (e.g. below around age 50 to 60). This is also because mortality rates at younger ages do not normally have a material impact on liabilities for pensions and annuities. For many pensioner populations, it may not even be necessary to have mortality assumptions for younger ages. These would only be needed in the context of a retirement income arrangement covering the active employed population or for survivor pensions where the beneficiary could be a younger spouse or dependent child.

The easiest approach is to simply assume that the mortality rates for younger ages are the same as those for the general population. The rates for younger ages could then be interpolated with the mortality rates for central ages. This approach takes the view that the selection effect observed for central ages, where the mortality of the pensioner or annuitant population is lower than that of the general population, is not material at younger ages. This could be a reasonable assumption where the drivers of socio-economic differences in mortality tend to manifest themselves more at older ages. Indeed, this is the case for causes of death such as heart disease and lung cancer linked to smoking. Nevertheless, other causes of mortality such as suicide or drug use that can have an impact on mortality rates at younger ages may demonstrate a socio-economic gradient.

A common approach to set mortality assumptions for younger ages is to base them on a ratio of the graduated mortality rates of the pensioner or annuitant population to some reference population. This could be based on the ratio observed at the youngest age included in the graduation of mortality for central ages, for example. The reference population could be either the general population, or another mortality table developed for an insured population. This approach reflects an assumption that younger ages should demonstrate a similar selection effect as middle ages. It also maintains the shape of the mortality curve of the reference population for younger ages.

A less common approach for pensioner and annuitant mortality tables is to extend the graduation function used to smooth the central mortality rates to the youngest ages. This has the advantage of joining coherently with the central age range, however the selected model may not reasonably reflect the shape of the mortality curve observed elsewhere if it has not been fitted with the mortality for younger ages.

3.2.2. Modelling mortality for older ages

The mortality assumptions at older ages are particularly relevant for pensioners and annuitants. While the financial impact that these assumptions have for the valuation of liabilities may not be significant for a newly retired individual around age 65, the impact will increase with the age of the individual, and is relatively more material for deferred retirement income obligations beginning payments at older ages.

To establish mortality assumptions at the oldest ages above the central age range on which mortality experience was directly graduated (e.g. above ages 85-95), the chosen model needs to reflect the desired shape of the mortality curve at these ages. This requires forming a view not only regarding the extent to which mortality continues to increase with age and any maximum age to be attained, but also regarding the expected shape of the mortality curve of one population relative to another.

Significant uncertainty remains regarding the pattern of mortality at the oldest ages, even at the level of the general population. This is due first to the fact that the number of individuals who attain age 100, and more so age 110, is not sufficient to derive robust estimates of mortality, although this is gradually changing as individuals continue to live longer. Secondly, and likely more importantly, the data quality for these ages tends to be poor, with problems of delayed or misreported deaths and misrepresented ages. Given the difficulty of observing a clear pattern in mortality at these ages, opposing views regarding the pattern that it should follow at these oldest ages have emerged.

The main debate around the pattern of mortality at the oldest ages is whether mortality rates continue to increase exponentially with age, in line with the Gompertz model, or whether they decelerate at very old ages. Gavrilov and Gavrilova are the most cited proponents of the Gompertz model for old ages, beginning with their seminal work from 1991 (Gavrilov and Gavrilova, 1991[3]). They later find that mortality increases exponentially until at least age 106 (Gavrilov and Gavrilova, 2011[4]). In a study analysing data for supercentenarians (ages 110 and over), they conclude that the exponential model is still appropriate even for these very old ages (Gavrilov, Gavrilova and Krut'ko, 2017[5]). The theory of an exponential pattern of mortality at old ages is also supported by the mortality experience of some other species, such as primates and rodents, for whom the Gompertz model demonstrates a good fit (Gavrilova and Gavrilov, 2014[6]) (Bronikowski et al., 2011[7]).

Nevertheless, other studies have disagreed that the exponential Gompertz model is appropriate for very old ages, finding evidence of a deceleration of mortality beyond around age 110 and indicating that a logistic model is more appropriate. One frequently cited study concludes that the annual probability of death actually plateaus at around 50% after age 110, implying a constant force of mortality of around 0.7 (Gampe, 2010[8]). Similar patterns were confirmed in later studies. A study on several countries concluded that the force of mortality plateauing at around 0.8 for females and 1.2 for males, translating into a 55% and 70% annual probability of dying, respectively (Rau et al., 2017[9]). Nevertheless, the authors note that this conclusion was stronger for females than for males, potentially due to a lower number of observations for the latter. Another study finds evidence of mortality deceleration in Canada (Ouellette and Bourbeau, 2014[10]). Most recently, the Continuous Mortality Investigation in the United Kingdom concluded that mortality patterns in England and Wales do not follow a Gompertz pattern at very high ages, and that a pattern of deceleration is more appropriate. They suggest to assume a force of mortality at age 120 of around 1 (CMI, 2017[11]).

Gavrilov and Gavrilova argue that the observed deceleration is largely due to poor data quality at old ages (Gavrilov and Gavrilova, 2011[4]). However, others note that they study the mortality on a cohort basis, which would tend to soften any observed deceleration due to the mortality improvements over time (CMI, 2017[11]).

The view taken regarding the shape of mortality at the oldest ages implicitly informs the assumption around the ultimate age of the table. A mortality plateau at high ages implies that there is no maximum age of survival, but this is also a matter of much debate. One side argues that the human body is subject to biological limits that prevent it from surviving beyond a certain maximum age. This view was supported most recently in a study of various biomarkers, which concluded that beyond a certain age – somewhere around 120 to 150 – the body can no longer recover from negative shocks like illness (Pyrkov et al., 2021[12]). But those of the opposing view point out that past estimates of maximum life expectancy have continually been disproven, and near-linear increases in the maximum life expectancy are consistently observed (Oeppen and Vaupel, 2019[13]; Oeppen, 2002[14]).

Another consideration when modelling old-age mortality is the expected relationship of mortality across different populations. Some evidence points towards a convergence of mortality with age (CMI, 2015[15]). That is, pensioner and annuitant mortality will approach that of the general population, and the difference in mortality between different groups of the population, such as across socio-economic groups or genders, will reduce with age. The main argument behind a convergence of mortality at old ages is one of selection: the most frail tend to die earlier, and only the healthiest and strongest individuals survive to the oldest ages. As such, there is less heterogeneity in the population, and mortality converges.[2]

Regardless, the view taken regarding the expected pattern of mortality at older ages should inform the model that is used to derive the mortality assumptions at these ages. When taking the view that mortality continues to increase exponentially with age, the most common model is the Gompertz/Makeham model. When taking the view that it slows at high ages, the most common model used is the Kannisto model, which is a type of logistic model that assumes that the logit force of mortality is linear and converges to 1.

When modelling directly the mortality at the oldest ages for pensioner or annuitant populations, the model can be a different model than that used to smooth the mortality rates at central ages that better reflects the expected shape of mortality at the oldest ages. The most common option to do this is to calibrate the model to the central age range by regressing the model on the oldest ages of the central range, for example the last 10 to 15 ages, and then extrapolating mortality based on the fitted model. With this approach, statistical test such as the Pearson's chi-squared test, the sign test, the runs test, and information criteria can aid in choosing the model that also fits the shape of the age range over which the model is regressed. The central age range and the old age range then need to be joined in some manner in order to have a smooth transition of mortality with age, which is typically done by blending or interpolating the two ranges.

Alternatively, mortality can be extrapolated directly with the chosen model from the oldest age of the central range by imposing certain constraints, such as the slope of the curve, to smooth the progression of mortality from the central to old age ranges. However, with this approach additional constraints – such as specifying the desired level of mortality at some maximum age – are usually needed to ensure that the shape of the mortality curve is also reasonable (CMI, 2015[15]).

The argument of convergence favors the alternative approach of using population experience to set mortality assumptions at the oldest ages rather than modelling the old-age mortality of pensioners and annuitants directly. This is typically done by blending or interpolating the mortality experience from the central age range to the population mortality experience at old ages. In this way the shape of the mortality curve for pensioners and annuitants will be consistent with that of the general population. Nevertheless, the shape of the mortality curve for the general population will still have to have been established in light of the considerations discussed above. This view will therefore inform the choice of which population mortality table the pensioner and annuitant rates should converge to.

For the sake of practicality, mortality tables include assumptions only up to some specified ultimate age regardless of the chosen model. Mortality probabilities at this age are generally fixed at 100% to have closure, even if the model selected implies a lower rate.

3.3. Accounting for selection in pensioner and annuitant populations

When there is not sufficient mortality experience for the pensioner or annuitant population, mortality assumptions must be based on an alternative population, such as the general population. However, pensioners and annuitants tend to have higher life expectancy on average compared to the general population, so the derived assumptions must be adjusted to reflect their lower mortality risk. These adjustments are referred to here as selection factors.

Lacking the pensioner or annuitant mortality experience in a particular jurisdiction, the difference between pensioner and population mortality in another country is often used as a basis for calculating selection factors. However, this involves a significant amount of judgement, as the underlying factors affecting the extent of selection can vary widely across jurisdictions. In particular, the proportion of the population that the pensioners or annuitants represent is a major factor impacting the level of selection. The smaller the population, the larger the selection effect. For example, the selection effect is generally larger for individual or voluntary arrangements compared to group or mandatory arrangements.

Selection can also vary across ages and time. Selection effects tend to be largest for the middle ages leading up to retirement age, increasing until around age 50-60, then decreasing again. For annuities, it is also expected to be higher in the initial years of the contract, as those who feel that they are in better health are also more likely to purchase an annuity. However, this effect wears off with time and mortality eventually converges to that of the general annuitant or pensioner population. At very high ages, selection may disappear altogether as the mortality of the pensioner and annuitant populations converge with that of the general population, in line with the frailty arguments that the surviving members of the population are all less frail on average.

Selection may also depend on gender, with male populations demonstrating larger selection effects than female populations. This is in line with the observation that the differences in life expectancy across subpopulations, such as different socio-economic groups, are generally larger for men than for women.

The most common way to account for selection is to apply a multiplicative factor to the mortality curve of the reference population. This is done by applying a reduction to the mortality of the reference population by multiplying it by a constant factor. Applying a single factor to all ages has the advantage of maintaining the original shape of the mortality curve, though it is less realistic and does not account for the convergence of mortality at high ages. Applying factors that vary across age may be more in line with the observed selection effects, however this approach may distort the shape of the resulting mortality curve if these effects are largest at middle ages. Similarly, applying a larger reduction to male mortality than to female mortality could result in males having a higher life expectancy than females, which is not a realistic scenario. Factors may therefore need to be adjusted to maintain coherent mortality curves that follow the expected or desired patterns and relationships.

Basing mortality assumptions on a proxy population that is expected to have a similar life expectancy to the pensioner or annuitant population is an alternative way to account for selection. This could be based, for example, on those in the population having a certain income level or occupation. Since the criteria used can be based on the actual characteristics of the pensioner or annuitant population, this approach involves less subjective judgement than using factors that are based on the experience of a different jurisdiction.

Another less common approximation is to use the reference mortality curve but assume a younger age for the pensioner or annuitant, effectively capturing the expected difference in life expectancy between the two populations. While a simplification, this approach maintains coherence between the mortality curves of the pensioners and the population.

Occasionally, selection factors are also applied to mortality improvement assumptions that are based on the general population to account for an expectation that the life expectancy of pensioners and annuitants will improve at a faster rate than that of the general population. Such assumptions, however, involve a significant level of judgement, particularly when there is not sufficient data on which to assess a mortality trend for the pensioner or annuitant population. As such, they are normally only used when it is preferable to err on the side of conservatism.

3.4. Projecting future mortality improvements

Assumptions regarding future mortality improvements are necessary to account for the continued future increases in life expectancy. This is needed to avoid underestimating life expectancy and to ensure that there will be sufficient assets to finance future pension and annuity payments. Improvement assumptions are most often expressed as an annual percentage reduction in the age-specific probability of death. In addition to varying by gender and age, they can also vary over time.

3.4.1. Data used

While base mortality assumptions can be calibrated directly to pensioner or annuitant data, there is rarely sufficient data for these populations on which to calibrate a mortality trend. A large amount of individual data and historical years of observation are required to ascertain robust trend assumptions.

In addition, populations of pensioners or annuitants may be more prone to changes in demographic composition than the general population that could make it difficult to assess the true underlying trend over time. This could be due, for example, to regulatory changes to the pension system such as expanding coverage to low-income individuals or different employment sectors, or removing any requirement to purchase an annuity at retirement. It could also be due to an economic shock that could impact the employment – and therefore pension coverage – of certain sectors or income groups. Any external shock that changes the demographic or socio-economic composition of the pensioner or annuitant population will have ramifications for the observed mortality trend of that population.

General population mortality is therefore normally used to derive mortality improvement assumptions. This means that different data sets are often used to calibrate the base assumptions and the future improvement assumptions for pensioners and annuitants. In this case, mortality improvement assumptions are developed separately and then applied to the graduated base mortality rates.

3.4.2. Mortality projection models

The types of models most often used to generate mortality improvement assumptions vary in terms of their complexity and functionality. The simplest approach is to apply a linear regression to historical mortality rates to derive the historical trend, and apply this trend going forward. Interpolative models, often using techniques more complex than linear regression to derive historical trends, have expanded on this approach to incorporate more judgement regarding expected future trends, and in particular the expected long-term rate of mortality improvement. Age period cohort (APC) models are commonly used extrapolative models that can project patterns of mortality by age and/or generation over time, and for the most part can also model stochastic projections. These have been more recently extended to accommodate stochastic projections for multiple populations simultaneously.

Simple regression models

The simplest, but also one of the most common, approaches to derive mortality improvement assumptions is to fit a linear regression to historical mortality rates. The regression is usually performed for individual ages or small groups of ages. The resulting trend can then be extrapolated forward for those ages into the future.

While this method is easy to execute and implement, it does come with a few disadvantages. First, regressing each age or age group separately means that there is no imposed relationship of improvements by age. As such, the initial pattern of mortality by age could become distorted over time, and result in unrealistic periodic mortality curves. Secondly, as with any extrapolative model, it assumes that past trends will continue indefinitely into the future. This may not be a realistic assumption, particularly as the drivers of the reductions in mortality have changed over time and impacted various age groups differently. For example, the large improvements in childhood mortality driven by increased vaccination have largely been realised in developed countries, and therefore will not likely continue at the same pace going forward. Similarly, the significant gains in life expectancy at older ages driven by medical advances and improvements in cardiovascular mortality have only emerged more recently, and would not necessarily be fully captured when regressing over a long range of historical data. Another example is the transition from a developing to a developed country, as occurred in South Korea over the past decades, when life expectancy caught up to the level observed in developed countries. Mortality improvements would be expected to slow down once life expectancy levels observed in other advanced economies has been achieved.

Interpolative models

While extrapolative models have the advantage of being objective, projecting forward historical trends indefinitely may not be realistic. Models allowing for more judgement and user input to shape future projections are therefore becoming increasingly common. In particular, mortality improvement assumptions are often assumed to converge to a lower long-term rate of mortality improvement for all ages, with the view that the high average improvements observed over the last several decades cannot be sustained indefinitely going forward.

The simplest variation on this approach is an extension of the linear regression discussed in the previous session, where the regressed trend is assumed to gradually converge – often linearly – to a long-term rate defined by the user.

More complex models smooth the historical mortality experience across ages and over time to derive initial mortality improvement assumptions. The Whittaker-Henderson model is one common approach used to smooth historical experience along two-dimensions. The smoothed improvement rates from the latest year(s) of historical data are used as the initial improvement rates, and are interpolated with a long-term rate defined by the user, often using polynomial interpolation. The length and slope of interpolation is defined by the model, and can incorporate convergence along birth cohorts in addition to along ages. The model developed by the Continuous Mortality Investigation (CMI) in the United Kingdom is the most well-known model of this type (Box 3.2).

Box 3.2. CMI mortality projections model

The Continuous Mortality Investigation (CMI), supported by the UK Institute and Faculty of Actuaries (IoFA), is widely regarded as being a leader in mortality research and modelling. Their mortality projections model (hereafter the 'CMI model') has been used as a reference for the development of standard mortality improvement assumptions in numerous jurisdictions beyond the United Kingdom. The CMI model is updated annually with the latest mortality experience, and allows for significant tailoring of inputs by the user to shape projections in line with their judgement and expectations for specific populations.

The CMI model adopts the following process to project future mortality improvements (CMI, 2021[16]):

- Adjust historical population mortality experience for each year by adjusting the raw rates at high ages and smoothing out any observed anomalies
- Fit an Age Period Cohort Improvement model
- Interpolate mortality improvements from fitted improvements to the long-term improvement assumption along both period and cohort dimensions, where the age-period and cohort components of improvements are summed to obtain the total improvement
- Convert improvements to reference q_x rather than m_x (see Box 3.1).

The CMI model allows for the following user inputs:

- Long-term rate of improvement
- Addition to initial mortality improvements if recent improvements resulting from historical mortality are judged to be too low
- Period smoothing parameter, which controls smoothing by calendar year of historical data when fitting the Age Period Cohort model, and thereby how sensitive the model is to recent experience, in determining the initial improvement rates
- Slope of interpolation to long-term rate of improvement, to speed or slow convergence
- Length of convergence periods along age-period and cohort dimensions
- Weight given to individual years of experience, to allow for example to exclude the impact of the COVID-19 pandemic.

Convergence periods are shorter for younger ages, increasing at ages around retirement and reducing again for older ages. Improvements at high ages are assumed to converge linearly to zero between ages 85 and 110.

The biggest advantage of these types of models is that they allow users to adapt the model to align with their expectations regarding future mortality. Nevertheless, determining the value of all of the different input parameters requires significant judgement by the modeler. Some objective measures can be used to set their values, however, such as looking at the historical experience over a large historical period to set the long-term rate of improvement.

One of the main disadvantages of models is the level of user input complicates comparability. Indeed, where individual users are allowed to adapt the model, as with the CMI model, this reduces comparability when assessing the liability values for different providers.

Age period cohort models

Age period cohort (APC) models deconstruct the patterns of mortality along some or all of age, period and cohort dimensions. They can thereby project mortality in a way that should better reflect the expected dynamics of the evolution in mortality compared to assessing the historical trend by individual ages or age groups. However, they remain extrapolative models, and therefore assume that the historical trends will continue indefinitely into the future.

These models fit a structure of mortality rates across ages, and can also capture patterns linked to the evolution of mortality for specific birth cohorts where this effect is included in the model. They are typically fitted to a two-dimensional range of historical data – by age and period – beyond which the parameter determining the mortality trend over time (aka ‘kappa’) is projected forward following the fitted trend. Box 3.3 explains the technical details of APC models. There are key trade-offs related to the decisions regarding the different components of these models that require additional description in order to understand their use.[3]

Box 3.3. Age Period Cohort (APC) mortality models

Hunt and Blake (2020[17]) provide a useful formulation to understand the different components of commonly used extrapolative mortality models. These types of models can be written with the following structure:

$$\eta_{x,t} = \alpha_x + \sum_{i=1}^{N} \beta_x^{(i)} \kappa_t^{(i)} + \beta_x^{(0)} \gamma_{t-x}$$

Where:

- x = age, t = period, and t-x = year of birth;
- $\eta_{x,t}$ is a function transforming the mortality rate (see Box 3.1) to the form used for modelling;
- α_x is an age function that defines a constant shape of mortality across ages;
- $\kappa_t^{(i)}$ is the period term driving the trend of mortality over time, with $\beta_x^{(i)}$ (the age-period term) controlling the magnitude of the period effect for each age, which can be non-parametric and fitted freely by the model, or parametric and defined as a function of other variables;
- γ_{t-x} is a cohort term determining enduring mortality effects specific to a generation, with the magnitude of the cohort effect by age defined by $\beta_x^{(0)}$.

Two of the main 'families' of APC models are those following from the Lee-Carter model and those following the Cairns-Blake-Dowd model.

The Lee-Carter model takes the form:

$$\ln(\mu_{x,t}) = \alpha_x + \beta_x \kappa_t$$

It models the log of the force of mortality, includes an explicit age function, and has a non-parametric age-period term that is fitted freely by the model with no pre-specified structure.

The Cairns-Blake-Dowd model takes the form:

$$logit(q_{x,t}) = \kappa_t^{(1)} + (x - \bar{x})\kappa_t^{(2)}$$

It models the logit of the probability of death, omits an explicit age function, and includes a parametric age-period term having a structure pre-defined as a function of age.

Both types of models are easily extended to include a cohort effect.

The first aspect of an APC model to consider is which mortality rate the model will project (Box 3.1). The choice of mortality rate should reflect the format of the available data on which the model is calibrated, and therefore also which distribution the number of deaths is expected to follow. If using central mortality rates calculated based on central exposures, deaths are normally assumed to follow a Poisson distribution. If using annual probabilities of death calculated based on the initial exposures for the year, deaths are assumed to follow a binomial distribution. The family of Lee-Carter (LC) models refers to the log of the force of mortality, whereas the family of Cairns-Blake-Dowd (CBD) models uses the logit of the probability of death.

A second modelling choice is how to incorporate age effects and model the pattern of mortality across ages. The LC model includes an explicit age function that captures the constant features of the age structure of mortality over time. The age-period parameter that moderates the effect of period parameter across ages is a second freely set variable. In contrast, the CBD model eliminates the static age function and also replaces the free age-period parameter with one defined in advance as a linear function of age. The former approach can improve the fit of the model, because it has dedicated parameters that capture the shape of mortality by age both independent of time and over time. But the latter approach results in a more parsimonious model with fewer free parameters. It also allows for more flexibility to shape the model to fit certain expectations as to how time trends should impact mortality by age through the function for the age-period parameter. The LC model does not allow for this, as the single parameter groups the various drivers in past mortality trends that could change over time, so the model is not able to capture changing trends by age over time. This can also make it very sensitive to the historical period used for the calibration. However, the CBD approach of having a parametric age-period parameter potentially reduces the applicability of the model for certain age ranges. The CBD model itself, for example, is only appropriate for ages over around 50 where the assumption that mortality increases linearly with age holds.

Finally, there is a choice around the inclusion of a cohort effect. In general, this is optional and it should only be included if the historical data demonstrates clear patterns by cohort, that is certain cohorts demonstrating consistently higher or lower improvements. When relevant, the cohort effect should normally be secondary to the period effect, and therefore modeled more simplistically. To improve parsimony, the age-cohort parameter can simply be set to one. Nevertheless, cohort parameters can be challenging to fit, particularly for the youngest and oldest cohorts for whom there is less data. Furthermore, if the age-period parts of the model are poorly specified, the cohort term could simply capture the remaining noise and bias future projections.

APC models can normally accommodate stochastic projections, which are useful if the models will be used to assess longevity risk. The most common approach is to assume that the variables driving the periodic trend follow a random walk with a drift. Cohort parameters can also be projected stochastically. However, because the LC model only has a single period term, the changes in mortality each year are perfectly correlated across all ages, which is not a realistic outcome. In addition, the LC model results in relatively narrow confidence intervals. CBD-type models allow for more complex correlation structures and wider confidence intervals, and therefore may be better suited to assessing risk.

Multi-population models

While the models discussed up to now calibrate and project mortality improvements for a single population – usually a specific gender of the general population – multi-population models simultaneously project mortality for two or more related groups. These models are usually extensions of the stochastic APC models discussed in the previous section, though some are extensions of deterministic approaches involving regression and smoothing.

There are two main reasons for using multi-population models rather than single-population models. The first is to overcome the lack of data for a small population of interest, such as a small pensioner population, by modelling its mortality in reference to a larger, but related, population. The second is to ensure coherent mortality projections for related populations, such as for males and females, or any other sub-populations of a larger population where one group is expected to consistently have higher mortality than another.

Modeling small data sets in reference to a larger population can result in more robust estimates of future improvement assumptions. Relatively small data sets, even at the general population level, can be problematic for calibrating mortality projection models, as the higher levels of volatility in the historical data can make long-term projections highly sensitive to the choice of input data. Nevertheless, calibrating a multi-population model still requires a sizeable data set for the target population, which is not often the case for annuitant and pensioner data sets. Villegas et al. (2017[18]) suggest that 8-10 years of historical experience with an annual exposure of 20 000-25 000 individuals for the target population is necessary to calibrate a multi-population model.

Numerous extensions of the Lee-Carter model to multiple populations have been proposed. There are three main approaches to doing so (Villegas et al., 2017[18]):

1. Calibrate two models separately for the reference and target populations, then assess their dependence
2. Assume a common parameter that drives the periodic trend for both populations, along with population specific parameters, or the "Joint-κ model"
3. Jointly estimate the two models using co-integration techniques

There are various considerations in choosing which approach to go with. The first approach ignores interdependence, so additional assumptions are still required regarding the relationship of the trend of the two populations to obtain coherent and integrated projections (Villegas and Haberman, 2014[19]). The second approach is the most common and is more transparent, parsimonious, and consistent across populations. It also allows for first calibrating a model for the reference population, and subsequently calibrating a model for the target population, which is appropriate where the reference population is substantially larger. However, simplified versions have as a disadvantage that the target and reference populations will always experience the same mortality improvements, which is unrealistic. Extensions have therefore included an additional term to allow for stochastic deviations in the mortality of the reference population from that of the target population, even if the trends for the two populations tend to converge in the long run. For the third approach, joint-estimation of the parameters is difficult with short data sets, and is better adapted to larger sets of data where the two populations are of similar size, which is normally not the case.

Academics have also proposed similar extensions of the Cairns-Blake-Dowd model (Villegas et al., 2017[18]). Additional approaches, such as the Saint model used in Denmark, aim to model the spread between the two populations directly, while limiting any long-term divergence of the mortality of the two populations (Jarner and Kryger, 2013[20]).

Model selection should also consider how the model will be used. If the purpose is only to establish mortality assumptions with which to value liabilities, there is no need to model additional deviations between the reference and the target populations. However, if there is a need to assess longevity risk, and in particular the risk of deviations in experience between the two populations, the model needs to allow for a non-perfect correlation between them. The additional advantages and drawbacks of the Lee-Carter and Cairns-Blake-Dowd models discussed in the previous section also apply here.

A final drawback of multi-population models currently used in practice is that they most often assume no long-term divergence between the target and the reference populations. Therefore, alternative time series models would need to be considered if the two trends are expected to diverge, as could be the case with a high-income annuitant population relative to the general population. This would increase the complexity of the model, as well as the judgement involved in its calibration.

3.4.3. Old-age improvements

There is not usually sufficient historical data on which to calibrate mortality improvements for very old ages, typically over 85-90, even for the general population. As such, setting assumptions at these ages requires significant judgement regarding the magnitude of improvements and the pattern of improvements across ages.

There is some evidence of positive mortality improvements at the oldest ages. Japanese women – who have long been world leaders in terms of life expectancy – experienced accelerating mortality improvements for ages 80 to 99 since the 1960s, reaching annual improvements exceeding 3% in the early 2000s (Rau et al., 2008[21]). Positive improvements have been observed in Japan even beyond age 100, with women aged 100 to 104 experiencing improvements exceeding 1% (Robine, Saito and Jagger, 2002[22]). Accelerating patterns, albeit at lower magnitudes, were also observed for age 80 to 99 in East Germany and Italy (Rau et al., 2008[21]). Combined experience in France, Japan, Switzerland and Sweden from the 1980s to the 1990s also show significant positive improvements, though declining with age, with females and males aged 95-99 experiencing a material average annual mortality decline of 1.25% and 0.9%, respectively (Vaupel, Rau and Jasilionis, 2006[23]).

Nevertheless, positive improvements at the oldest ages have not been observed in all countries. Women over 90 in the United States do not seem to have experienced any improvements over the 1990s, though improvements picked up slightly over this period for men (Rau et al., 2008[21]). Mortality for centenarians in the United States seems to have plateaued since the 1950s (Gavrilov, Gavrilova and Krut'ko, 2017[24]). Mortality has also plateaued for centenarians in Sweden and the United Kingdom (Drefahl et al., 2012[25]) (CMI, 2015[15]). Slightly negative improvements have been observed at the oldest ages in Canada (Adam, 2012[26]).

There does, however, seem to be consistent evidence that mortality improvements decline with age for the oldest ages. A common approach for mortality tables is therefore to impose a pattern for this decline, often simply a linear convergence to 0% at a certain age. Assuming no mortality improvements beyond a certain age is consistent with the view that there is a limit to life expectancy and that we will not observe increases in the ultimate age of mortality. Otherwise, mortality improvements could be assumed to reduce to some positive constant value.

An alternative approach when APC models are being used would be to extrapolate the calibrated age effect to extend to older ages (Dowd, Cairns and Blake, 2019[27]). This allows for less subjectivity in setting the assumptions for high ages, and results in future projections of mortality that remain consistent across ages.

3.5. Recent innovations applied to the development of mortality assumptions

Some recent proposals to establish mortality assumptions for pensioner or annuitant populations have sought to exploit developments in technology and data analysis to overcome some of the limitations of existing models and the challenge of the lack of data. The proposals are using advanced techniques, often employing machine learning, to improve both the calibration of base rates and the projections of future mortality.

Some approaches aim to inform the development of the base mortality rates. One example looks to overcome the lack of annuitant mortality data. The methodology used to develop a mortality table for annuitants in Cambodia relied on data science to train various models using insured lives mortality tables from the region combined with macroeconomic variables such as GDP, which is strongly correlated with life expectancy (Yeo Chee Lek, 2020[28]). Another example applies machine learning techniques to improve the assessment of differences in mortality across socio-economic groups (Wen, 2019[29]). The analysis groups geographic areas in England by their common socio-economic characteristics in order to model difference in mortality for these groups. The techniques aid in the selection of the most relevant variables on which to base these groupings, and therefore leads to more homogenous groupings than simply ranking the regions by decile would produce.

Innovative proposals are also being put forward to improve the estimation of future mortality. One uses machine learning to assess the adequacy of fitted models through back testing to better identify their shortcomings and improve their fit (Deprez, Shevchenko and Wüthrich, 2017[30]). Similarly, another proposal employs machine learning algorithms to better identify historical patterns in mortality and improve the goodness of fit of a Lee-Carter model (Levantesi and Pizzorusso, 2019[31]).

3.6. Concluding remarks

Developing mortality tables for pensioners and annuitants involves several steps. To calculate the base mortality rates, the raw mortality rates are graduated at central ages. The rates must then be extrapolated to younger and older ages. The assumptions must also account for any selection effect and the difference in mortality between the pensioner or annuitant population and the population on which the estimated rates were based.

Assumptions for future mortality improvements are also necessary. Numerous models exist to project future mortality, including simple regression models, age period cohort models such as the Lee-Carter and Cairns Blake Dowd models, interpolative models such as the CMI model, and multi-population models. Separate assumptions are necessary for improvements at the oldest ages since historical data at these ages are limited. A common approach is to assume a linear decline to zero at a terminal age.

Developing mortality tables for pensioners and annuitants therefore requires numerous modelling choices. These decisions involve trade-offs with respect to model complexity and the level of judgement required. They also require taking a stance on expected mortality patterns, both current patterns for ages where less data may be available as well as how future mortality improvements will evolve. Choosing the appropriate model will therefore always require a certain level of expert judgement.

Understanding the trade-offs involved and what they imply for the expected mortality patterns should help regulators and supervisors assess whether the process to establish the mortality tables for pensioners and annuitants is appropriate for a given context.

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Notes

[1] Getting to this point involves a significant amount of work to clean the data and calculate the correct number of deaths and exposures, but this chapter does not cover the details of these preparatory steps for modelling mortality.

[2] This same argument supports a model of decelerating mortality at older ages, with the frailer members of society passing away earlier and leaving a more strong and homogenous group of survivors with lower mortality.

[3] The discussion that follows largely draws from Hunt and Blake (2020[17]).

4 Global approaches to developing standard mortality tables for the provision of retirement income

Jessica Mosher

This chapter reviews the mortality tables developed and used in 40 jurisdictions in the context of retirement income provision. It looks at how the tables are used in practice, and the methodologies used to develop the tables. It also compares the life expectancies calculated from the tables that are available compared to those of the population.

This chapter reviews the standard mortality tables developed and used in 40 jurisdictions, that is in all 38 OECD jurisdictions as well as Brazil and Peru. It first looks at whether standard mortality tables exist across jurisdictions and how they are used in practice. It then considers the methodology used to establish the base mortality assumptions, that is the level of mortality observed today. It subsequently discusses the different ways that the tables account for mortality improvements and the difference in modelling techniques employed. Finally, it compares the life expectancies calculated from the tables that are available compared to the general populations. Annex 4.A summarises the features of the standard mortality tables reviewed, and Annex 4.B provides additional details by jurisdiction.

4.1. The development and use of standard mortality tables

The institutions most often responsible for the development of the standard mortality tables are regulatory/supervisory bodies, actuarial associations, or industry associations. Providers are often required to use these tables for particular valuations, at least as a minimum benchmark. Statistical associations and academics may also produce mortality tables used by providers, particularly where markets are less developed. However, these tables are normally only used as a reference for providers to benchmark any mortality assumptions they may develop themselves.[1] Table 4.1 summarises the jurisdictions in which each type of institution is responsible for the development of (or takes the initiative to develop) a standard mortality table. It also indicates whether providers are required to use the tables developed as a reference, even if they may be allowed to use their own assumptions if deemed to be more appropriate.

Table 4.1. Institutions developing standard mortality tables and whether providers are required to use them

Regulator/Supervisor	Actuarial Association		Industry Association		Statistical Institute	Academic
Required	*Required*	*Not required*	*Required*	*Not required*	*Not required*	*Not required*
Belgium	Canada	Australia	Korea	Brazil	Estonia (population life tables)	Czech Republic
Chile	France	Austria	Norway	Germany (pensions)	Mexico (pensions + improvements)	Hungary (studies only)
Colombia	Germany (insurance)	Italy (pensions)	Slovenia	Italy (insurance)	Poland (population life tables)	Türkiye
Costa Rica	Iceland	Ireland	Spain	Switzerland	Portugal (pensions)	
Denmark	Japan (insurance)	New Zealand (studies only)			Slovak Republic (population life tables)	
Finland (life expectancy coefficient)	Netherlands	United Kingdom			Switzerland (improvements for pensions)	
Israel	Portugal (insurance)					
Japan (pensions)	United States					
Lithuania						
Luxembourg						
Mexico						
Peru						

Note: Required tables are often as a minimum valuation standard, and providers may still choose to use more conservative assumptions or alternative assumptions where justified.

For jurisdictions where separate tables exist for pension and annuity providers, different institutions may develop the standard mortality tables. This is the case in 6 of the 11 jurisdictions having distinct standard mortality tables for pensions and annuities.[2]

In jurisdictions where the regulatory or supervisory body is responsible for the development of mortality tables, providers are always required to use them in some manner. This is the case in 12 jurisdictions, though while the Finnish Government defines the mortality assumptions used to calculate pension income, these assumptions are not a fully-fledged mortality table, but rather a longevity coefficient that is calculated to adjust the retirement income of each subsequent cohort of pensioners to reflect recent improvements in life expectancy. In some jurisdictions, the regulator or supervisor only develops assumptions for either insurance or pensions, even where standard tables exist for both. For example, the Japanese regulator determines the tables to be used by pension providers.

Actuarial associations are the most common body taking responsibility for developing standard mortality tables. These tables are required to be used by providers in the majority of the 14 jurisdictions where this is the case. Here again, the associations may only develop mortality assumptions for either insurance or pensions. The actuarial associations of Germany and Japan develop assumptions used by annuity providers, whereas those in Italy develop the assumptions used by occupational pension providers. The table commonly used by annuity providers in Portugal was developed by the actuarial association in Switzerland.[3] Where the tables are not required, they often serve as a benchmark or reference for providers to set their own assumptions, as in Australia and Ireland. While the New Zealand Society of Actuaries performs benchmark mortality studies that annuity providers can use to develop their own assumptions, they do not produce themselves complete mortality tables.

Industry associations are also commonly involved in the development of standard mortality tables. They are not required to be used by providers in half of the eight jurisdictions where this is the case.

It is less common for statistical institutes to be the main body producing a standard mortality table used by pension and/or insurance providers. The population life tables serve as a reference for providers in Estonia, Poland, and the Slovak Republic, but the annuity markets in these jurisdictions are not developed. In Portugal minimum funding requirements are based on tables for the French population, though in practice providers tend to use more recent tables than those required. In Switzerland, the mortality improvements commonly used by pension providers are developed in co-operation with the Federal Office of Statistics, although the base assumptions are developed by industry associations.

In a small number of jurisdictions (Czech Republic, Hungary, and Türkiye) academics have taken the initiative to develop studies or standard tables for the pensioner or annuitant population that providers can use as a benchmark. This has mainly been in response to the lack of existing mortality studies for these populations, and providers are not required to use these tables.

The majority of jurisdictions (23) have a standard mortality table that either pension or annuity providers are required to use. However, five of these jurisdictions do not require that those tables account for future mortality improvements (Colombia, Finland, Japan (pensions), Luxembourg, Portugal).

Usually, where providers are required to use standard mortality tables, they serve as a minimum basis for the calculation of reserves or technical provisions and funding requirements, though providers can adapt these assumptions if they are inadequate. However, the standard tables can also serve as a minimum requirement for establishing the retirement income that providers can pay. This is the case in Belgium, Finland, France, and Norway. The standard mortality tables also serve as the basis for calculating the allowed programmed withdrawals from pension funds in Chile, Colombia, and Peru. In the United States, the standard mortality tables are used for the calculation of the premium that pension providers must pay to be covered by the pension protection fund in addition to funding calculations.

4.2. Base mortality assumptions

The mortality assumptions for annuitants and pensioners are usually developed in two parts. The first step is to develop the base mortality rates that reflect the level of mortality at the time of the observed mortality experience. The second step is to develop assumptions around how mortality rates will decline over time, and thereby how life expectancy will improve going forward.

Ideally, there will be sufficient pensioner or annuitant data on which to calculate the current base mortality assumptions so that the estimated rates will accurately reflect the mortality of the population to which the assumptions will apply. The majority of jurisdictions (23) are able to develop mortality assumptions based directly on the pensioner and/or annuitant populations.[4] However, this tends to be more common for pensioner populations, as annuitant populations tend to be much smaller.

4.2.1. Mortality at central ages

There is usually only sufficient mortality experience for pensioners or annuitants to calculate mortality rates for a central range of ages, typically within the rage of ages 50-95. For ages younger than this, mortality rates tend to be too low to observe a sufficient number of deaths, and older than this the number of observations tends to be too low for estimates to be reliable.

The raw mortality rates calculated from the experience of these populations for the central age range typically demonstrate significant volatility across ages due to their smaller size, and therefore need to be smoothed to ensure that mortality rates increase monotonically with age, in line with biological expectations. This is done using a smoothing function that allows for an exponentially increasing curve. The most common functions used are Gompertz and Whittaker-Henderson functions and their variations.

4.2.2. Extrapolation of mortality to younger and older ages

Mortality rates at younger ages are not always needed in the context of pensions and annuities, however many tables do include mortality assumptions for younger ages. The most common way is to apply an adjustment factor to the population mortality at younger ages to reflect the difference in mortality between the general population and the pensioner/annuitant population (e.g. German annuitants). Factors can also be applied to other mortality tables that reflect the expected shape of mortality at younger ages. The pensioner table in Canada, for example, applies a factor to an older mortality table to determine the mortality rates for younger ages. These factors would be based on the ratio of the pensioner/annuitant mortality to the mortality being referenced at other age(s). Alternatively, the mortality at younger ages can be extrapolated directly from the central age range (e.g. Brazil). In contrast, tables in the United Kingdom assume that the mortality at younger ages is the same as that observed in the population, under the assumption that the selection effect at younger ages is not material.

Mortality assumptions at the oldest ages are more relevant and important to adequately estimate in the context of retirement income. They are usually set using some sort of extrapolation technique. Many tables use models that are calibrated on the smoothed mortality rates of the last 10-15 ages in the central age range, and therefore result in a shape of mortality at the oldest ages that is cohesive with that for the central ages (e.g. Brazil, Chile, Costa Rica, France, Japan, Peru, and the United States). However, these types of models result a wide range of possible outcomes. As such, constraints are often imposed, such as a maximum age (e.g. France) or a maximum mortality rate (e.g. United States). Alternatively, mortality can be interpolated from the last ages in the central age range directly to a desired level of mortality (e.g. Colombia). A final approach is to graduate mortality rates from the central age range to an alternative set of mortality rates, such as the general population (e.g. United Kingdom) or an alternative mortality table (e.g. Canada pensioners). This latter approach is consistent with the assumption that mortality rates of different populations tend to converge with age, as the selection effect wears off and only the least frail of every population have survived.

Normally tables assume an ultimate age beyond which there will be no survivors. The most prevalent ultimate age assumed is 120 (Austria, Germany (insurance), Italy, the Netherlands, Slovenia, United Kingdom, and the United States), although a few jurisdictions assume 115 (e.g. Canada, Costa Rica, and Spain) and others assume an even older age (e.g. Belgium, France, and Japan). The minimum age assumed is generally 110 (e.g. Australia, Chile, Colombia, Mexico, and Peru), although the ultimate age for the table in the Czech Republic is lower at 103.

4.2.3. Accounting for selection effects

Where annuitant or pensioner mortality data is not sufficient to derive mortality assumptions directly from these populations, mortality rates for an alternative population may be used, which is typically the general population of the jurisdiction. In this case, a selection factor is normally applied to account for the lower pensioner/annuitant mortality compared to that of the general population. The selection factor is typically based on the experience in other jurisdictions, in particular the experience in Germany, Switzerland and the United Kingdom.

However, the reference population for which a selection factor is needed is not always the general population of the jurisdiction in which the tables apply. For example, Türkiye makes an adjustment to the mortality rates of all insured people to account for the difference between annuitants (who live longer) and those with life insurance (who die earlier) based on experience in the United States.[5] A few jurisdictions tend to reference the population outside of their own jurisdiction, for example tables in Luxembourg refer to the European population, and tables used in Ireland tend to benchmark tables developed in the United Kingdom. Portuguese pension providers tend to rely on the tables for the French population, and their annuity providers on tables developed for Swiss group annuitants.

Some jurisdictions use alternative approaches to account for the selection effect. Rather than relying on experience in other jurisdictions to account for selection, the table for the centralised annuity provider in Lithuania approximates the selection effect by calibrating the mortality assumptions to the pensioners in the public system falling within the top two quintiles of pension income. Belgium takes an approximate approach by specifying an age correction, which assumes that an annuitant aged 65 will have the mortality of a younger Belgian.

Where selection is accounted for with a factor applied to the reference population mortality, the factors applied can vary by age and gender. Selection factors for the annuitant tables in Austria and Slovenia are gender distinct and decrease from around age 60, that is the annuitant mortality approaches that of the reference population after age 60. In contrast, the selection effect for Tax Qualified Pension Plan pensioners in Japan is a flat 15% for all.

Some jurisdictions do not apply selection factors despite the reference population being the general population. This is usually based on the justification that there is very high coverage of the system and the pensioner/annuitant population mortality should be very close to that of the whole population (e.g. Costa Rica, Finland, Iceland, the Netherlands).

4.2.4. Granularity of assumptions

At a minimum, all standard mortality tables have distinct assumptions for males and females.

Tables for the insurance sector more broadly usually distinguish assumptions by type of insurance, namely death and survivor (i.e. annuity) insurance (e.g. Brazil, Japan, the Slovak Republic) or group and individual (e.g. Austria, Sweden).

Different assumptions can also apply depending on the type of beneficiary. Some tables distinguish between active or deferred members and pensioners (e.g. Israel and Korea) or pensioners and their spouses/beneficiaries (e.g. Chile and Peru). Others allow for adjustments based on proxies for socio-economic status like annuity amounts, income, or sector of employment (e.g. Canada, the United Kingdom, and the United States).

4.2.5. Risk margins

Some standard mortality tables may also include risk margins on top of the best estimate mortality assumptions to ensure prudence in valuations and reserving. This can depend on the purpose of the calculation using the tables, as in Japan where additional reductions must be applied to the EPI table for wind-up valuations. While it is more common to apply a margin directly to the base mortality rates, some jurisdictions also apply margins to the improvement rates (e.g. Austria, Germany, and Norway).

4.3. Mortality improvement assumptions

Most standard mortality tables include not only base assumptions but also assumptions regarding expected future mortality improvements to account for future increases in life expectancy.[6] However, 12 jurisdictions have not produced standard mortality improvement assumptions for either pensioners or annuitants (Brazil, Colombia, Estonia, Finland, Greece, Hungary, Luxembourg, New Zealand, Poland, Portugal, the Slovak Republic, and Türkiye). In addition, while improvement assumptions in Japan are developed for annuitants, pensioner tables do not account for them. Improvement assumptions are usually developed as part of the standard base table, but are occasionally developed separately and applied to a base table (Australia, Canada, Israel, Mexico, Switzerland, the United Kingdom, and the United States).

4.3.1. Data used

No standard mortality table calibrates the improvement assumptions solely on the pensioner or annuitant population directly.[7] The majority base the mortality improvements on the historical mortality experience of the general population of the jurisdiction. However, England and Wales use improvements calibrated specifically to this population rather than the entire UK population. Occasionally, larger populations are considered, as is the case for the ATP in Denmark as well as in the Netherlands, who both use Western European experience to calibrate their improvement assumptions. France is one jurisdiction that uses the mortality experience of the annuitant population, where they apply a relational model that considers how the mortality of the annuitant population has evolved relative to the general population to project expected trends.

4.3.2. Projection model

As mortality improvements involve future predictions of how mortality will evolve, they must be estimated from a model that projects future mortality based on past experience. The approaches taken vary in their complexity, the underlying data used, and the extent to which user inputs shape the projections. Table 4.2 summarises the approaches taken by different jurisdictions to account for mortality improvements.

One of the most common, and simplest, approaches is to extrapolate future mortality rates based on a linear regression of historical log mortality rates. This type of regression is normally done by age or age group, and effectively assumes that the historical trend observed over the regression period will continue in the future. Eight jurisdictions adopt this approach to establish mortality improvement assumptions.

Alternative extrapolative models, such as Age Period Cohort (APC) models, which explicitly take into account the age-structure of mortality improvements, are also quite common and are implemented in eight jurisdictions. The most common of these models is the Lee-Carter model and its extensions, implemented in six jurisdictions (Chile, Costa Rica, Italy, Peru, Slovenia, and Sweden). The Lee-Carter model is a simple model, which can also be used for stochastic simulations, and incorporates age-dependent parameters as well as a parameter driving the overall mortality trend for all ages. While the table used by pension providers in Austria relies on an alternative methodology – a Markov Chain Monte Carlo method – the results are very close to those using the Lee-Carter model. Iceland uses the Cairns-Blake-Dowd (CBD) model, which is adapted primarily for older ages and has an overall trend parameter as well as a parameter that determines the slope of the mortality across ages in any given year.

Table 4.2. Types of models used by jurisdictions to account for future mortality improvements

Linear extrapolation of log mortality	Other extrapolative model	Graduation/Interpolation	Multi-population	Demographic projections	Approximation
Australia	Austria (pensions)	Austria (insurance)	Denmark (ATP)	Italy (Insurance)	Belgium (MR-FR)
Belgium (Plan3)	Chile (MT-2014)	Canada	France	Mexico	Japan (insurance)
Czech Republic	Costa Rica	Chile (TM-2020)	Netherlands	France (IA2015)	Korea
Denmark (FSA)	Iceland	Ireland			
Germany	Italy (pensions, various models used)	Israel			
Lithuania	Peru	Switzerland (Menthonnex)			
Norway	Slovenia	United Kingdom			
United States (insurance)	Sweden	United States (pensions)			

Note: The Chilean TM-2020 table refers to the approach taken for the draft published for consultation.

One approach that has more recently been gaining popularity is the interpolation of improvement rates between recent improvements – derived from a graduation of historical mortality experience – and some assumption regarding a lower long-term rate to which improvements should converge. This approach was initially advanced by the model developed by the Continuous Mortality Investigation (CMI) of the Institute and Faculty of Actuaries (IFoA) in the United Kingdom. Variations on this approach have been adopted in seven jurisdictions (Austria (insurance), Canada, Chile, Ireland (CMI), Israel (CMI), United Kingdom (CMI), United States (pensions). The Menthonnex model is an alternative graduation approach and is used by pension providers in Switzerland. It relies on time-dependent variables to model the age structure of mortality over time, and implicitly assumes the ‘rectangularisation’ of survival over time, that is a higher concentration of deaths around the modal age of death. As such, the model results in slowing mortality improvements over time.

Some jurisdictions implement multi-population models to be able to calibrate expected trends that account for the relationship between the evolution of multiple sets of mortality rates. Multi-population models are used in three jurisdictions. The ATP in Denmark and the Royal Dutch Actuarial Association use stochastic models that model short-term deviations between the mortality experience of their respective general populations and the larger Western European population, with the assumption that the difference in the trend of these two populations will eventually stabilise. The Dutch model also ensures coherence between the projections of the male and female populations. While the French tables also rely on a multi-population model, they take a different approach with the objective to account for any differences in the evolution of mortality between the general French population and that of the annuitants.

Other jurisdictions rely on the mortality projections of the statistical institutions which generally account for other demographic factors, namely fertility and migration, though these projections may be somewhat adapted. The latest tables developed by the Institute of Actuaries in France use a relational model referencing the mortality projections of Institut National de la Statistique et des Études Économiques (INSEE). The tables developed for insurers in Italy rely on ISTAT projections along with a Lee-Carter model. In Mexico, the tables use mortality improvement assumptions based on the projections of CONAPO.

Less common are simplified and approximate approaches to indirectly account for mortality improvements. Annuity providers in Japan and Korea use tables that apply a static factor to reduce the base mortality rates estimate in the level of life expectancy that historical trends in mortality improvements would imply for the future. Belgium takes an alternative approach for the MR-FR table by specifying an age reduction of five years that intends to account for both selection and future mortality improvement.

Occasionally, additional improvements are added to those implied by the model to account for potential selection effects and the expectation that pensioners or annuitants may experience higher mortality improvements than the population on average. The table used by annuity providers in Germany includes an additional 0.2% annual improvement, and the one used by annuity providers in the United States includes an additional 0.4% annual improvement for ages 65-82, grading to an additional 0.2% for ages 87 and over.

4.3.3. Convergence to a long-term improvement rate

Mortality improvements developed for standard mortality tables are moving more and more towards an approach that assumes that the recently observed mortality improvements will eventually converge to a lower long-term rate. This reflects the expectation that the relatively high improvements observed particularly over recent decades are not sustainable in the longer term. Table 4.3 summarises assumptions used by different tables regarding the long-term rate of improvement.

Table 4.3. Long-term mortality improvement assumptions for standard mortality tables

Jurisdiction	Model	Long-term improvement rate
Austria (insurance)	Lee-Carter	Halves initial value over 100 years
Canada	WH graduation + interpolation	1% over 20 years for age 60-80, grading down linearly to 0.2% at age 100 and 0% at age 105
Chile	WH graduation + interpolation	1% over 20 years
Denmark (ATP)	Saint model	Western European trend
Germany (Insurance, 2nd order)	Linear extrapolation	75% of population experience1972-1999 (1-3%); period of convergence is user input
Iceland	CBD	Decline over years 20 to 45 to 1%
Ireland	CMI	User input (default of 1.5%)
Israel	CMI	1.25% for males, 1.5% for females
Lithuania	Linear extrapolation	Lithuanian experience over 1995-2017 over 20 years
Netherlands	Li-Lee	Average difference with European population since 1983
Switzerland	Menthonnex	Implicit – allows for the rectangularisation of the curve
United Kingdom	CMI	User input (default of 1.5%)
United States (pensions)	WH graduation + interpolation	1.35% over 10/20 years horizontal/diagonal convergence

Note: Abbreviations used are: Whittaker Henderson (WH), Cairns Blake Dowd (CBD), Continuous Mortality Investigation (CMI). The Chilean table refers to the approach taken for the draft TM-2020 published for consultation.

In in their basic form, extrapolative models rely on the assumption that mortality improvements observed in the past will continue indefinitely into the future. However, some jurisdictions adapt these models to rely on the model outputs for the short term only, and interpolate the mortality between these assumptions and an assumed long-term rate. For Germany and Lithuania, who both rely on linear extrapolative models, long-term improvement assumptions are based on longer-term historical trends in the respective jurisdictions. In Germany, this is calculated as 75% of the historical trend over the period 1972-99, subject to minimum and maximum boundaries of 1% and 3%. In Lithuania, the long-term rate is calculated as the historical experience over 1995-2017. The long-term improvement assumption in Iceland is defined as 1%.

In Switzerland a long-term rate is not explicitly set, rather the interaction of the model parameters results in a gradual slowdown of mortality improvements. The model used by annuity providers in Austria does not set an explicit long-term rate either, rather the model assumes that the initial mortality improvements will be halved over the next 100 years to avoid unreasonably low mortality rates in the long term.

Jurisdictions using an interpolative approach to project graduated historical experience to a long-term improvement rate explicitly set that rate by definition. In Canada and Chile, the rate is set to 1%, and to 1.35% for the United States. In Ireland and the United Kingdom – who rely on models developed by the CMI – the long-term improvement assumption is input by the user, though for the latest CMI model the default assumption is 1.5%. Israel also relies on the CMI model, but sets long-term improvement assumptions at 1.25% for males and 1.5% for females.

Multi-population models can incorporate a long-term assumption regarding the relationship of mortality improvements between populations. The models used in Denmark and the Netherlands reference Western European experience as a basis for their long-term improvement assumptions, and assume that the local mortality improvements will mirror those of larger and similarly developed countries in the long term.

The period of convergence is a key assumption for models explicitly assuming a long-term improvement rate. This is set at 20 years in Canada and Chile. In Iceland, convergence is delayed for 20 years, at which point improvements are assumed to converge to the long-term rate over a period of 25 years. For improvement assumptions used by pension providers in the United States, the convergence period is 20 years across cohorts but only 10 years across periods. The period/cohort convergence periods also vary for the CMI model used in the United Kingdom, though the period length and shape can be adjusted by the user and younger cohorts are subject to shorter convergence periods.

4.3.4. Mortality improvements at older ages

As with setting the base mortality assumptions, mortality improvement assumptions are often only directly calibrated for a range of central ages due to the lack of sufficient data at older ages on which to establish a robust trend. In general, mortality improvements at older ages are assumed to be lower than those for central ages.

A common approach is to assume a linear decline in mortality improvements to 0% at a certain age. This is done in Canada, Chile, Iceland, Peru, the United Kingdom and the United States. The tables used by annuity providers in Austria assume rather an exponential decline. In contrast, the tables used by annuity providers in Germany maintain positive improvements at older ages, specifying a minimum initial mortality improvement of 1% and a long-term improvement of 0.76%.

4.3.5. Dimension of the mortality table

The dimension of the mortality table is a consideration with respect to the complexity of using the table to model and value liabilities. While models now can typically incorporate two-dimensional mortality assumptions, some jurisdictions continue to reduce tables to a single dimension. The most common approach is to have a single dimensional base mortality table (rates by age for a given year) coupled with a two-dimensional mortality improvement scale (annual improvements by age and year). This allows improvement rates to change over time, in particular where lower long-term rates are assumed. Where the population used to calibrate the base mortality and mortality improvements are the same, the model can be fully integrated and produce both current and future mortality rates directly (e.g. in the Netherlands). Having a single-dimensional improvement scale, where improvements by age remain constant in the future, is also common.

Table 4.4 summarises the different types of approaches and provides examples of the tables taking each approach.

The most common approach is to have a single dimensional base mortality table (rates by age for a given year) coupled with a two-dimensional mortality improvement scale (annual improvements by age and year). This allows improvement rates to change over time, in particular where lower long-term rates are assumed. Where the population used to calibrate the base mortality and mortality improvements are the same, the model can be fully integrated and produce both current and future mortality rates directly (e.g. in the Netherlands). Having a single-dimensional improvement scale, where improvements by age remain constant in the future, is also common.

Table 4.4. Different formats for the dimensions of mortality tables

Type	Description	Accounting for improvements	Example
Period table	Mortality rates by age for a single year	Age-shift	Belgium (MR-FR)
Cohort table	Mortality rates by age for a single cohort	Cohort mortality + age-shift	Slovenia
Period table + single dimension improvement scale	Mortality rates by age for a single year + annual mortality improvements by age	Improvements by age applied each year in the future	Peru
Period table + 2 dimensional improvement scale	Mortality rates by age for a single year + annual mortality improvements by age and year	Improvements by age applied each year in the future	United Kingdom
Fully integrated	Model produces both current and future mortality	Usually stochastic projection of the population mortality with no additional selection	Netherlands

A few jurisdictions, however, still reduce the mortality table to a single dimensional base table even when they intend to account for future mortality improvements. These are sometimes provided only as alternative assumptions where it is not possible to use a two-dimensional table, as in the Czech Republic, Italy and Slovenia. The reduction of the tables to a single dimension is typically done using the age-shift method, where the mortality rates for a specific cohort are specified, and an age adjustment is applied to other cohorts. For example, the mortality of a 65-year-old from the 1960 cohort could be equivalent to the mortality of someone two years younger from the 1955 cohort to account for the higher life expectancy of the younger cohort. In contrast, the Belgium MR-FR table is a periodic table, where an age shift of five years is applied to account for both the selection factor and future mortality improvements, i.e., a 65-year-old is assumed to have the same cohort life expectancy as the period life expectancy of a 60-year-old today.

4.4. Life expectancies at age 65

Comparing the life expectancies given by the standard mortality tables for pensioners and annuitants with the life expectancy of the general population shows the large impact that selection and mortality improvements can have.[8] Selection refers to the tendency for the pensioner or annuitant population to have a higher life expectancy than the general population, and mortality improvements refer to the expected future gains in life expectancy for each cohort. Table 4.5 shows the life expectancies at age 65 for the general population and standard mortality tables in each jurisdiction. The life expectancy for the standard tables is provided both accounting for future improvements (cohort) and without them (period). The difference between the period life expectancy of the standard table and the population life expectancy is the impact of selection.

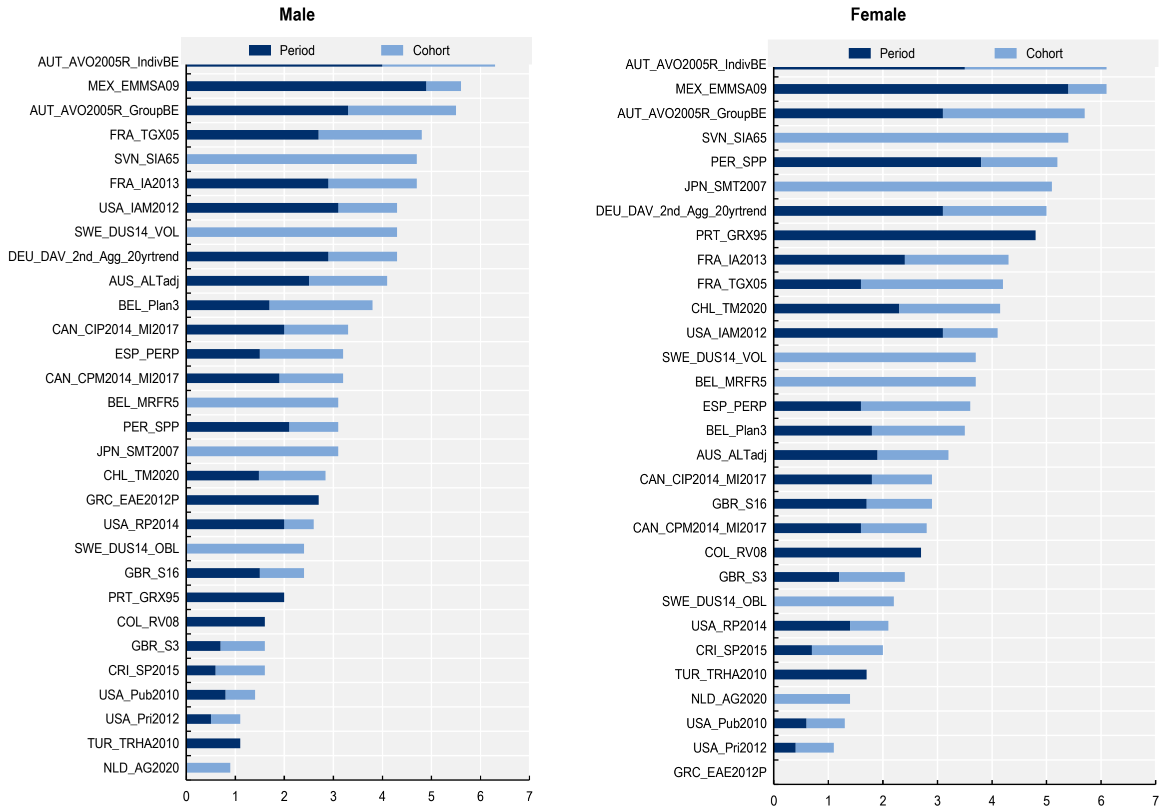
Table 4.5. Life expectancy at age 65

Year	*Country ISO_Table Name*	Male			Female		
		Population	*Period*	*Cohort*	*Population*	*Period*	*Cohort*
2019	AUS_ALTadj	20	22.5	24.1	22.7	24.6	25.9
2019	AUT_AVO2005R_GroupBE	18.7	22	24.2	21.7	24.8	27.4
2019	AUT_AVO2005R_IndivBE	18.7	22.7	25	21.7	25.2	27.8
2019	BEL_MRFR5	18.9		22.0	22.1		25.8
2019	BEL_Plan3	18.9	20.6	22.7	22.1	23.9	25.6
2019	CAN_CIP2014_MI2017	19.5	21.5	22.8	22.2	24	25.1
2019	CAN_CPM2014_MI2017	19.5	21.4	22.7	22.2	23.8	25
2019	CHL_TM2020	18.5	20	21.3	21.8	24.1	26
2019	COL_RV08	17.4	19.0		20	22.7	
2019	CRI_SP2015	18.8	19.4	20.4	21.3	22	23.3
2019	DEU_DAV_2nd_Agg_20yrtrend	18.3	21.2	22.6	21.4	24.5	26.4
2019	ESP_PERP	19.8	21.3	23	23.9	25.5	27.5
2019	FRA_IA2013	19.8	22.7	24.5	23.9	26.3	28.2
2019	FRA_TGX05	19.8	22.5	24.6	23.9	25.5	28.1
2019	GBR_S16	18.8	20.3	21.2	21.1	22.8	24.0
2019	GBR_S3	18.8	19.5	20.4	21.1	22.3	23.5
2019	GRC_EAE2012P	19	21.7		21.7	21.7	
2019	JPN_SMT2007	19.8		22.9	24.6		29.7
2019	MEX_EMMSA09	16.6	21.5	22.2	18.6	24	24.7
2019	NLD_AG2020	19		19.9	21.4		22.8
2019	PER_SPP	19.6	21.7	22.7	20.8	24.6	26
2019	PRT_GRX95	18.5	20.5		22.3	27.1	
2019	SVN_SIA65	18.1		22.8	21.8		27.2
2019	SWE_DUS14_OBL	23.9		26.3	26.5		28.7
2019	SWE_DUS14_VOL	23.9		28.2	26.5		30.2
2019	TUR_TRHA2010	16.3	17.4		19.6	21.3	
2019	USA_IAM2012	18.2	21.3	22.5	20.8	23.9	24.9
2019	USA_Pri2012	18.2	18.7	19.3	20.8	21.2	21.9
2019	USA_Pub2010	18.2	19	19.6	20.8	21.4	22.1
2019	USA_RP2014	18.2	20.2	20.8	20.8	22.2	22.9

Note: Life expectancy shown for Sweden for age 60. Population figures for Chile, Sweden and the United Kingdom are 2019, whereas the selection and improvement effects reflect 2020. The calculations for CHL_TM2020 table refer to the draft table published for consultation.
Impact for selection not available for Belgium, Japan, Slovenia, and Sweden and the figure for improvements reflects both selection and improvements for these countries. Population life expectancy for Peru is for the age group 65-69.
Source: Own Calculations and OECD (2022[1]), Life expectancy at 65, https://doi.org/10.1787/0e9a3f00-en; World Health Organisation (2019[2]) Life tables: Life tables by country Peru (who.int).

Figure 4.1 shows more clearly the additional years of life expectancy at age 65, relative to the general population, that result from accounting for selection and mortality improvements. Selection adds on average around 2 to 2.5 additional years of life expectancy at age 65, while mortality improvements add around an additional 1.5 to 2 years. The average of both components combined is around 3 to 3.5 years.

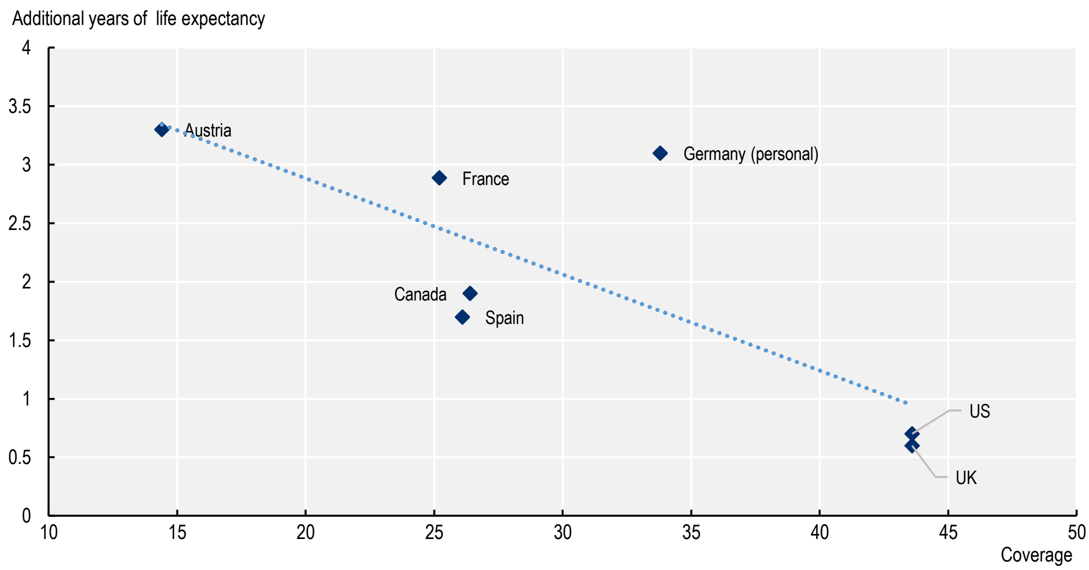
Figure 4.1. Additional life expectancy at age 65 due to selection and mortality improvements relative to the general population



Note: See Annex 4.A for the table names referenced. The calculations for CHL_TM2020 table refer to the draft table published for consultation.
Source: Own calculations.

The impact of selection is related to the proportion of the population that is covered by the arrangement. The larger the proportion of the population that pensioners or annuitants represent, the closer the mortality of the pensioner or annuity population will be to that of the general population, and thereby the smaller the selection effect will be. Figure 4.2 demonstrates this tendency for a select sample of countries. Indeed, the higher the coverage, the lower the impact that selection has on life expectancy.

Figure 4.2. Relationship between coverage and extent of mortality selection



Note: The population that the data on coverage represents does not exactly correspond to the population to which the mortality tables apply, but these countries were selected as these two populations should correspond more closely.
Source: Coverage figures from OECD (2019[3]), Coverage of funded and private pension plans, https://doi.org/10.1787/983bdeef-en. Selection factors are own calculations.

4.5. Summary of main features of standard mortality tables

For the jurisdictions included in this report, standard mortality tables are developed by regulators/supervisors, actuarial associations, industry bodies, statistical institutions and/or academics. Where providers are required to use these mortality tables, they are most often developed by the regulator/supervisor.

There are two components to mortality tables. The first is the level of mortality observed today, or the base mortality assumptions, and the second is the projection of future mortality improvements to account for expected increases in life expectancy.

The base mortality assumptions are either based directly on the level of mortality observed for the pensioner or annuitant population or on the experience of the general population. In the latter case, an adjustment factor is usually needed to account for selection effects and the fact that the mortality of the pensioner or annuitant population tends to be higher than the general population. Due to the lack of mortality experience at higher ages, mortality rates are normally extrapolated to some ultimate age beyond which no survivors are expected, commonly around age 120. Tables typically distinguish mortality rates at least by gender, but can also specify them by product or plan type, type of beneficiary, or by socio-economic indicator.

Mortality improvement assumptions require a model to project future mortality rates from past observed experience to determine the expected future increases in life expectancy. Most often these models are extrapolative, either linearly extrapolating historical trends in the log mortality rates or using another extrapolative model such as Lee-Carter that takes into account an age structure for the improvement rates. Another common approach is to interpolate mortality improvements from smoothed historical experience to some long-term rate of mortality improvement in the future. Occasionally projections rely on demographic projections of statistical institutes or use an approximate approach such as a simple reduction factor. The most accurate approach with respect to the dimension of the mortality table is to allow mortality improvements to vary by age and year, but some jurisdictions take a simplified approach, adjusting a single vector of mortality rates to account for the different mortality across cohorts.

The life expectancies given by standard mortality tables are typically significantly higher than the life expectancy for the general population due to the selection effects and future expected mortality improvements. On average, these increase life expectancy at age 65 by around 2.5 years and 1.5 years, respectively, resulting in a life expectancy at age 65 around 3.5 years higher for pensioners/annuitants relative to the period life expectancy of the general population.

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Annex 4.A. Main features of standard mortality tables for pensioners and annuitants

Annex Table 4.A.1 summarises the main features of the standard mortality tables reviewed in this chapter.

Annex Table 4.A.1. Features of standard mortality tables for pensioners and annuitants

Jurisdiction	Table	Developed by	Sector	Required	Base population	Selection factor	Improvement population	Improvement model	Long-term rate
Australia	AltAdj	Actuaries Institute of Australia	Insurance	No	Australia	UK	Australia	Extrapolation	No
Austria	AVÖ 2018-P	Austrian Association of Actuaries	Pensions	No	Pensioners	NA	Austria	Markov Monte Carlo	No
Austria	AVÖ 2005-R	Austrian Association of Actuaries	Insurance	No	Austria	Switzerland and Germany, Old Austrian tables	Austria	Lee-Carter	Halves initial value over 100 years
Belgium	MR-FR	Financial Services Markets Authority	Insurance	Yes; income and technical provisions minimum basis	Belgium	Age correction of 5 years	NA	Age correction	NA
Belgium	Plan3	Federal Planning Bureau	Insurance	No	Belgium	Age correction of 3 years	Belgium	Linear trend of log regression	No
Brazil	BR-EMS-2015	Brazilian Association of Insurance and Pension Companies (FenaPrevi)	Insurance	No; supervisor considers as standard reference	Insured lives	NA	NA	NA	NA

Jurisdiction	Table	Developed by	Sector	Required	Base population	Selection factor	Improvement population	Improvement model	Long-term rate
Canada	CPM2014+MI2017	Canadian Institute of Actuaries	Pensions	Effectively yes; actuarial standards board promulgates for termination valuation and solvency funding	Pensioners (RPP)	NA	Canada	WH Graduation	Yes; 1% over 20 years
Canada	CIP2014+CPM-B	Canadian Institute of Actuaries	Insurance	Yes	Insured lives, annual income <72k	NA	Canada	WH Graduation+ cubic interpolation to long term rate	Yes
Chile	TM-2014	SP/CMF (regulatory bodies)	Pensions and Insurance	Yes; reserving and programmed withdrawal income	Pensioners and Annuitants	NA	Chile	Lee-Carter	No
Chile	TM-2020	SP/CMF (regulatory bodies)	Pensions and Insurance	Yes; reserving and programmed withdrawal income	Pensioners and Annuitants	NA	Chile	WH Graduation+ cubic interpolation to long term rate	Yes; 1% over 20 years
Colombia	RV08		Pensions and Insurance	Yes; reserving and programmed withdrawal income	Pensioners and Annuitants	NA	NA	NA	NA
Costa Rica	SP-2015	SUPEN	Pensions and Insurance	Yes; technical provisions of annuities	Costa Rica	None	Costa Rica	Lee-Carter	No
Czech Republic	Czech Generational Table	Charles University of Prague	Pensioners	No	Czech Republic	German (Munich Re Data)	Czech Republic	Linear regression of log mortality	No

Jurisdiction	Table	Developed by	Sector	Required	Base population	Selection factor	Improvement population	Improvement model	Long-term rate
Denmark	Pensions Benchmark	FSA	Pensions and Insurance	Minimum benchmark	Pensioners and Annuitants	NA	Denmark	Linear extrapolation	No
Denmark	ATP	ATP	ATP (Insurance)	No	ATP	NA	Western European+ Denmark	Saint multi-population model	Western European experience
Estonia	Population life tables	Statistics Estonia	Population	No	Estonia	Portfolio experience	NA	NA	NA
Finland	TyEL	Government	Pensions	Yes	Finland	None	NA	NA	NA
France	TGH/F 05	Institute des Actuaires	Insurance	Yes; minimum basis for pricing and technical provisions	French annuitants	NA	France	Relational model extrapolated with cubic splines	No
France	IA2015	Institute des Actuaires	Insurance	No; benchmark for SII	French annuitants	NA	France	Relational model with INSEE projections to 2060	No
Germany	Heubeck	Heubeck-Richttafeln-GmbH	Pensions	No	German employees	NA	Germany	Linear extrapolation	1987-2011
Germany	DAV04	German Institute of Actuaries	Insurance	Yes for technical provisions	German annuitants	+0.2% improvement	Germany	Linear extrapolation	Yes: 75% of population experience1972-1999, btw 1-3%; period of convergence is user input
Hungary	Academic studies	Academics	Pensions	No	Pensioners	NA	NA	NA	NA
Iceland	IAA2019	Icelandic Actuarial Association	Pensions	Yes	Iceland	None	Iceland	CBD	Yes; decline over year 20 to 45 to 1%
Ireland	Benchmark studies only	Society of Actuaries of Ireland	Insurance	No	Irish annuitants compared to UK	UK	Ireland/E&W	CMI	Yes

Jurisdiction	Table	Developed by	Sector	Required	Base population	Selection factor	Improvement population	Improvement model	Long-term rate
Israel	Pensioner	Commissioner of Capital Markets, Insurance and Savings	Pensions	Yes; minimum benchmark for technical provisions	Israeli pensioners	NA	Israel	CMI	Yes
Israel	Insurance	Commissioner of Capital Markets, Insurance and Savings	Insurance	Yes; reserving	Israeli pensioners	ND	Israel	CMI	Yes
Italy	Pensioner	Italian National Order of Actuaries	Pensions	No	Italian pensioners	NA	Italy	Various	Various
Italy	Insurance	Association of Italian Insurance Companies	Insurance	No	Italian population	UK	Italy	Lee-Carter + ISTAT projections	No
Japan	EPI		Pensions	Yes; Funding and valuation	EPI	NA	NA	NA	NA
Japan	TQPP		Pensions	Yes	Japanese population	15%	NA	NA	NA
Japan	SMT	Institute of Actuaries of Japan	Insurance	Yes; reserving	Japanese population	ND	Japan	Margin based on 1960 cohort	No
Korea	EMT	Korean Insurance Development Institute	Insurance and Pensions	Yes; reserving	Insured lives	NA	Korea	reduction factor	No
Lithuania	Centralised Annuity Provider	Centralised Annuity Provider	Insurance	Yes	Public pensioners	Top two income quintiles	Lithuania	Linear extrapolation	Lithuanian experience over 1995-2017 over 20 years
Luxembourg			Insurance	Yes	European	Annuitant	NA	NA	NA
Mexico	EMSSAH-CMG-09+CONAPO	Regulator	Insurance and Pensions	Yes	IMSS and ISSSTE	NA	Mexico	CONAPO projections	No
Mexico	EMSSA97	Regulator	Pensions	No	Mexico	None	NA	NA	NA
Netherlands	AG2020	Royal Dutch Actuarial Association	Pensions	No	Netherlands	None	Western Europe + the Netherlands	Li-Lee two population model	Absolute difference with reference population based on experience since 1983

Jurisdiction	Table	Developed by	Sector	Required	Base population	Selection factor	Improvement population	Improvement model	Long-term rate
New Zealand	Mortality Studies only	New Zealand Society of Actuaries	Insurance	No	NA	NA	NA	NA	NA
Norway	K2013	Finance Norway	Pensions	Yes; technical provisions and pricing	Pensioners of Association's members	NA	Norway	ND	No
Peru	Pensioner	SBS	Pensions and Insurance	Yes; reserving and programmed withdrawal income	Pensioners and Annuitants	NA	Peru	Lee-Carter	No
Poland	GUS	Central Statistical Office of Poland	Insurance	No	Poland	Portfolio experience	NA	NA	NA
Portugal	TV 73/77	French INSEE	Pensions	Yes	France	None	NA	NA	NA
Portugal	GKX95	Swiss Actuarial Association	Insurance	No	Switzerland	Portfolio experience	NA	NA	NA
Slovak Republic	Population life table	Statistical Office of the Slovak Republic	Insurance	No	Slovak Republic	NA	NA	NA	NA
Slovenia	SIA65	Slovenian Association of Insurers	Insurance	Yes; reserving (older contracts use DAV 94)	Slovenia	UK and Germany	Slovenia	Poisson log bilinear	No
Spain	PERM/F 2000	UNESPA	Insurance	Yes	Spain	Switzerland	Spain	ND	No
Sweden	DUS14	Swedish Insurance Companies Industry Organisation	Pensions and Insurance	No; used in practice	Swedish insured and pensioner lives	NA	Sweden	Lee-Carter	No
Switzerland	BVG+Menthonnex	Private company (industry association?) + Statistical office for improvements	Pensions	No	Swiss pensioners of private plans	NA	Switzerland	Menthonnex	Implicit – allows for the rectangularisaion of the curve
Switzerland	ERM/F		Insurance	No	Swiss Insured	NA	Switzerland	ND	ND

Jurisdiction	Table	Developed by	Sector	Required	Base population	Selection factor	Improvement population	Improvement model	Long-term rate
Türkiye	TRHA-2010	Hacettepe University	Insurance	No	All insured lives	US (to adjust to annuitant level)	NA	NA	NA
United Kingdom	16 Series+CMI	IFoA	Insurance	No	Annuitants	NA	England & Wales	CMI	Yes
United Kingdom	S3+CMI	IFoA	Pensions	No	Pensioners	NA	England & Wales	CMI	Yes
United States	RP-2014	SOA	Pensions	Yes, funding and protection fund premiums	Pensioners	NA	US	WH Graduation	Yes, to 1.35% over 10/20 years horizontal/diagonal convergence
United States	Pri-2012/Pub-2010+MP2020	SOA	Pensions	No	Pensioners	NA	US	WH Graduation	Yes; to 1.35% over 10/20 years horizontal/diagonal convergence
US	IAM 2012+G2	SOA	Insurance	No	Annuitants	Additional 0.4% improvement for age 65-82, grading to 0.2% for ages 87 and over	US	SSA historical trends plus margin	No

Note: NA = Not Applicable; ND = Not Available. The Chilean TM-2020 table refers to the approach taken for the draft published for consultation.

Annex 4.B. Country profiles

Australia

Country context for standard mortality tables

Although life annuities are available as an option at retirement in the context of the Australian superannuation defined contribution system, the annuity market in Australia remains very small.

The Actuaries Institute of Australia has published an indicative reference mortality table for each gender that can be used as a benchmark for the level of mortality for pricing and reserving. However, it is based on data from a limited number of providers and therefore cannot be relied upon by itself.

The Australian Government actuary publishes mortality improvements based on the experience of the Australian population.

Technical details

The Actuaries Institute of Australia engaged the consulting firm Rice Warner to develop mortality tables that could be used as a reference for the development of retirement income products in 2018. Unfortunately, they found that there were not sufficient data on annuities in Australia to develop tables directly from this population. They therefore derived a selection factor to apply to the Australian general population data from the annuitant mortality experience in the United Kingdom. Their proposal also involved a second adjustment to the Australian Life Table (ALT) 2010-12 that intends to account for the lower mortality in Australia by increasing the ratio of annuitant to population mortality applied to the life table. The selection factor is calculated arbitrarily by taking half of the observed mortality difference between the Australian and UK populations, and applying this to the observed mortality difference between the UK annuitant and general population. The tables intend to provide a reasonable range for annuitant mortality in Australia (Rice Warner, 2018[4]).

The mortality improvement assumptions published by the Australian Government actuary are based on observed population trends over the last 25 and 125 years, up to 2010-12 (Australian Government Actuary, 2018[5]).

Austria

Country context for standard mortality tables

The Austrian Association of Actuaries (AVÖ) publishes mortality tables for the calculation of technical provisions for both pension funds and pension annuity insurance.[9]

The AVÖ 2018-P, published in 2018, provides the calculation basis to assess the obligations of pension funds. The ÖFdV GmBH, a subsidiary of AVÖ, sells and licenses the calculation bases. The tables account for retired, disabled, and survivor benefits (Kainhofer, Hirz and Schubert, 2018[6]).

The AVÖ 2005-R, published in 2005, provide the calculation basis for pension annuity insurance. The tables are intended for use by insurance companies with guaranteed products. There are tables for group and individual annuitants for both genders. The Calculation Basis Working Group of the AVÖ regularly assesses these tables for adequacy. The last assessment in 2019 concluded that the table continues to be adequate and should still be used for the calculation of private pension insurance in Austria (Kainhofer, 2019[7]).

Technical details

AVÖ 2018-P

The AVÖ 2018-P is based on data from Pension Insurance Institutions (PVA), the Farmers Social Insurance Institution (SVB), the Social Insurance Institution for the Commercial Economy (SVA), and the Insurance company for railway and mining (VAEB). It allows for a full stochastic valuation of obligations by using a Markov model with transition probabilities among the states of retired, disabled, and survivor. The base table refers to the year 2008, and is smoothed using a Whittaker Henderson formula. The Heligman Pollard formula is used to extrapolate mortality to the oldest ages. Mortality improvements are based on the Austrian population from 1980-2017, and is projected forward using a Markov Chain Monte Carlo method that assumes no reversion of the trend to a long-term rate. The results of this model are very close to the results using the Lee-Carter model to project future mortality improvements (Kainhofer, Hirz and Schubert, 2018[6]).

AVÖ 2005-R

The annuity valuation table AVÖ 2005-R is based on Austrian population data, with a central year of 2001, as there is not sufficient mortality experience for Austrian annuitants on which to base the tables. Two tables are developed: a 2nd order best estimate table, and a 1st order table that includes substantial safety margins for model and parameter risk. The 1st order table includes an additive addition to the base mortality of 0.003 and a multiplicative factor of approximately 1.1 to the trend assumptions.

The selection factors used to adjust the Austrian life tables were developed in reference to the Swiss ERM/F 1999 tables for annuitants, the German DAV 2004-R tables for annuitants, and the old AVÖ 1996 tables. The selection factors follow a function that is constant at 0.8 until age 40, declining linear to age 60 before converging with a quadratic function to 1 at age 100. There are different selection factors by gender for individual and group annuitants, the latter group’s mortality being closer to that of the general population. The selection effect does not account for selection in terms of the amount of the annuity, only in terms of individuals. The table provides rates to age 120.

The mortality improvement assumptions are based on 30 years of Austrian population data, from 1972. The initial trend is derived from the Lee-Carter model. The trend slows over time in a non-linear fashion, halving its initial value over 100 years, in order to limit the table and avoid death probabilities near zero in the far future. Improvements for old ages assume a slow exponential decline to zero, with an upper limit at younger ages of 5%. Additional adjustments ensure monotonicity (Kainhofer, Predota and Schmock, 2005[8]).

A one-dimensional table has also been developed using the age-shift method, but it is not recommended for use over the two-dimensional generational table.

Belgium

Country context for standard mortality tables

Since 2003, the Financial Services and Markets Authority (FSMA) requires insurers to use a minimum mortality table based on the Belgian population, the MR-FR, to calculate annuity income and technical provisions. Since 2011, an age correction of five years is required to account for the selection factor and future mortality improvements. These tables do not explicitly take future mortality improvements into account (Commission des Pensions Complementaires, 2011[9]).

The Federal Planning Bureau has since developed generational tables that explicitly account for mortality improvements of the Belgian population.[10] The FSMA suggests insurance companies to use this for annuities by applying an age correction of three years to account for the selection factor (Commission des Pensions Complementaires, 2011[9]).

The Institute of Actuaries in Belgium set up a mortality working group, with one subgroup investigating mortality in the second pillar of the pension system, including annuities.[11] Notwithstanding, the annuity market remains extremely small.

Technical details

The MR-FR tables are defined through input parameters to the Makeham formula specified in the law (IAA Mortality Working Group, 2013[10]).

The mortality projections of the Federal Planning Bureau project Mortality improvements forward with an exponential formula based on smoothed trends derived from a linear regression of the logarithm of the historical rates since 1970. The method is modified for older ages to provide more stability at these ages (Paul, 2009[11]).

Brazil

Country context for standard mortality tables

The mortality tables for the Brazilian insurance market are the result of a joint initiative between the government, the insurance companies, the Brazilian Association of Insurance and Pension Companies (FenaPrevi). The first table, the BR-EMS-2010 was based on insured experience from 2004-06. These tables were updated in 2015 to incorporate experience from 2007-12. Tables are constructed by gender and type of insurance (death/survivor). The Brazilian regulator SUSEP considers these tables to be the standard reference for mortality tables for insurance providers (De Oliveira et al., 2016[12]).

Technical details

The mortality experience used to develop the BR-EMS-2010 tables represents approximately 80% of the insured population, which in turn represents around 22% of the Brazilian population. The calculation of the mortality rates are weighted towards the most recent observations, and rates at the middle ages are smoothed with moving averages. Mortality at the youngest and oldest ages are extrapolated using the Heligman Pollard model.

Canada

Country context for standard mortality tables

The Canadian Institute of Actuaries (CIA) develops and publishes mortality tables that serve as an expected reference for the mortality assumptions used for pensions and insurance in Canada. The Actuarial Standards Board (ASB) generally promulgates the tables for the purposes of calculating termination values and solvency funding.

In 2014, the CIA published the first mortality tables based on Canadian pensioner data, the CPM2014. Tables are gender distinct, and also include separate tables for public and private sector experience. The ASB has promulgated the use of these tables to calculate the commuted values for the termination of benefit entitlements within defined benefit plans.

In 2015, the CIA published the first mortality table based on Canadian experience for payout annuities, the CIP2014.

The base tables are used in conjunction with mortality improvement scales that the CIA develops separately. The first improvement scale based on Canadian data was the CPM-B mortality improvement scale developed in 2014 alongside the CPM2014 table (Canadian Institue of Actuaries, 2015[13]). The improvement scale is two-dimensional, although a one-dimensional approximation was also published. Then in 2017 the CIA published the MI-2017 improvement scale, which updated the CPM-B improvement scale published in 2014. While the former scale was based on Canadian pensioner data from the CPP and the QPP, the new scale reflects the mortality improvements of the whole Canadian population (Canadian Institute of Actuaries, 2017[14]). The ASB now promulgates this latter scale for use along with the base CPM2014 table.

Technical details

CPM2014

The CPM2014 mortality tables are based on the mortality data of individuals having registered pension plans (RPP) over 1999-2008. Rates are calculated on an amount basis rather than individual exposures, and size adjustment factors are provided to adjust the mortality expectations for different pension levels. Deaths are adjusted to account for mortality improvements to 2014 rather than using the central year of observation as the base year. Exposures and deaths are also weighted by industry to reflect the distribution across industries for all Canadian DB plans so as to be more representative of the Canadian experience on average. Raw mortality rates for central ages are graduated using the Lawrie variation of the Whittaker Henderson model. Mortality rates for younger ages are derived by applying a factor to the insurance table CIA9704 and interpolating the two curves with a 5th order polynomial. Rates for the oldest ages use those obtained directly from the Human Mortality Database (HMD), up to a maximum age of 115. Tables are split between public and private sector (Canadian Institute of Actuaries, 2014[15]; Howard, 2014[16]).

CIP2014

The CIP2014 is constructed using both individual and joint annuitant mortality experience having policies with an annualised income less than CAD 72 000. The experience used ranges from age 70 to 100 and covers the years 2000-11. The central mortality rates are smoothed using the Whittaker Henderson model. Ages over 106 are those developed for the CPM2014 table, and interpolated with a 4th degree polynomial. (Canadian Institue of Actuaries, 2015[13]).

CPM-B improvement scale

The CPM-B mortality improvement scale was developed alongside the CPM2014 table, and is based on Canadian pensioner data from the C/QPP. Short-term rates are based on ten years of mortality experience. The short-term rates are linearly interpolated from 2012 to a long-term rate in 2030 of 0.8% up to age 82, decreasing gradually to 0% at age 115 (Canadian Institute of Actuaries, 2014[15]).

MI-2017 improvement scale

The MI-2017 improvement scale uses the Whittaker Henderson model to smooth historical rates. The initial improvement rate is the smoothed rate two years before the final observed year. It uses cubic interpolation to project to a long-term improvement rate of 1% to age 90, which grades down linearly to 0.2% to age 100 and 0% at age 105. The convergence period is 20 years for ages 60-80, grading linearly down to 10 years for ages below 40 (Canadian Institute of Actuaries, 2017[14]).

Chile

Country context for standard mortality tables

The pension and insurance regulatory bodies in Chile, the Superintendence of Pensions (SP) and the Financial Market Commission (CMF), are jointly responsible for developing the mortality tables used in the context of the Chilean pension system. The tables for pensioners are used to calculate the allowed levels of programmed withdrawals and to determine the required reserves that insurers must hold to back their annuity business. The tables must be reviewed and updated on a regular basis.

The TM-2014 was developed in 2014. They are gender distinct, with separate tables for beneficiaries and the disabled. These tables were updated in 2020, and the new TM-2020 table will be required from July 2023.[12]

Technical details

TM-2014

The TM-2014 tables were based on non-disabled annuitant, pensioner and beneficiary data from 2008-13. Those having a pension below the basic solidarity pension were excluded. A separate table was produced for female pensioners and survivors, while a single table was produced for male pensioners and survivors. Central ages were smoothed using the Whittaker-Henderson model. Younger ages were based on the Chilean population mortality, and older ages were extrapolated using the model that demonstrated the best fit for each table.

Mortality improvements were based on the Lee-Carter model calibrated with 30 years of Chilean population data. To facilitate the implementation of applying the improvement scale, it was reduced to a one-dimensional table for each gender by age. Improvements over 80 were linearly graduated down to 0% at age 100.

TM-2020

The [draft] TM-2020 tables use broadly the same methodology for the base rates as the TM-2014 tables for data covering 2014-19. However, the new tables change the way in which they account for future mortality improvements. Rather than a one-dimensional improvement scale, a two-dimensional scale is developed based on Chilean population data from 1992-2016. Initial improvement rates are determined by the 2016 improvements after smoothing the historical data with a two-dimensional Whittaker Henderson model to age 90. Initial improvement rates are assumed to decline linearly to 0% at age 105. The initial rates are extrapolated to a long-term rate over 20 years using a cubic polynomial. The long-term improvement rate is set at 1% for ages up to 90, and then declines linearly to 0% at age 105.

Colombia

Country context for standard mortality tables

Resolution 1 555 of July 2010 imposes a legal requirement for the standard mortality table RV08 to be used for the calculation of programmed withdrawals and annuity reserves within the Colombian pension system. This table is based on annuitant mortality experience in Colombia.

Technical details

The RV08 mortality tables is based on Colombian annuitant and pensioner experience over the period 2005-08. Central ages are smoothed according to Makeham’s law. Mortality at the oldest ages are determined using a second order polynomial setting the mortality rate to 0.6 at age 106 and 1 at age 110. Morality for younger males is determined using the female table as a reference. No safety margins are included (Ortiz, Villegas and Zarruk, 2013[17]).

Costa Rica

Country context for standard mortality tables

The National Council for the Supervision of the Financial System approves the mortality tables that must be used for the calculation of technical provisions for annuities. Since 2014 these tables have accounted for mortality improvements. The most recent tables, the SP-2015, were updated in 2019. Superintendence of Pensions (SUPEN) calculates the mortality improvements to be used with the tables.

Technical details

The SP-2015 tables are based on the mortality experience of the Costa Rican population data over the period 2010-15 (Centro Centroamericano de Población, 2018[18]). An earlier study concluded that the mortality of the pensioner population did not differ substantially from that of the general population, and the use of census data for the construction of mortality tables for pensioners was appropriate (Rosero Bixby and Collado Chaves, 2008[19]). To construct the SP-2015 tables, mortality rates based on census data are smoothed and extrapolated to a maximum age of 115 using the Gompartz model (Centro Centroamericano de Población, 2018[18]). The mortality improvements are based on the Lee-Carter model calibrated to Costa Rican population data over the period 1950-2015 (Centro Centroamericano de Poblacion, 2018[20]).

Czech Republic

Country context for standard mortality tables

There is no legal requirement for the mortality table that pension funds or insurance companies use for the calculation of the technical provisions for annuity products. Typical practice has been to base the mortality tables on the life tables developed for the Czech population. Nevertheless, the Charles University of Prague has developed a generational life table for the Czech pensioner population as a reference.

Technical details

The Czech Generational pensioner mortality table is based on the Czech life tables over the period 1900-96 and ages through 103. The trend is based on a linear regression of the log mortality rates, with some adjustments to ensure monotonicity and reasonableness of results. Selection factors are based on data from Munich Re, and the same factors are used for both genders. They decrease to age 60, and increase again to 0.75 from age 75. The tables include a safety margin at a 99% confidence level. A one-dimensional table is also provided based on the age-shift method from the base cohort born in 1955 (Cipra, n.d.[21])

Denmark

Country context for standard mortality tables

The Danish Financial Supervisory Authority (FSA) develops a benchmark mortality table every year for pension funds and insurance companies based on data provided by the Danish Centre of Health and Insurance. While providers are allowed to use their own mortality assumptions, they must justify any deviation from the benchmark table.

While the ATP is also subject to the requirement to use the FSA tables, they justify developing their own tables by showing that the mortality experience of ATP members differs significantly from the FSA tables. The ATP uses the Saint model to model the mortality used for pricing and valuation exercises. They update their assumptions every year with the latest data available.

Technical details

The FSA's benchmark tables are based on pensioner and insured data supplied on a voluntary basis, covering around 50-60% of the Danish population. Mortality improvements are based on 20 years of experience of the general Danish population, extrapolated linearly for each cohort.

The Saint model used by the ATP is a multi-population stochastic model that projects the mortality of a sub-population with reference to a larger population. The reference population is made up of the pooled experience of a group of Western European countries. The Saint model aims to overcome the challenge of modelling mortality for small populations and to also allow for improvements for different ages to move in different directions. The long-term trend is based on a reference population, while the short-term trend is based on a stationary time series model fitted to the deviations in mortality experience between the sub-population and the reference population. Variability in projected mortality comes from both variability of the trend and variability in the difference in mortality from the reference population, the latter which is subject to boundaries so that the deviations do not become too large (Jarner and Kryger, 2013[22]).

Estonia

Country context for standard mortality tables

The only standard tables that exist in Estonia are the life tables published by Statistics Estonia for the general population. Insurers are allowed to determine their own assumptions for the valuation of pension contracts. The mortality assumptions used tend to be somewhat more conservative than the population figures. While insurers are free to set assumptions, they are obliged by law to share 50% of the technical profits with their policyholders and beneficiaries (Rahandusministeerium, 2015[23]).

Finland

Country context for standard mortality tables

Mortality rates are used to calculate the life expectancy coefficient that determines the amount of retirement income that a retiree will receive from the partially funded TyEl pension scheme. The purpose of this coefficient is to adjust the amount of retirement income downwards to reflect longer life expectancies for each cohort.

Technical details

The life expectancy coefficient is calculated each year for the cohort aged 62 in reference to the average population mortality over the last fve years relative to the population mortality in 2009, up to a maximum age of 100. The coefficient for 2020 is based on unisex mortality rates over the period 2014-18. Expected mortality improvements are not accounted for. The coefficient assumes a discount rate of 2% (Finnish Centre for Pensions, 2019[24]).

France

Country context for standard mortality tables

French legislation requires that pension funds and annuity providers use the TGH/TGF 05 mortality tables as a minimum basis to value their liabilities and to price annuities.

The French Institute of Actuaries have more recently built a standard mortality table (IA2013) intended to be used by insurers as a reference to assess their best estimate mortality assumptions in the context of Solvency II.[13]

Technical details

TGH/TGF 05

The TGH 05 (males) and TGF 05 (females) are based on French annuitant mortality data over the period 1993-2005. The base table was smoothed with a Gompartz model. Ages beyond 95 were extrapolated using a variation on a quadratic extrapolation. Younger ages were based on population data. Future mortality rates were projected using a relational model referencing French population data from 1962 to 2000 smoothed and extrapolated with cubic splines. Projections were adjusted to maintain a coherent relationship between the annuitant and population mortality (Planchet, 2007[25]).

IA2013

The base tables rely on insured data from 2007-11, smoothed with a generalised linear model adjusted for maximum likelihood. Rates for ages over 95 were extrapolated using a method proposed by Denuit and Goderniaux imposing a maximum age constraint of 130. The mortality trend is projected via a non-parametric model referencing the INSEE projections of French population data to 2060 (Tomas and Planchet, 2016[26]).

Germany

Country context for standard mortality tables

The German Institute of Actuaires (DAV) produced the DAV 2004 R standard table. The DAV reviewed the tables over 2016 and 2017, and determined that they are still appropriate for the valuation of new business (Deutschen Aktuarvereinigung, 2018[27]). The German supervisor prescribes these tables, with a margin for conservatism, as a minimum standard for the valuation of pension and annuity liabilities of life insurers, non-regulated Pensionskassen and insurance-type Pensionsfonds. However, these entities may use their own tables if justified as more appropriate.

The firm Heubeck-Richttafeln-GmbH periodically produces generational mortality tables based on the mortality experience of German employees. While not required, these tables are used by some institutions to assess obligations of occupational pension arrangements. The latest tables were released in 2018.[14]

Technical details

The DAV 2004 R table is based on insured experience over the period from 1995 to 2002. In addition to the base tables, select and ultimate tables for benefits in payment are also produced to reflect the higher selection effect in the five years following the commencement of annuity payments. Raw mortality rates are smoothed using for central ages using the Whittaker Henderson model. Selection factors are based on the ratio of the smoothed mortality rates during the selection period relative to the population mortality. Ultimate mortality rates are based on all available annuitant data. Mortality rates for younger ages derived from the population mortality based on the ratio of the ultimate rates to the general population. Mortality is extrapolated to age 120 using a logistic model.

Two tables are produced: a 2nd order table reflecting best estimate expectations, and a 1st order table containing safety margins. The 1st order table includes a margin for volatility risk of around 6-7%, and a 10% margin for parameter risk, resulting in a total margin of 15.6% for males and 16.5% for females.

Initial mortality improvements are based on Western German population experience from 1990 to 1999. For the 2nd order best estimate tables, the initial trend is extrapolated to a long-term trend based on 75% of the German population experience from 1972-99, within the boundaries of a maximum of 3% and a minimum of 1% at the oldest ages. The tables assume an additional 0.2% annual improvement to reflect expectations that the life expectancy of the insured population will improve at a faster rate. The period of convergence is left to the user. 1st order tables assume that the mortality improvement will continue at the initial rate, and also assume an additional 0.25% annual improvement as a safety margin for parameter risk (Pasdika and Wolff, 2005[28]).

Technical details for the Heubeck table are not available.

Greece

Country context for standard mortality tables

The Bank of Greece previously published the mortality tables that life insurance companies were required to use to calculate their reserves. They produced tables for both survival and annuity products, but did not include mortality improvement assumptions. Annuity providers are now free to use any mortality table that represents their best estimate assumptions, so the Bank of Greece no longer develops mortality tables.

For pension providers, secondary legislation is planned to allow pension providers to use their own mortality tables.

Hungary

Country context for standard mortality tables

No standardised mortality table exists in Hungary, though some academic studies have investigated in detail the mortality of pensioners in the country, including old-age pensioners in the public system. Hablicsekné (2011[29]) looks at the mortality and life expectancy of pensioners across different types of benefits (old-age, survivor, disability) and constructs abridged mortality tables to age 90 for each benefit type and gender. Hollósné and Molnár (2015[30]) investigate the socio-economic differences in pensioner mortality by assessing mortality by gender and size of pension.

Iceland

Country context for standard mortality tables

In 2019, the Icelandic Actuarial Association updated the life tables for the Icelandic population. In 2020, they approved a new approach to forecasting future mortality improvements for pension fund members.

Technical details

The base mortality tables are based on life tables produced by the Icelandic Actuarial Association for data covering the period 2014-18. Projections of future mortality improvements are done with the Cairns-Blake-Dowd model calibrated to Icelandic population data over the period 1981-2018 for the age range 45-89 for males and 50-94 for females. Improvements at younger ages assume the improvement of a 45-year-old male, and older ages assume improvements decreasing to 0% at old ages. Improvements are assumed to begin declining after 20 years, and converge to 1% at age 85 over the following 25 years (Félag íslenskra tryggingastærðfræðinga, 2020[31]).

Ireland

Country context for standard mortality tables

The Society of Actuaries of Ireland (SAI) produces mortality experience studies and projections to serve as a reference for actuaries, including for annuitants. However, they do not produce Irish-specific mortality tables. In practice, Irish experience is benchmarked to the mortality experience of the United Kingdom and the studies carried out by the Continuous Mortality Investigation of the UK Institute and Faculty of Actuaries. They most recently found that the Irish annuitant experience is most closely approximated by the PXL08 tables based on UK pensioner data in 2007-10 (Society of Actuaries in Ireland, 2019[32]). The SAI also recently published a report in which they calibrated the CMI model for Ireland (Society of Actuaries in Ireland, 2020[33]).

Technical details

The SAI took two approaches to calibrate the CMI model to Irish experience. The first calibrated the model directly to Irish population mortality experience for age 20 to 100 and years 1977-2017. They reduced the smoothing parameters, which determine how much weight the model gives to the most recent observations, by 1.22 for females and 1.28 for males from the default of 7. This decision was to reflect the smaller size of the Irish population and the higher volatility of historical experience. The second approach was a simplified approach that calibrated the CMI model with data from England and Wales, but adjusted the initial improvement to reflect the differences between the mortality improvements experienced in the two populations. The latter approach tended to underestimate the mortality improvements in Ireland (Society of Actuaries in Ireland, 2020[33]).[15]

Israel

Country context for standard mortality tables

The Commissioner of Capital Markets, Insurance and Savings produces the mortality tables that pension funds must use to value pension liabilities. Separate tables are produced for pensions in deferral and pay-out. However, pension funds are allowed to use their own assumptions so long as they can justify that their assumptions are more appropriate.

Since 2001, the Commissioner also mandates the table that must be used to calculate the reserves for insurance products having a Guaranteed Annuity Option (GAO), or a guaranteed annuity conversion rate. These tables were based on the mortality experience of pension funds with an additional selection factor to account for the expected lower mortality of annuitants of insurance companies. In 2016, the government Actuary performed the first experience analysis of Israeli annuitants to inform the construction of the mortality table (International Actuarial Association, 2017[34]).

Regulations require that both pension funds and insurance companies account for future mortality improvements. Assumptions are based on the Israeli population using the CMI model that assumes a convergence to a long-term improvement rate of 1.25% for males and 1.5% for females. The latest factors were revised in 2018. A separate table is developed for the male cohorts born between 1929 and 1945 who have historically experienced higher mortality improvements than other cohorts. Assumptions more conservative than the best estimate assumptions are required for reserving (OECD, 2014[35]).

The Central Bureau of Statistics (CBS) has also produced projections of mortality since 2012 for the Israeli population.

In 2018 The Israeli Association of Actuaries, at the request of the Commissioner, published a report to investigate the projection of mortality improvements in Israel. The investigation studied several different models, but did not recommend a single model and the development of a mortality tables for the pensioner and annuitant populations was outside of its remit (Israeli Association of Actuaries, 2018[36]).

A major challenge identified with respect to setting mortality assumptions in Israel is the large rates of immigration in the country, which reduces the stability of the demographic characteristics of the population.

Italy

Country context for standard mortality tables

Various institutions construct mortality tables that can be used as a reference for assumption setting for pensioners and annuitants in Italy.

The Italian National Order of Actuaries performed a study to develop mortality tables for Italian pensioners based on pensioner data over the period 1980-2009 and projected to the year 2040 using several different models (Ordine Nazionale degli Attuari, 2012[37]).

The Association of Italian Insurance Companies (ANIA) constructed mortality tables for life annuitants in 2014. These two-dimensional A1900-2020 tables are used to derive a one-dimensional table based on an age-shift method referencing the 1962 cohort. Separate tables have been constructed for immediate, deferred, and group life annuities by gender (ANIA, 2014[38]).

Technical details

Pensioner tables

The base tables reference Italian pensioner mortality experience in 2009 for pension plans managed by both public and private institutions. The working group implemented several projection models calibrated on Italian population data from 1980 to 2009. These models included the Lee-Carter model, the log-bilinear Poisson model, the Renshaw Haberman model with cohort effect, and the CMI model (pre-2018 version) implementing the Age-Period-Cohort model (Ordine Nazionale degli Attuari, 2012[37]).

A1900-2020

The mortality tables are based on the ISTAT projections of population data, which use the Lee-Carter model and account for demographic factors such as fertility and immigration. The ISTAT projections were extended to age 120 for the 2020 cohort through a linear extrapolation of the log mortality rates. Selection factors are based on UK pensioner experience (the “life office pensioners”) (ANIA, 2014[38]).

Japan

Country context for standard mortality tables

Regulation requires that pension schemes use the EPI mortality tables for funding and valuation requirements. These tables are based on the experience of the public Employee’s Pension Insurance, and are updated every five years. They do not explicitly take mortality improvements into account. While the tables can be used as-is for going concern valuations, wind-up valuations require that the EPI mortality rates be reduced by 5% for males and 7.5% for females. Reductions in the mortality assumptions for going concern valuations are subject to a maximum of 10% for males and 15% for females (OECD, 2014[35]).

Tax Qualified Pension Plans (TQPP) are required to use a different mortality table to value their liabilities. It is specified as 85% of the mortality of the Japanese Life Table for the population, though it is not clear whether the most recent Life Table must be referenced (Mitchell and McCarthy, 2001[39]).

Insurance companies are required to use the Standard Mortality Table (SMT), developed by the Institute of Actuaries of Japan (IAJ) to calculate annuity reserves. The latest of these tables was the SMT 2007. The IAJ reviews the adequacy of this table in each year, and released an updated version of the table, the SMT 2018, however the updated tables only apply to life and medical insurance, and the valuation of annuity reserves must continue to use the SMT 2007 tables (Yamazaki, 2017[40]).

The Life Insurance Association of Japan (LIAJ) performs periodic studies on the mortality of insured lives, but does not disclose the results of these evaluations (International Association of Actuaries, 2017[41]).

Technical details

SMT 2007

The mortality for the SMT 2007 based on the 19th Life Table for the Japanese population, representing the mortality in the year 2000. Mortality rates for ages over 94 are extrapolated with a cubic function to age 122 for males and 126 for females. Mortality improvement calculations are based on Japanese population data over the period 1980-2000 by gender, five-year age group and cause of death. The table provides the mortality for the 1960 cohort. Based on these improvements, a reduction factor is then applied of 85% for central ages and 60% for younger ages to account for the expected mortality improvements (Yamazaki, 2015[42]).

Korea

Country context for standard mortality tables

The Korean Insurance Development Institute (KIDI) is legally responsible for the construction of mortality tables for the life insurance sector since 1989. Insurers are required to use these tables for reserve calculations, though they can use their own experience for pricing. The KIDI updates the tables every three years. The rates are based on the mortality experience of the insurance sector (Korea Institute of Finance, 2013[43]). The tables used for annuitants implicitly account for expected future mortality improvements and include additional safety margins. Three separate tables are applicable to the pensioner and annuitant populations. The EMT table for pensioners applies to pensioners before retirement, and is only used to ensure that the employer has sufficient reserves to meet its liabilities. The EMT table for life insurance applies to annuitants before retirement. The EMT table for annuitants applies to both populations after retirement.

Latvia

Country context for standard mortality tables

There are no standard mortality tables in Latvia, and annuity providers are free to set their own assumptions. In practice, the assumptions used account for future mortality improvement. However, the populations on which the tables are based are not necessarily the annuitants themselves nor the Latvian population. The tables used by annuity providers tend to result in a life expectancy around two years greater than the period life tables for the Latvian population (OECD, 2018[44]).

Lithuania

Country context for standard mortality tables

Individuals having accumulated at least EUR 10 000 in the retirement savings accounts for the second pillar pension in Lithuania are required to purchase an annuity. Since 2020, a centralised annuity provider managed within the State Social Insurance Fund Board (Sodra) issues these annuity contracts. To price and value the annuity liabilities, it uses a mortality table based on Lithuanian pensioner mortality and the mortality improvements of the Lithuanian population.

Prior to 2020, private insurers provided the annuity products for the second pillar system. They are still allowed to provide voluntary annuities. There is no standard mortality table for the private sector. Providers tend to calculate their mortality assumptions using a selection factor based on UK experience and mortality improvements of the Swedish population.

Technical details

The centralised annuity provider’s mortality table is based on the mortality experience of Lithuanian pensioners having a pension level within the top two income quintiles. Short-term improvements are based on the latest 10 years of mortality experience of the Lithuanian population, calculated with a linear regression of the log mortality rates. These rates converge linearly over 20 years to a long-term improvement assumption based on Lithuanian mortality experience over 1995-2017.

Luxembourg

Country context for standard mortality tables

Insurers are required to use mortality tables that are based on recent European population mortality to calculate their technical provisions, adapted to the risk that the insurers face, that is longevity risk in the case of annuities. Insurers can adapt the mortality tables if they are able to justify the differences (Commissariat aux Assurances, 2012[45]).

Mexico

Country context for standard mortality tables

There are no specific requirements regarding mortality assumptions for occupational pension plan sponsors. In practice, providers commonly used the EMSSA97 table that is based on population mortality experience and improved only to 2011 for males and 2013 for females based on projections by CONAPO (OECD, 2014[35]). However, since 2017 the EMSSA-09 table is more commonly used in more pension plans' valuations (CONSAR, 2019[46]).

Annuity providers are required to use, as a minimum, the EMSSAH-CMG-09 to value their liabilities, the same table that they use for pricing. They are also required to take future mortality improvements into account. Reserve requirements stipulate that an additional 2% be set aside to cover technical provisions. The base mortality for the tables are based on data from IMSS and ISSSTE over the period 1998 to 2008. Mortality improvement assumptions are based on CONAPO's projections for the Mexican population (OECD, 2016[47]).

Netherlands

Country context for standard mortality tables

The Royal Dutch Actuarial Association publishes a new mortality table every two years, with the latest table published in 2020. This table intends to serve as a reference for pension and insurance companies to develop their own mortality assumptions. Tables are based on the mortality of the Dutch population and include future expected mortality improvements.

Technical details

Since 2014, the Royal Dutch Actuarial Association uses the Li-Lee two-population stochastic model to forecast future mortality improvements. The model projects Dutch mortality in reference to a larger population of European countries having a similar prosperity level to the Netherlands, which makes the model less sensitive to annual volatility of Dutch mortality experience. The model projects and overall trend of the reference population following a random walk with a drift, and the deviation of the Dutch mortality from the reference population is explicitly modelled with a first order autoregressive process. Both genders are modelled simultaneously, and since 2016 the model also incorporates a correlation in experience between males and females. The European trend is based on data since 1970. The model assumes that the difference in mortality between the Dutch population and the reference population will converge to an absolute value that is based on mortality experience since 1983 (AG Projections Life Tables Working Group, 2020[48]).

New Zealand

Country context for standard mortality tables

The annuity market in New Zealand is very small, and insurers typically develop their own mortality assumptions. The New Zealand Society of Actuaries has published mortality investigations on insured lives, but does not itself produce graduated mortality tables (New Zealand Society of Actuaries, 2019[49]).

Norway

Country context for standard mortality tables

Finance Norway has developed the mortality table K2013. The Financial Supervisory Authority requires the use of this table as a minimum basis for the calculation of technical provisions for and pricing for collective pension insurance provided by life insurers and pension funds. Finance Norway monitors these tables against observed mortality experience (International Actuarial Association, 2018[50]). The table is available for purchase only.

Technical details

The K2013 table is based on mortality experience over the period 2005-09 of pension members in Finians Norge's member companies. Rates are projected to 2013. Additional security margins of 12% of the base mortality and 10% of mortality improvements are included (Finans Norge, 2013[51]). The mortality rates incorporate mortality improvements by age and gender (The Financial Supervisory Authority of Norway, 2013[52]).

Peru

Country context for standard mortality tables

The Superintendence of Banking, Insurance and Private Pension Funds Administrators of Peru (SBS) is responsible for the development of the mortality table used in the context of the Peruvian Private Pension System (SPP). These tables are used for the calculation of annuity reserves and the level of programmed withdrawals that old-age pensioners can withdraw from their pension savings. The latest tables are the first to be based specifically on the Peruvian population and to incorporate future mortality improvements. Providers have been required to use them since 2019.

Technical details

The mortality tables for healthy lives are based on Peruvian old-age pensioner and annuitant data within the SPP over the period 2010-16. Central ages are smoothed using the Whittaker Henderson model. Extrapolation to older ages relies on the Makeham and Gompartz models for females and males, respectively. Younger ages are extrapolated as a function of the mortality rates for the general Peruvian population. Mortality improvements are modelled with the Lee-Carter model calibrated to Peruvian population data over the period 1991-2016 through age 80. Improvement rates decrease linearly to 0% between the ages of 80 and 100 (SBS, 2018[53]).

Poland

Country context for standard mortality tables

Official population mortality tables produced by the Central Statistical Office of Poland (GUS) are commonly used, though individual companies may apply adjustment factors to these tables to reflect their own experience. GUS does not produce projections of future mortality. Companies may develop their own improvement assumptions or rely on academic studies to develop them (International Association of Actuaries, 2016[54]).

Portugal

Country context for standard mortality tables

Regulation issued by the Portuguese supervisor specifies a minimum funding scenario for pension funds, whose purpose is to establish a minimum ‘safety net’ funding rule, based on the mortality table TV 73/77. The TV 73/77 is an old mortality table for annuities based on the French population over 1973-77. The assumptions to be used in the minimum funding scenario, however, are currently under revision and a public consultation has been launched with a proposal to update the mortality table assumption to the TV 88/90. For funding purposes, providers already commonly use the more recent TV88/90 table. No mortality improvements are taken into account (OECD, 2019[55]).

Life insurers often use the GKX95 tables, though in practice they do tend to adjust the mortality assumptions used based on the mortality experience of their portfolios. The GKX95 tables are based on the experience of group annuitants of Swiss insurance companies over the period 1986-90 (Correia, 2018[56]).

Slovak Republic

Country context for standard mortality tables

The Statistical Office of the Slovak Republic has constructed a mortality table based on based on the Slovak population structured by age and gender. In practice, insurance companies often construct their own mortality tables. The annuity market is not yet developed in the Slovak Republic.

Pension fund providers are required for the purpose of pension benefit statements to use the projected mortality tables published on the website of the Statistical Office of the European Communities to calculate pension forecasts. However, for the actual calculation of annuity income and liabilities, providers use their own tables.

Slovenia

Country context for standard mortality tables

Regulation specifies the mortality tables the pension companies must use to calculate their reserves. For contracts issued before 1 October 2016, they must use the German table DAV 1994R. For contracts issued since then, new tables SIA65 based on Slovenian data must be used. These tables serve as a minimum basis for the reserves of insurance companies (Ahčan et al., 2012[57]).

Technical details

The base mortality rates for the SIA65 are based on the Slovenian population of 2010 adjusted with selection factors. Selection factors are derived from experience in the United Kingdom and Germany. Additional selection factors are applied for the immediate annuity table (SIA65), which is the same as the deferred annuity table (SDA65) from age 60 (Ahčan et al., 2012[57]).

Mortality improvements are based on Slovenian population data since 1945, projected forward using a Poisson log bilinear model similar to the Lee-Carter model. The projected improvements are reduced to a one-dimensional table using the age shift method. The maximum age for the table is 120 (Ahčan et al., 2012[57]).

Spain

Country context for standard mortality tables

The Insurance Supervisor in Spain recommends the use of the PERM/F 2000 tables for the valuation of annuity contracts. Separate tables are applicable for policies in force before and after 1 November 2000. The tables are based on the Spanish population mortality, adjusted by a selection factor based on the Swiss population and incorporating mortality improvements (OECD, 2014[35]).

Technical details

The base mortality for the PERM/F 2000 tables is derived from the Spanish population mortality in 1990 improved to the year 2000. Improvement factors are based on an analysis of Spanish mortality improvements from 1960 to 1990. Selection factors are derived based on the Swiss EVK90 tables for group insurance, with factors increasing over age 50 to 100 (de Vicente Merino et al., 2000[58]).

Sweden

Country context for standard mortality tables

The Swedish Pensions Agency uses mortality tables based on Swedish population data to calculate technical provisions and annuity income for the Premium Pension. Technical provisions are based on best estimate mortality with a loading factor.

For private pension providers, the Swedish Insurance Companies Industry Organisation publishes mortality tables (DUS14) based on data from Swedish life insurance companies. Separate tables are produced for voluntary insured (life insurance) and compulsory insured (occupational pensions). These tables are used in practice to calculate technical provisions.

Technical details

Premium pension

Mortality assumptions are based on Swedish population data forecasted by Statistics Sweden, and use cohort mortality by decade rather than individual age. Forecasts are updated every three years. Mortality rates are smoothed with the Gompertz Makeham law, and extrapolated linearly from age 100.

DUS14

The DUS14 tables are based on Swedish insured and pensioner data over the period 2001 to 2012. Mortality improvements are modelled with a Lee-Carter model calibrated to Swedish population data over the period 1968-2012 (Svensk Försäkring, 2014[59]).

Switzerland

Country context for standard mortality tables

Occupational pension funds, which are mandatory in Switzerland, tend to rely on either the Standard BVG/LPP tables (for private pension funds) or the VZ tables (for public pension funds), potentially adjusted to reflect the mortality experience of the specific plan (Wan and Bertschi, 2015[60]). The latest BVG/LPP tables (the LPP 2020) are based on pensioner mortality from 15 large pension funds over the period 2015-19. These tables are available for purchase only. Most pension funds rely on the BVG tables, however only around half of them account for future mortality improvements, though one study indicated that two-thirds of pension funds did so (Willis Towers Watson, 2019[61]).

Mortality improvement assumptions developed by Menthonnex, in collaboration with the Federal Office of Statistics (OFS), tend to be used when mortality improvements are assumed. The Menthonnex mortality improvements are based on Swiss population mortality experience from 1900-2013, projected to 2 150 (Menthonnex, 2015[62]).[16]

Life insurers tend to rely on the ERM/F 2013 tables to value annuity liabilities, which are based on Swiss life insurance experience between 1981 and 2011.

Technical details

Menthonnex mortality improvements

The Menthonnex model smooths mortality rates across birth cohorts with a law that, in contrast to the Makeham-Gompertz model, has parameters that model the interaction of the drivers of the trend over time with age. In contrast to the Lee-Carter model, which extrapolates improvements indefinitely into the future, this model allows for the retangularisation of the mortality curve over time, and thereby implicitly assumes that the rate of decline in mortality rates will slow.

Türkiye

Country context for standard mortality tables

The Turkish Treasury co-ordinated a working group with Hacettepe University, Başkent University, Marmara University and BNB Consulting Firm to develop Mortality Tables, resulting in the Turkish Annuitant Life table TRHA-2010 (International Association of Actuaries, 2016[63]).

A Working Group from Hacettepe University is updating these tables to improve them and incorporate future mortality improvements.

Technical details

As there is not sufficient annuitant data from insurance companies to construct a table, all insured data is used over the period 2004-08 to construct the TRHA-2010 table. Rates for central ages are smoothed with the Whittaker Henderson model. Age specific reduction factors based on older American CSO tables are applied to these rates to result in the mortality table for annuitants (International Association of Actuaries, 2016[63]).

United Kingdom

Country context for standard mortality tables

The Continuous Mortality Investigation (CMI) of the Institute and Faculty of Actuaries (IoFA) in the United Kingdom carries out mortality experience studies and the development of mortality tables used by pension and annuity providers. They develop a number of base mortality tables reflecting different populations. The '16' Series tables are the latest able for pension annuities in payment provided by insurance companies. They are based on insurance data over the years 2015-18, including annuities purchased with pension savings as well as buy-outs. The 'S3' Series tables are the latest tables for self-administered pension schemes. They are based on pensioner data from 2009-16.

The CMI also makes a tool available to project future mortality improvements. The last major revision of the methodology of this model occurred in 2016. This latest model includes user inputs to control the sensitivity of the model to the most recent data, the pattern of convergence and long-term improvement rates.

Technical details

16 Series

The 16 Series tables includes separate tables by internal and external buy-outs as well as tables by both lives and amounts (by gender). The central ages are graduated using the Gompertz model, and are blended to general population mortality for both younger and older ages (CMI Annuities Committee, 2020[64]).

S3 Series

The S3 Series includes separate tables by gender, status (all pensioner, normal health, ill health, dependent), tables based on lives or amounts, and tables based on bands of pension amounts (high, medium, and low). The graduation method used was the one most appropriate given the data, and low and high ages are blended to population mortality (CMI, 2018[65]).

CMI improvement model

The CMI projection model first smooths each year of historical rates for England and Wales across ages to follow an exponential pattern (the previous model smoothed historical rates across both years and ages using a p-spline model). An age-period-cohort improvement model is fitted to these smoothed historical rates to determine the initial rates, which are the last fitted rates of the historical period. Initial rates are interpolated to long-term rates via a function that allows users to define the weight of the most recent input data, the slope of the convergence pattern, as well as the rate of long-term improvement. Convergence periods across periods and cohorts differ, and the convergence period for younger cohorts is shorter. Long-term improvements are linearly graded down to zero between ages 85 and 110 (CMI, 2017[66]). The default settings for the 2020 version places no weight on 2020 data due to COVID-19 (CMI, 2021[67]).

United States

Country context for standard mortality tables

The Society of Actuaries (SOA) in the United States publishes mortality tables that are used to value pension liabilities. They published the RP2014 tables in 2014 based on the mortality experience of uninsured private pension plans. The Internal Revenue Service (IRS) requires these tables to be used for minimum funding calculations and for PBGC (the pension guarantee fund) premiums. Plans are required to use these base tables in conjunction with the MP-2019 mortality improvement scale, though smaller plans commonly reduce the two-dimensional generational table to a one-dimensional static table for ease of calculations (Society of Actuaries, 2014[68]).

The SOA updated the RP2014 tables in 2019 with the Pri-2012 based on more recent mortality experience of private pension plans. They also for the first time developed a table based on the experience of public pension plans, the Pub-2010.

To accompany the RP-2014 table, the SOA produced a two-dimensional mortality scale for the first time in 2014, the MP-2014, and since then updates its projections annually. The methodology underlying the model was revised in 2018 and 2021, and the latest improvement scale issued is the MP-2021. Mortality rates are projected to converge to a long-term improvement assumption (Society of Actuaries, 2020[69]). These improvement scales are intended to be used with the base tables described above. The MP

Improvement Scale was not updated for 2022, as the Committee in charge of developing the assumptions felt that it was inappropriate to include the mortality experience of 2020 in future projections without adjustment (Society of Actuaries RPEC, 2022[70]).

Separate tables are developed for annuities provide by life insurers. In 2011 the American Academy of Actuaries issued the latest annuity valuation mortality table, the IAM 2012, at the request of the National Association of Insurance Commissioners (NAIC). The table is based on the payout annuity experience of insurance companies. It is accompanied by the improvement scale G2 (American Academy of Actuaries, 2011[71]).

Technical details

RP-2014

The RP-2014 table is based on the mortality experience of uninsured private pension plans over the period 2004-08. Central ages are smoothed using the Whittaker-Henderson-Lowrie model. Mortality for older ages are extrapolated using the Kannisto model, subject to a cap on the mortality rate of 0.5. Mortality for younger ages are derived from the older 2008 VBT. Separate rates are developed for employees and retirees by gender are provided based on amounts rather than lives (Society of Actuaries, 2014[68]). Rates are also provided by blue and white collar, and top and bottom income quartile. A separate table was also published, the RP-2006 table, which reflects the rates at the central year of observation rather than improved to 2014.

Pri-2012

The Pri-2012 table updates the RP-2014 table, and is based on the mortality experience of private pension plans over the period 2010-14. The same methodology was used for its construction as for the RP-2014 table, and tables are provided both by lives and amounts (Society of Actuaries, 2019[72]).

Pub-2010

The Pub-2010 table is based on the experience of public pension plans over the period 2008-13. Its construction follows the methodology used for the RP-2014 and the Pri-2012 tables. Tables are provided for both amounts and lives, and separate tables are developed with scaling factors for employees of different sectors (teachers, public safety, general) and retirees with benefits above and below the median (Society of Actuaries, 2019[73]).

MP-2021 Improvement Scale

The MP-2021 Improvement Scale is based on a new model MIM-2021 introduced in 2021 and replacing RPEC_2014. It intends to allow projections that are applicable to a wider range of practice areas. It incorporates data from the National Center for Health Statistics (NCHS), which allows the model to make projections for specific socio-economic deciles based on geographical indicators. It also allows users to set intermediate rates of improvement before reaching the model-specified long-term rate of improvement. It also allows the user to adapt the basis for the initial mortality improvement rate, and make their own adjustments to account for the expected impact of COVID-19.

The MP-2021 Improvement Scale uses a 3rd order Whittaker Henderson method to smooth historical rates of the period 1950-2019, though a smoother alternative scale based on 2nd order differences is also issued. The initial improvement rate is the smoothed rate two years before the final observed year. It uses polynomial interpolation to project to a long-term improvement rate of 1.35% at age 62, which grades down linearly to 1.1% at age 80, 0.4% at age 95, and 0% at age 115. The horizontal convergence period (along ages) is 10 years and the diagonal convergence (along birth cohorts) is 20 years, with the convergence formula using a 50%/50% blending process to smooth the projected rates (Society of Actuaries, 2021[74]).

2012 IAM with Scale G2

The 2012 IAM tale is based on insurance companies' experience of immediate annuities and annuitisation and life settlement options of individual insurance policies over 2000-04. The 2012 IAR (Individual Annuity Reserving) table includes additional margins and the projection scale G2. Central mortality rates were smoothed using P-splines weighted by income amount. Rates for younger ages were derived from the 1994 GAM table projected to 2002, and the oldest ages were extrapolated using the Kannisto model. The improvement Scale G2 is set to be slightly higher than the Social Security Administration's (SSA) projections for the public pensioners, with an additional 0.4% improvement for age 65-82, grading to 0.2% for ages 87 and over. Younger ages were assumed to improve at 1% and improvements grade to 0% for ages 105 and over (American Academy of Actuaries, 2011[71]).

Notes

[1] The statistical institutions in most jurisdictions develop life tables for the general population, but these are not included within the scope of this chapter unless pension or annuity providers reference them in practice due to a lack of mortality tables specifically for these sectors. Nevertheless, population life tables can still a provide useful reference for the development of mortality assumptions, particularly where these tables are developed at a granular level by socio-economic groups, as is the case for example in France and the United Kingdom.

[2] The same institutions develop the tables for pensions and insurance in Austria, Canada, Israel, Korea and the United Kingdom, whereas different institutions have developed tables for the respective sectors in Germany, Italy, Japan, Mexico, Portugal, Switzerland, and the United States.

[3] This table is used to calculate more than half of the total technical provisions for the annuity market in Portugal.

[4] The technical details discussed in the following sections are not always available for all jurisdictions. The examples given are often intended to demonstrate the range of approaches, but do not necessarily accurately represent how prevalent each approach is.

[5] Life insurance here refers to the insurance product that pays benefits to beneficiaries upon the death of the policyholder.

[6] The information included in this section refers only to the latest mortality improvement assumptions developed in each jurisdiction.

[7] Although some may reference the population covered by the public pension system, which is generally quite close to the general population.

[8] Some tables may also include a security margin, for example if they are used for reserving purposes, which further increases the gap in life expectancy between pensioners/annuitants and the general population.

[9] https://avoe.at/rechnungsgrundlagen/

[10] https://www.plan.be/databases/database_det.php?lang=nl&ID=50

[11] https://iabe.be/expert-groups/working-groups/mortality2/overview

[12] The information included here is based on the draft tables published for consultation. The official tables will be published in early 2023.

[13] http://www.ressources-actuarielles.net/gtmortalite

[14] https://www.heubeck-richttafeln.de/

[15] Technical details of the CMI model are described in the section detailing the United Kingdom.

[16] http://www.bvg-grundlagen.ch/franz/embargofr15122020.htm

5 Good practices for developing standard mortality tables for retirement income arrangements

Jessica Mosher

This chapter presents a set of good practices that can serve as guidance to assist in the development and assessment of the standard mortality assumptions used for pensioners and annuitants in the context of the provision of retirement income.

Mortality assumptions are crucial for the provision of any lifetime retirement income in order to ensure the sustainability of the income stream given the amount of assets available to finance it. However, the development of mortality tables is a complex process requiring the consideration of numerous factors and involving many modelling decisions. There is no single correct approach to take, and a certain amount of expert judgement is always required.

Drawing on the previous chapters and experience in OECD member countries, this chapter puts forward a set of good practices that can serve as guidance for the development of standard mortality tables for pensioners and annuitants in the context of the provision of retirement income. These principles should help to guide the process to develop mortality assumptions and to justify the various modelling decisions made.

The guidelines presented in this chapter are organised around four broad areas that should be considered when developing mortality assumptions. The first is accounting for the context in which the assumptions will be developed and used. This involves understanding historical patterns and drivers of mortality, determining the extent of granularity and standardisation needed for the assumptions, and being open to innovative approaches, particularly when data may not be readily available. The second area is the development of baseline mortality assumptions. This involves choosing the data on which to calibrate these assumptions, graduating the calculated mortality rates and adjusting those assumptions to the target population where necessary, and determining appropriate assumptions for the oldest ages. The third area is the development of assumptions for future mortality improvements. This involves making sure that improvements are accurately accounted for, selecting a model in line with future expectations, and choosing the data on which to calibrate the model. The final area involves ensuring internal consistency. Here it is important to ensure coherency and transparency in the assumptions developed. This chapter explains the importance of each of these issues and discusses in more detail the considerations to take into account in the development of mortality assumptions in the context of the provision of retirement income.

5.1. Accounting for the context in which mortality assumptions are developed and used

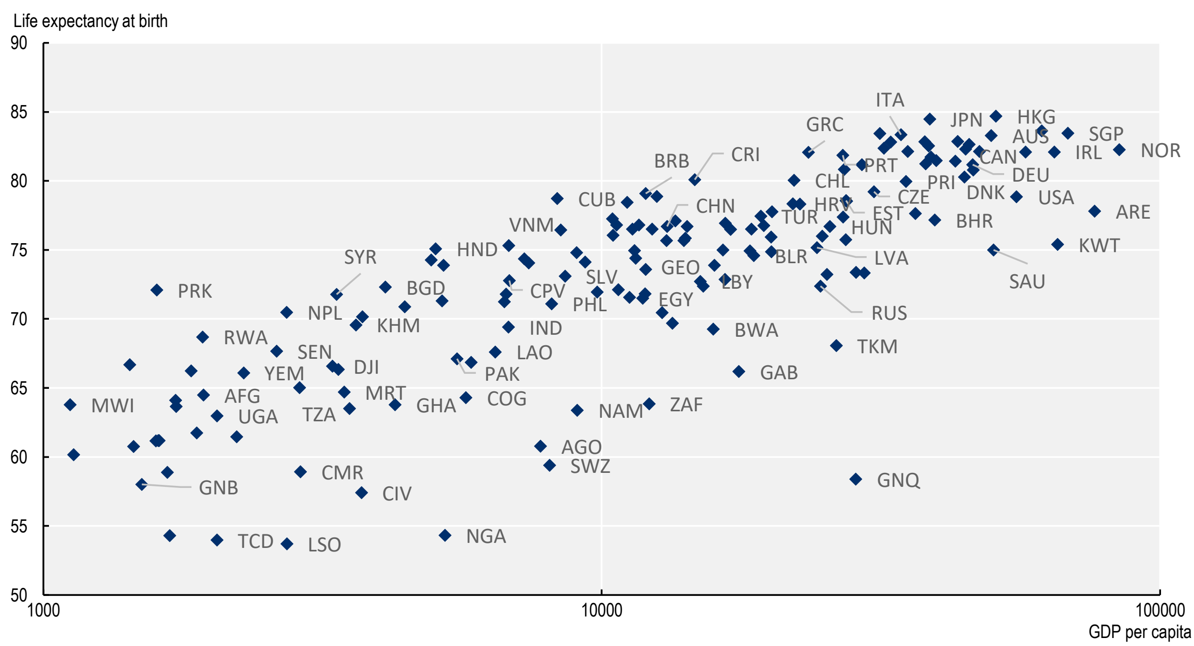
The development of mortality assumptions should consider contextual factors and drivers that can influence the patterns of mortality, as well as the purpose for which they will be used, in order to ensure that they will be accurate and appropriate for their use. Having an understanding of historical patterns and the drivers of mortality will aid in forming expectations about what will happen going forward. The purpose of the assumptions will influence the preference for more or less granularity and standardisation, as these preferences could differ depending on whether the assumptions are being used, for example, to establish reserves or calculate retirement income. In addition, the techniques to model mortality are constantly evolving, so the development of assumptions and the assessment of their appropriateness should remain open to innovative approaches that could improve their accuracy.

5.1.1. Understand historical patterns to inform future expectations

Understanding the trends in mortality and life expectancy is important to inform decisions regarding the selection and calibration of the models used to develop mortality assumptions. Economic and political contexts as well as societal trends can influence the historical trend of mortality, and changing contexts mean that certain historical experience may not always be an appropriate base for future expectations. Understanding the specific drivers of mortality in these contexts can help to inform whether observed trends will continue or whether changes are likely, providing a rationale for longer-term expectations regarding an acceleration or deceleration of improvements in life expectancy. In addition, an analysis of patterns for different groups of the population can aid in determining whether expectations might be different for the pensioner or annuitant population of interest.

Economic context can have a material influence on the speed of mortality improvement, particularly for countries that are rapidly developing. Current OECD countries who were lagging behind the OECD average life expectancy in the 1960s have since gained significant ground as they developed economically and their life expectancy caught up with the level observed in other OECD countries. Chile, Colombia, Costa Rica, and Korea, whose life expectancies at birth lagged at least 10 years behind the then-OECD average, have since caught up to the current OECD average life expectancy of just over 80 years, with Korea even exceeding this level (OECD, 2021[1]). Indeed, life expectancy is highly correlated with economic development, as Figure 5.1 clearly shows. Once the life expectancy of developing countries reaches that of economically advanced countries, the rapid growth will be likely to slow to the rate observed in the latter countries rather than continuing its rapid progression indefinitely into the future.

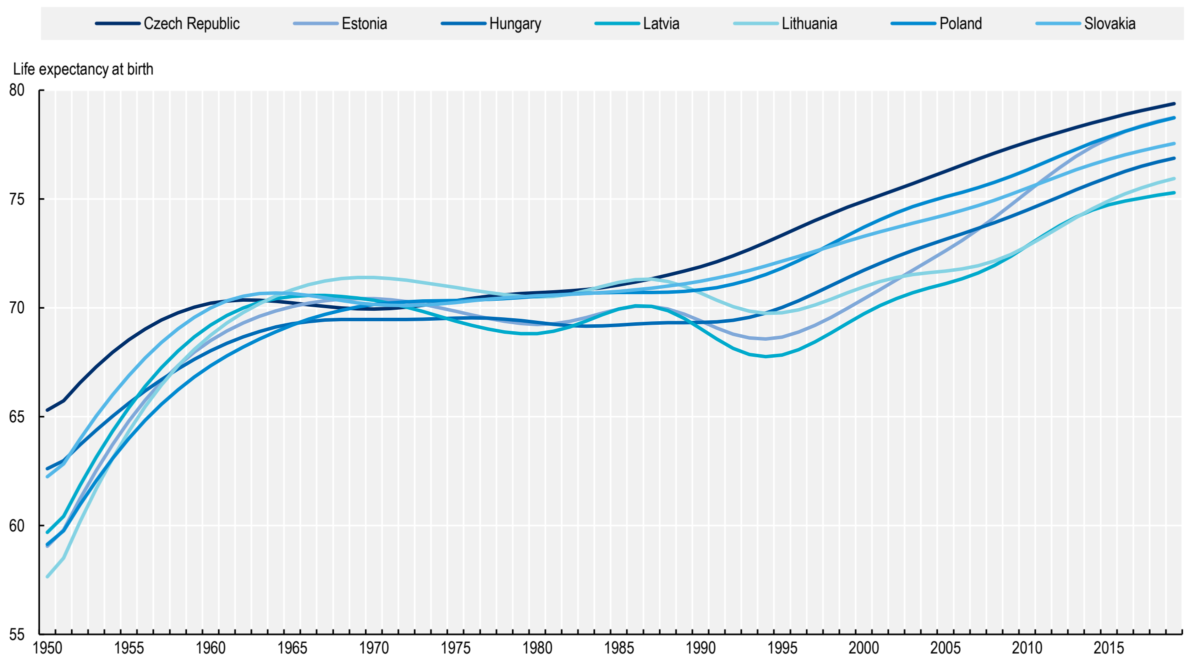
Figure 5.1. Life expectancy and GDP per capita, 2018



Note: GDP per capita is measured in 2011 international dollars, which corrects for inflation and cross-country price differences. For readability, not all countries are labled.
Source: Data from “Life Expectancy” Published Online at OurWorldInData.org: https://ourworldindata.org/life-expectancy

Political context can also influence the direction of trends in life expectancy. Shifts in political regimes, for example, can lead to clear breaks in historical patterns. The trends in life expectancy of Eastern European and Baltic countries illustrate the influence of the political context. Figure 5.2 shows that after years of stagnation, many of these countries experienced accelerated increases in life expectancy following the collapse of the Soviet Union, breaking with earlier observed trends.

Figure 5.2. Life expectancy at birth in selected Eastern European countries, 1950-2019

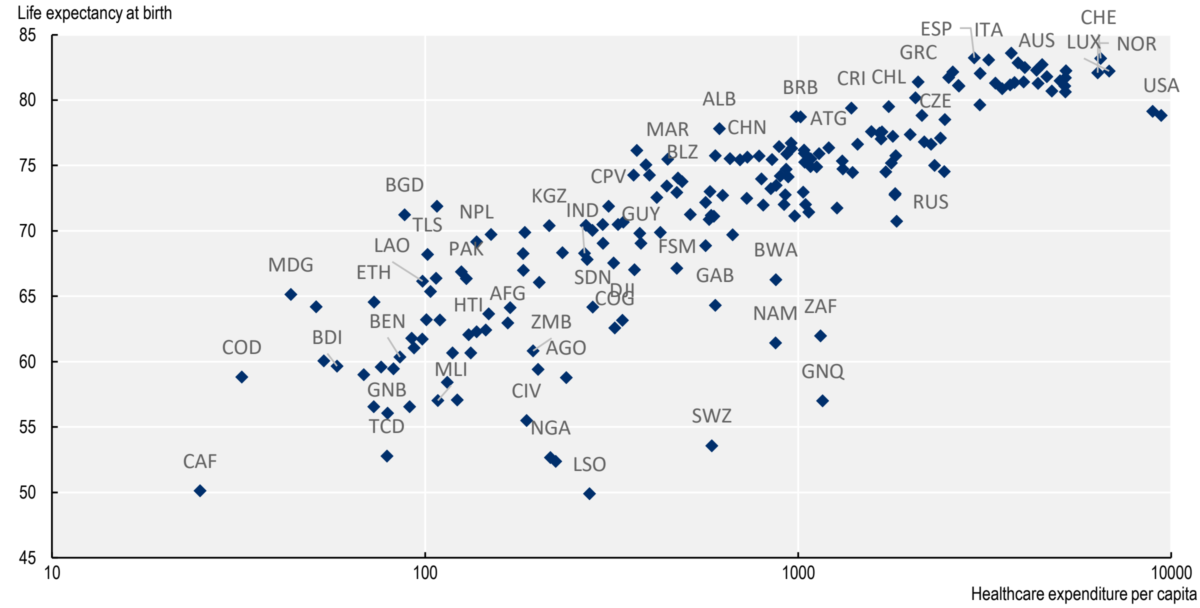


Source: Data from "Life Expectancy" Published Online at OurWorldInData.org: https://ourworldindata.org/life-expectancy

Breaks in historical mortality patterns may also be temporary. The COVID-19 pandemic led to significant excess mortality over 2020 and 2021. However, these spikes in mortality should largely be anomalous, with mortality levels returning to their pre-COVID-19 levels and trajectory. As such, it may be prudent to omit these years from any calibration of mortality going forward, as these high levels of mortality are not expected to continue for those who have survived the pandemic. Indeed, in response to the pandemic, the latest mortality projections model developed by the Continuous Mortality Investigation (CMI) in the United Kingdom allows users change the weight given to specific years in the calibration of the model (CMI, 2021[2]).

Specific policy initiatives can also affect life expectancies. For example, increased health care expenditure is strongly correlated with higher life expectancies, as seen in Figure 5.3. As such, policy initiatives that aim to increase public health care spending, such as the introduction of universal health care, should have a positive impact on life expectancy trends. Other policies aim to encourage more healthy behaviours, which can also have a direct impact on life expectancy. Cigarette taxes, for example, have been effective at reducing the prevalence of smoking, particularly for young adults and lower socio-economic groups (Sharbaugh et al., 2018[3]; Wilkinson et al., 2019[4]).

Figure 5.3. Life expectancy and health care expenditure, 2014

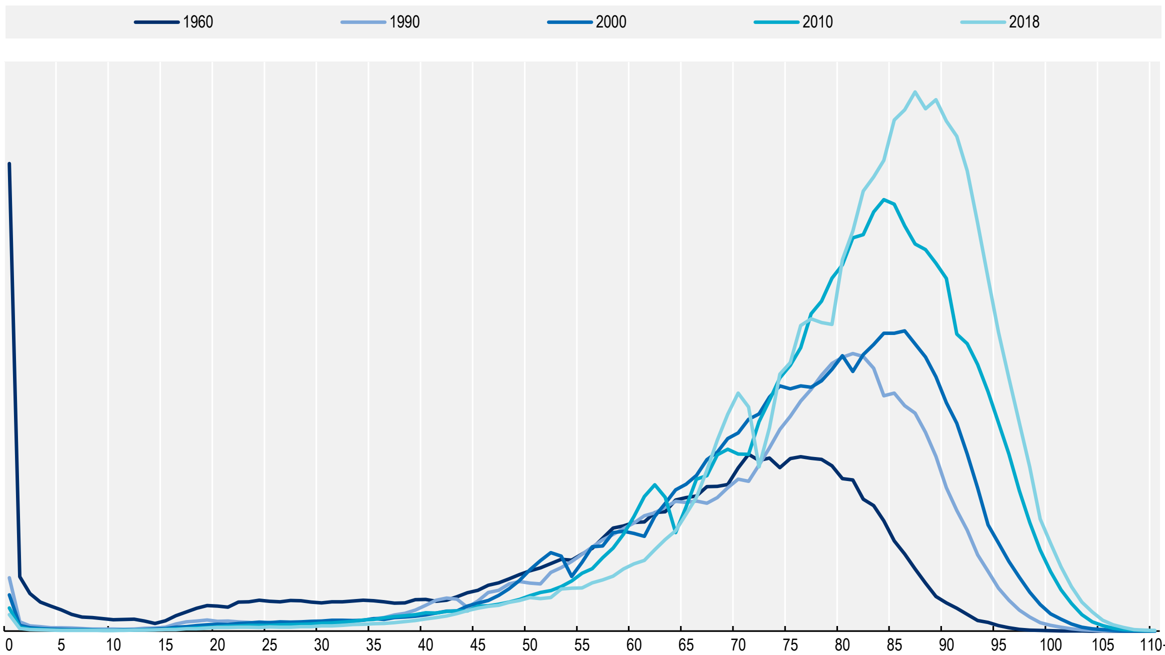


Note: Total health care expenditure per capita is adjusted for price differences between countries and for inflation and measured in international dollars. For readability, not all countries are labled.
Source: Data from “Life Expectancy” Published Online at OurWorldInData.org: https://ourworldindata.org/life-expectancy

An understanding of the specific drivers underlying the observed historical patterns can better inform future expectations and provide a rationale for why changes could be expected. In many countries, reduced improvements in mortality from cardiovascular diseases have been a large driver in the overall slowdown in improvements observed over the last decade in many high-income countries (OECD/The King's Fund, 2020[5]). Furthermore, while declining smoking rates were contributing to rapid mortality improvements, rising obesity as well as increased rates of diabetes are now offsetting some of these gains. Increased mortality from dementia at the oldest ages is also a concern, and is contributing to these negative trends. In Canada and the United States, deaths from drug overdoses have been a significant driver of the slowdown in mortality improvements (Ye et al., 2018[6]; Case and Deaton, 2017[7]). In Mexico, the stagnation of life expectancy since around 2000 has been mainly due to high rates of violence and homicide (Alvarez, Aburto and Canudas-Romo, 2019[8]). Identifying the direction of these types of drivers can provide an indication of whether long-term improvements could be higher or lower than historical trends imply.

The evolution of the distribution of lifespans can provide some insight as to where there is the most room for future improvement, the extent to which the maximum lifespan may be increasing, and the extent of longevity inequalities within the population. Where the left side of the distribution has decreased substantially, mortality improvements are more likely to shift to older ages where there is more room for additional improvements. A rightward shift of the distribution over time would indicate that the maximal age of survival is still increasing. A compression of the curve around the modal age of death would indicate a reduction in the variance of lifespans and therefore a likely reduction of longevity inequalities within the population. For example, Figure 5.4 shows a significant decrease in deaths below age 65 in Japan since 1960, accompanied by an increase in both the modal and maximal age of death.

Figure 5.4. Distribution of the age at death in Japan, 1960-2018



Note: Distributions are not adjusted for population composition, and the maximum age is capped at 110.
Source: Data from the Human Mortality Database: www.mortality.org.

Looking at the patterns of mortality improvements for different subgroups of the population will provide clearer insight as to any underlying inequalities in longevity and how longevity trends may differ across population subgroups. Some jurisdictions, such as Denmark, the United Kingdom and the United States, have seen the differences in life expectancy across socio-economic groups increasing over the last decades (Cairns, 2019[9]; Wen, Cairns and Kleinow, 2020[10]; Case and Deaton, 2017[7]). This is relevant to pensioner and annuitant populations, who tend to be from higher socio-economic groups, as they may experience more rapid mortality improvements than observed on average for the general population. Changes in certain mortality drivers could also imply a change in any underlying inequalities in the population. In many countries, the lower life expectancy of more disadvantaged populations is linked to unhealthy behaviours and habits such as smoking, lack of exercise, or drug use (Cairns, 2019[9]; Geronimus et al., 2019[11]; Tarkiainen et al., 2011[12]). It would therefore be likely that any improvement in these negative trends would be accompanied by a reduction in longevity inequalities across socio-economic groups.

5.1.2. Determine the granularity of assumptions given the availability of data and the purpose for which the assumptions will be used

Mortality experience can vary widely across different subgroups of the population. As such, mortality assumptions often differentiate between select groups. The level of granularity of assumptions will depend on the relevance of the indicator, the data available on which to calibrate the assumptions, as well as the purpose for which they will be used.

In all contexts, age and gender are the most relevant variables to consider when deciding the granularity of assumptions. At a minimum, mortality assumptions systematically account for differences in mortality across age, as mortality generally increases exponentially with age. Mortality also differs significantly between genders, with females normally having lower mortality than males at all ages within the same population group. At birth, women in OECD countries can expect on average to live around five-and-a-half years longer than males, but this difference can even exceed ten years (OECD, 2021[1]). Women aged 65 can expect to live over three years longer than their male counterparts in the OECD (OECD, 2022[13]). Given these differences, age and gender are the most common variables by which to differentiate mortality assumptions.

Variables indicating the socio-economic status of the individual may also be relevant, as higher socio-economic groups tend to have significantly higher life expectancy than those in lower socio-economic groups, even at older ages (OECD, 2016[14]). Furthermore, pensioner and annuitant populations tend to have a higher socio-economic level than the general population on average, with populations of voluntary annuitants typically demonstrating the largest differences from the population average. Common indicators used to differentiate among socio-economic groups for standard mortality tables are the level of pension income, the type of worker (e.g. blue or white collar), or geographical location.

Other indicators may aim to differentiate among types of beneficiaries. This could involve setting separate assumptions for members of public schemes and private schemes, or whether the pensioner is the original beneficiary or the surviving beneficiary. The extent to which mortality differs between these groups may depend on the particular context in which these schemes operate.

Mortality assumptions may also vary by some indicator of health. Distinct mortality assumptions are often used for smokers or for disabled populations, for example.

Developing separate assumptions for different groups requires sufficient data on which to base these assumptions. In many cases, there may not be sufficient data even if there is some evidence of substantial differences in mortality. For example, female disabled and male survivor beneficiaries tend to both be very small populations compared to the same groups of the opposite gender, largely driven by the historically male-dominated labour force covered by asset-backed pension arrangements. Where there is insufficient data, approximations may be used to adjust the mortality assumptions for other groups. For example, the CPM mortality tables in Canada provide factors to adjust the base mortality rates to the desired income band. In Peru, the mortality of the female disabled population is derived from the general population mortality based on the percentage of excess mortality that the male disabled population demonstrates.

The appropriate level of granularity also depends on the purpose for which the mortality assumptions will be used. Mortality assumptions used to determine retirement incomes are often unisex so as to not disadvantage women. In certain contexts, the use of socio-economic variables may also be considered discriminatory. On the other hand, income or health measures could be used as a way to increase the retirement income for more disadvantaged populations.

Mortality assumptions used for the purpose of calculating liabilities and reserves to secure future retirement incomes may be more granular so as to ensure a more accurate estimation of the level of assets needed to be set aside to finance future retirement incomes. As such, even if unisex mortality assumptions are used to calculate retirement incomes, the calculation of reserves usually relies upon separate assumptions for each gender. To capture the socio-economic gradient of mortality, assumptions used for reserving are also often based on pension amounts rather than individual lives.

The level of granularity of assumptions may also be different for the base assumptions and the mortality improvement assumptions. Mortality improvement assumptions usually only distinguish between ages and gender, whereas base mortality assumptions can vary by several additional variables.

5.1.3. Allow for flexibility to adapt assumptions where appropriate for their purpose

The level of standardisation required for mortality assumptions will depend in part on the purpose for which they are used. Standard mortality tables may serve as a basis for calculating retirement incomes or reserve requirements, or they may serve as a benchmark or reference from which to tailor assumptions to a specific population.

The use of standard mortality assumptions may be preferable where there is a need for consistency and comparability. This may be the case, for example, where standard assumptions are used to calculate the allowed level of programmed withdrawal, as in Chile, or where used for financial reporting or tax purposes, as in the United States.

Nevertheless, more accuracy may be preferred where the mortality assumptions are needed to value liabilities or for risk management purposes. Here, entities should be able to adapt the standard assumptions to better reflect the mortality of their actual pensioner or annuitant population if they can justify a different level of mortality based on experience. While many jurisdictions require standard tables as a minimum basis for valuation, this could potentially discourage providers from creating products to serve markets with lower life expectancies. Therefore, providers should ideally be able to adjust the standard assumptions in either direction so long as it is justifiable. Chile and Denmark take this approach, and providers are required to justify any deviation in assumptions from the benchmark mortality rates established by the supervisor.

5.1.4. Be open to innovative approaches

It may not always be possible or desirable to use traditional approaches to model mortality and develop standard mortality tables. The modelling of mortality is an evolving field, with new approaches being developed to overcome challenges relating to a lack of data or experience, or to better align assumptions with realistic expectations.

The lack of available or reliable data can be a major hurdle in the development of mortality tables, particularly for small pensioner or annuitant populations. Overcoming this limitation typically involves a significant amount of expert judgement. However, emerging techniques for data analysis, such as machine learning, are starting to be used to improve mortality estimates where data is lacking and to reduce the reliance on expert judgement alone.

Machine learning techniques are also starting to be applied to the calibration of existing mortality models to improve mortality estimates. These techniques can aid in the selection of data or the optimisation of parameters to improve the model’s fit and the accuracy of the modelled mortality rates, for example.

5.2. Establishing baseline mortality assumptions

Baseline mortality assumptions reflect the current level of mortality, without accounting for expected mortality improvements in the future. The calibration of these assumptions should be on a population that is as similar as possible to the pensioner or annuitant population to whom they will apply. Where the population is not the same due to a lack of available data, adjustments are needed to align the assumptions to the target population. The calibration of baseline mortality assumptions also requires assumptions around the pattern of mortality across ages, and in particular for older ages where less data is available. As such, model selection should aim to smooth and extrapolate observed data across ages in line with expectations, up to some maximum age that is set to ensure that the mortality assumptions apply to all surviving pensioners or annuitants.

5.2.1. Calibrate assumptions for baseline mortality on data that is as similar as possible to the target population

Mortality differs widely across different populations groups, so it is important to calibrate baseline mortality assumptions on data that reflects the actual mortality of the target pensioner or annuitant population to whom the assumptions will apply. Ideally, assumptions will rely on data from the target population itself. However, these populations are sometimes too small to reliably calibrate assumptions, so larger populations for whom more data is available are often used. In this case, adjustments may be needed to ensure that the calibrated assumptions will reflect the expected mortality of the target population.

At a minimum, assumptions should rely upon mortality data from the same jurisdiction as the target population, as the differences in life expectancy across countries can be large. Among OECD countries, life expectancy at age 65 ranges from 17.9 years in Hungary to 24.6 year in Japan for women, and from 13.6 years in Lithuania to 20.2 years in Iceland for men (OECD, 2022[13]). This is a difference of over six years for both genders, which is very significant when assessing how long retirees can expect to live and how much they will need to finance their retirement.

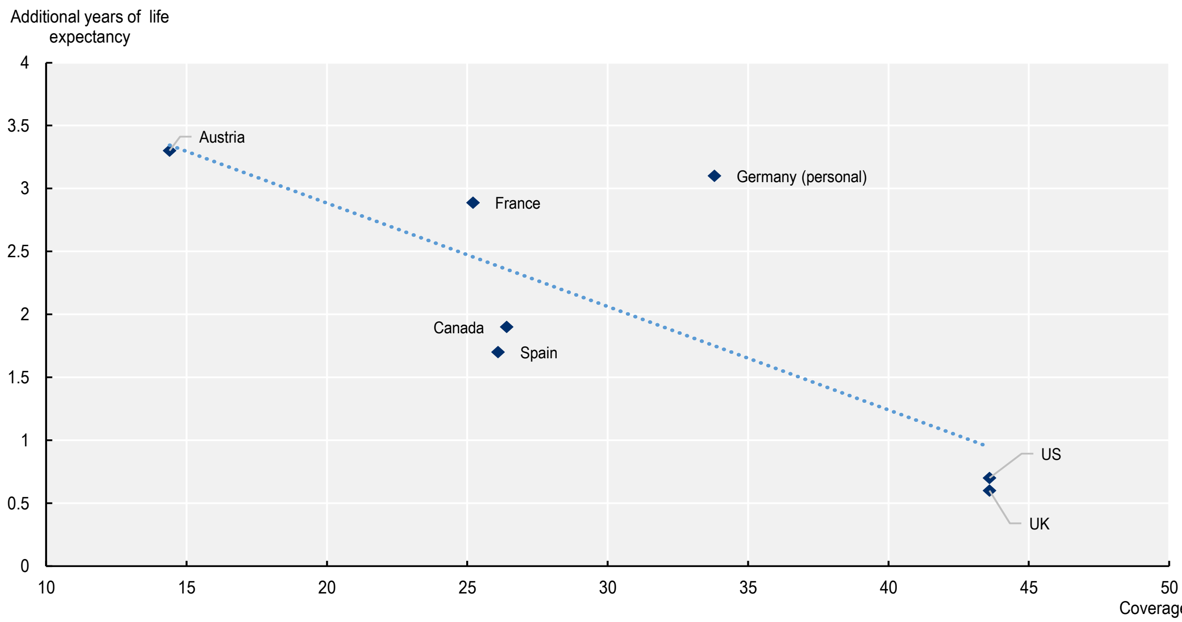
Life expectancy also varies significantly across groups within a given jurisdiction, so the calibration of assumptions should rely upon a population within the jurisdiction that is representative of the target population, where possible. Pensioners and annuitants in particular tend to be better off than the general population on average, and as such tend to have life expectancies higher than the general population. In practice, baseline mortality assumptions for pensioner or annuitant populations tend to result in life expectancies at age 65 of around 2 to 2.5 years higher on average than the general population.[1] Where these populations are smaller relative to the general population, as tends to be the case for annuitant populations, these differences can be even larger.

One approach to account for these differences is to rely upon a proxy population that demonstrates the same characteristics as the target population to calibrate baseline mortality assumptions. This approach can be useful when the target population is a specific subset of a population for which data is available. In Lithuania, for example, the public annuity provider created in 2020 uses mortality assumptions based on mortality data for higher-earning pensioners covered by the public system to proxy the expected mortality of new annuitants.

However, accurately defining a proxy population may be difficult given the data available, so lacking data for the target population, the general population most often serves as the basis for the calibration of baseline mortality assumptions. Where the general population is not representative of the target population, adjustment factors – or selection factors – are also needed to account for the lower expected mortality of the pensioner or annuitant population. These factors are often based on the observed magnitude of differences in mortality between the pensioner or annuitant population and the general population in other jurisdictions where data is more readily available.

Calibrating selection factors on experience in other jurisdictions nevertheless requires some caution, as the level of coverage of any given type of scheme in a specific jurisdiction can substantially affect the size of the selection factor. Figure 5.5 demonstrates the negative relationship between coverage and the magnitude of the difference in life expectancy at age 65 between the general population and the pensioner/annuitant population. In view of this, it would not be advisable for a jurisdiction having a small population of annuitants, for example, to base selection factors solely on the UK pensioner population, where closer to half the population is covered.

Figure 5.5. Relationship between coverage and extent of mortality selection at age 65



Note: The population that the data on coverage represents does not exactly correspond to the population to which the mortality tables apply. The countries shown are selected based on the likelihood that these two populations more closely correspond to each other.
Source: Coverage figures from (OECD, 2019[15]). Selection factors are own calculations.

The magnitude of selection observed typically also varies across ages and between genders. Differences generally increase until around age 60 and decrease thereafter. Differences tend to be larger for men than for women.

5.2.2. Graduate baseline mortality considering available data and the desired fit and smoothness

Standard mortality tables should provide smooth estimates of mortality rates across ages. This requires graduating the raw baseline mortality rates calculated directly from the data. The selection of the graduation model should consider the characteristics of raw mortality rates as well as the trade-off between fit and parsimony.

The age range over which the baseline mortality rates are calibrated may inform the choice of graduation model. The Gompertz model is a simple model that captures the typically observed pattern of an exponential increase in mortality with age. However, this pattern is most appropriate for ages above around 65. If the graduation needs to extend to younger ages, variations on the Gompertz model that account for differing patterns at young and middle ages may be more appropriate for smoothing mortality across all ages. The Gompertz-Makeham model better reflects excess mortality at middle ages, while the Heligman-Pollard better captures mortality patterns for younger ages.

Alternative models, such as the Whittaker-Henderson model, can fit the pattern of the raw data more closely and across years as well as ages, but at the expense of parsimony. The Whittaker-Henderson model is commonly used to smooth baseline mortality assumptions for standard tables, but involves fitting significantly more parameters compared to simpler models. It also requires more judgment to set the user-defined parameters, such as those regulating the smoothness of the graduated mortality rates. Statistical tests, in particular information criteria, can aid in the selection of the appropriate model to balance the trade-off between fit and parsimony.

Where the same population is the basis to calibrate both baseline mortality assumptions and future mortality improvements, it is possible to use a fully integrated model that fits past mortality and simultaneously projects it into the future. In selecting these types of models, the trade-off between fit and parsimony remains applicable.

5.2.3. Consider the expected pattern of mortality when extrapolating assumptions to the oldest ages

It is necessary to extrapolate the graduated rates for old ages to derive the mortality assumptions for the oldest ages – e.g. beyond age 90 or 95 – as the data at these ages are normally insufficient to calibrate mortality rates. The model chosen to do this should result in a plausible pattern of mortality at the oldest ages, in line with any trends observed at the national or regional level.

There are conflicting views regarding the pattern of mortality at the oldest ages, particularly ages over 110 where there is insufficient data on which to base any robust analysis. One side argues that mortality rates continue increasing exponentially with age, while the other side argues that mortality rates eventually plateau at around age 110 (Gavrilov, Gavrilova and Krut'ko, 2017[16]; Gampe, 2010[17]). In practice, both views are taken in the development of standard mortality tables. Those taking the former view most commonly use some variation of the Gompertz model to extrapolate mortality to the oldest ages. For the latter view, a logistic model such as the Kannisto model is often used.

The selected model should result in a pattern of mortality at the oldest ages that is consistent with expectations and available evidence. The extrapolated mortality rate should not reach 1 at an age below the desired maximum age (see the following guideline). If assuming that mortality rates ultimately plateau, most available evidence suggests that the force of mortality plateaus between around 0.7 and 1.2, which translates into an annual probability of dying of around 50% to 70%.

Input parameters to calibrate the model can also influence the pattern of the extrapolated rates to shape them in the desired direction. These parameters can include the age range over which the model is calibrated, the constraints imposed such as the maximum age, or any external (e.g. population) mortality table referenced.

5.2.4. Set the maximum age of the mortality table to ensure that assumptions will apply to all members of the target population

The mortality table should cover all of the ages that the target population includes, in particular the oldest of the population. If the target population includes individuals aged 115, the mortality table should include mortality assumptions at least to this age.

In practice, mortality tables normally assume an ultimate age beyond which there will be no survivors for the sake of practicality, regardless of the view taken on the pattern of mortality at the oldest ages. This ensures the ultimate run-off of any pension or annuity liabilities.

The ultimate age assumed, however, should be inclusive of everyone included in the target population to which assumptions apply. This is not always the case. Several standard mortality tables in OECD jurisdictions assume an ultimate age of 110 or lower, whereas individuals over this age may exist. Assumptions are still needed to apply to these oldest individuals regardless of how the mortality tables are used, whether to value liabilities or to calculate a retirement income.

Most standard mortality tables in OECD jurisdictions assume a maximum age of at least 120. Globally, no individual over the age of 120 is currently alive, and only one person has been verified as ever reaching an age older than 120.[2]

Nevertheless, this does not necessarily mean that the ultimate age of survival cannot be higher. Patterns in the evolution of distribution of lifespans of a population can inform assumptions regarding the maximum age of the mortality table. If this distribution has been shifting rightward, it could indicate that the maximum age of survival may still be increasing, thereby justifying a higher ultimate age than the oldest observed survivor.

5.3. Developing assumptions for future mortality improvements

Assumptions for mortality improvements capture the expected future improvements in life expectancy by reducing the baseline mortality rates. Mortality tables need to include assumptions for future improvements to avoid underestimating the life expectancy of pensioners and annuitants, which would result in setting aside insufficient assets to secure future retirement incomes. The model chosen to project future mortality rates should be able to reflect future expectations regarding mortality trends, while remaining as transparent as possible for users to understand. The historical data used to calibrate the model to estimate future trends in mortality should be stable in terms of demographic characteristics and be as representative as possible of the target population.

5.3.1. Account for future mortality improvements in a way that reflects reasonable expectations

Standard mortality tables need to account for future expected improvements in mortality, as they add materially to the life expectancy of pensioners and annuitants. The way that mortality tables incorporate improvement assumptions should accurately reflect reasonable expectations regarding the impact that improvements will have on life expectancy.

The impact of mortality improvements on the calculation of life expectancy is significant. Mortality improvements represent on average around 1.5 additional years of life expectancy at age 65 relative to the life expectancy calculated using only current baseline mortality rates.[3]

The most realistic format with which to account for mortality improvements is a two-dimensional improvement scale that varies by both age and time. Indeed, this is the most common format for improvement assumptions included with standard mortality tables in the OECD. The way in which mortality tables take mortality improvements into account should accurately reflect their expected impact on life expectancy. In reality, mortality improvements are different across ages and emerge gradually over time. Each year, the mortality rate at a given age usually declines compared to the previous year. Furthermore, trends by age may not be constant over time, but may accelerate or decelerate.

Simplifications of two-dimensional improvements may be preferred in light of constraints to incorporate two-dimensional mortality assumptions into modelling, but this should not be a prevailing constraint given current technological capabilities. An alternative to a two-dimensional improvement scale is a one-dimensional scale that provides improvements by age but does not vary over time. Depending on the model used to calibrate the assumptions (e.g. extrapolative models such as the Lee-Carter model), this may not make a material difference in calculations compared to a two-dimensional improvement scale. However, age-shift methods that proxy the increased life expectancy of younger cohorts by simply assuming that they have a younger age are not very accurate (e.g. assuming that a 65-year-old in five years will have the same life expectancy as a 63-year-old today), and can become less accurate over time.

5.3.2. Choose a projection model compatible with future expectations taking into account the trade-off between transparency and complexity

A variety of models are available to calibrate mortality improvement assumptions, each of which demonstrates a range of advantages and drawbacks. Selection of the appropriate model will need to consider expectations regarding how mortality will evolve in the future and how to best match those expectations while minimising the level of complexity in the model. While complex models may better fit the data and result in mortality improvement assumptions that better align with realistic expectations, they can reduce the transparency of the model, thereby making it more difficult for the end-user to understand how assumptions were derived.

Mortality projection models that are commonly used to derive future improvement assumptions vary in how they reflect future expectations and are able to incorporate expert judgement. The simplest approach is to apply a linear regression to historical mortality rates to derive the historical trend, and extrapolate this trend going forward. Interpolative models incorporate more judgement regarding expected future trends, and assume improvements will eventually converge to an expected long-term rate of mortality improvement. Age Period Cohort (APC) models deconstruct the patterns of historical mortality along age, period and/or cohort dimensions to extrapolate future mortality rates. Multi-population models extend these approaches to simultaneously project mortality for two or more related groups.

A key question in selecting a model for projecting mortality forward is whether future mortality improvements will reflect past experience indefinitely, or whether mortality improvements are more likely to converge to some other rate in the long term. If taking the former view, modelling options include simple regression models or age-period-cohort (APC) models. Both of these approaches can also be incorporated into an interpolative model to accommodate the latter view of a convergence to a long-term rate of improvement. A multi-population model, which is often an extension of an APC model, is another option that can also assume convergence to a long-term rate based on some reference population.

Increased model complexity can allow the model to better account for the relationship of mortality rates across ages. Simple regression models extrapolate future mortality improvements based on linear regressions of log mortality rates by age (group). APC models, such as the Lee-Carter and Cairns-Blake-Dowd models, are extrapolative models that deconstruct mortality patterns along age, period, and potentially cohort dimensions. While APC models are more complex to fit and to explain than simple regression models, they are better able to capture the age structure of mortality improvements and maintain coherent mortality rates in future years. The inclusion of a cohort effect is not always justified however, and unless historical experience suggests that mortality patterns have been very different for specific cohorts, they may add unnecessary complexity to the model.

The level of complexity involved in interpolative models can vary widely, and is driven by the sub-models used for the graduation and interpolation of mortality rates. Interpolative models generally involve two main steps:

1. Smooth historical mortality experience by fitting it to a model in order to establish an initial rate of mortality improvement by age.
2. Interpolate the initial rates of mortality improvement to a long-term rate of improvement.

Interpolative models can employ several types of the models already discussed to smooth historical mortality experience. Both simple regressions and APC-type models can be fit to historical mortality rates to derive smoothed historical improvement rates. In addition, models such as the Whittaker-Henderson model, which is also common to establish baseline mortality rates, can be fit across two-dimensional historical mortality experience. The latter model is the most complex and involves more user input to fit, but is also able to better reflect the specific patterns in mortality observed. APC models involve less subjectivity than models like Whittaker-Henderson, but are still able to reflect the age structure of mortality rates, which is not possible with a simple regression model.

The interpolation of the initial mortality improvement to a long-term rate of improvement can also involve more or less complexity. The simplest approach is to apply a linear interpolation by age, but this ignores any differences in the speed of convergence across time or ages. More complex approaches allow for different convergence rates across period and cohort dimensions, or changes in the slope of convergence over time. However, this also involves significantly more judgement in setting the parameters for convergence.

Multi-population models are the most complex option for projecting future mortality improvements. They nevertheless offer a potential solution to model mortality improvements for smaller populations for whom there is not sufficient data to calibrate a model, or to ensure coherent mortality projections across several related populations (e.g. for males and females). However, they can more be difficult to calibrate and to understand.

Another consideration for assessing the desired model complexity is the extent to which stochastic longevity scenarios are needed for longevity risk assessments that are consistent with the mortality tables developed. If this is the case, APC models and their extensions (e.g. multi-population models) lend themselves more easily to stochastic projections.

Generally, the modelling of mortality improvements for the oldest ages can adopt a simpler approach. As with establishing baseline assumptions, there is not sufficient data at the oldest ages on which to calibrate robust assumptions for improvements. There is mixed evidence as to whether older ages have recently experienced positive mortality improvements, but there does seem to be consistent evidence that mortality improvements decrease with age. A common approach for standard mortality tables is therefore to simply assume that mortality improvements decrease to 0% at a certain age. Alternatively, the rates fitted to the projection model can be extrapolated in each future year to cover the oldest age groups.

5.3.3. Calibrate mortality projection models on a stable population representative of the target population

Mortality projection models should be calibrated on data from a population that is representative of the target population, and which has not been subject to any major shocks or shifts over the historical period selected for calibration.

As with baseline mortality assumptions, mortality improvement assumptions should be based on a population that is related to the target population of interest. There is not normally sufficient historical data for pensioner or annuitant populations on which to calibrate robust trends. General population mortality is commonly used to establish mortality improvement assumptions for standard mortality tables, with the assumption that the mortality of the pensioner or annuitant population should improve at the same rate as the population on average. Where evidence indicates that life expectancies across socio-economic groups are diverging, mortality improvement assumptions may include an additional selection factor to account for the higher expected improvements of pensioner and annuitant populations.

The impact of different policies on historical demographic patterns also need to be considered. Some policies affecting a population's demographic composition can make it difficult to measure historical patterns on which to base future expectations. Israel's relatively open immigration policy, for example, has led to high levels of immigration that reduces the stability of the demographic characteristics of the population, which could potentially distort any measurement of historical patterns of mortality improvement (Israeli Association of Actuaries, 2018[18]). Another example is in Chile, where a reform of the pension system in 2008 greatly expanded its coverage to lower income individuals, changing the socio-economic composition of the pensioner population (Pensiones, 2015[19]).

The historical period selected to calibrate the models used to derive improvement assumptions should not demonstrate any major breaks in trend and overall should reflect at least near-term expectations regarding future mortality improvement. Model calibration should therefore ideally refer to a period over which the average trend is relatively stable. It should also consider excluding large, anomalous shocks such as the years demonstrating excess mortality due to COVID-19.

Model calibration should also take into account the sensitivity of the model outputs to the selection of the historical period. Purely extrapolative models are generally more sensitive to the length of the historical period than interpolative models where initial improvement rates are reflective of the most recent fitted historical data.

5.4. Ensuring internal consistency

It is prudent to ensure that the mortality assumptions developed and the modelling decisions made demonstrate a certain level of consistency. Many distinct modelling decisions have to come together to establish the assumptions included in standard mortality tables. The resulting assumptions should be coherent with expectations regarding the relationships across different population groups, and modelling choices should be transparent and clearly disclosed.

5.4.1. Ensure coherency across different ages and groups

Mortality rates for different groups of the population consistently demonstrate certain relationships that the standard mortality table should reflect. As such, it is prudent to make sure that model outputs are coherent across different ages and population groups.

Mortality rates should generally increase monotonically with age. As a starting point, the model selected to graduate the baseline mortality assumptions should ensure that this is the case. A model that over fits the data, for example a Whittaker-Henderson model that does not put sufficient weight on smoothness, may result in a ‘bumpy’ mortality curve that does not demonstrate the expected pattern of increasing mortality with age. Mortality projections should also be coherent across ages. Projection models that do not impose a certain age structure may eventually distort the shape of the mortality curve across ages.

Male mortality should generally be higher than female mortality within the same population group. If this pattern is not apparent in the calibration of baseline assumptions, there is likely not sufficient data on which to develop robust assumptions. Any selection factors applied could also potentially distort the relationship of mortality across genders. Selection factors tend to be larger for males, so there could be a risk that their application could result in lower mortality for males than for females. The relationship between genders could also change over time as a result of higher projected mortality improvements for males. This is a particular risk when using extrapolative projection models, as the difference in life expectancy between men and women in many countries has been decreasing over the last few decades, meaning that males will have experienced higher mortality improvements than females.

The mortality for disabled populations should generally be higher than for healthy populations. This is because their underlying deteriorated health condition often leaves them more vulnerable to death, though this depends to a certain extent on the type of disability. A simple way to ensure that this relationship is not distorted in the future is to assume the same mortality improvement assumptions for both the healthy and disabled populations. This is a reasonable assumption, as the disabled population should benefit at least as much from the medical advances and external factors that are driving continued improvements in mortality for the healthy population.

While not an absolute constraint, evidence points to a convergence in mortality across population groups with age, whether between genders, across socio-economic groups, or for different categories of health. This is a result of a selection effect, whereby only the strongest and healthiest of the population survive to the oldest ages. This means that the differences in mortality across population groups should gradually diminish with age. The easiest way to ensure that this is the case is to reference a common mortality table when extrapolating mortality rates for different groups to the oldest ages.

5.4.2. Be transparent regarding modelling decisions

The modelling of mortality and development of standard mortality tables involves a considerable amount of judgement at each step of the process. The documentation for the development of the tables should identify areas where judgement was required and provide a rationale and justification for the modelling decisions made. It should also include information, such as sensitivity tests, to help the user understand the impact that the different decisions have had on the final assumptions. Ensuring transparency will help the user to determine whether the tables are appropriate for their intended use.

5.5. Summary of guidelines

The guidelines put forward in this chapter to establish standard mortality assumptions in line with good practices are summarised as follows:

Accounting for the context in which mortality assumptions are developed and used

When beginning to develop mortality assumptions, it is important to understand the context in which they are developed and the purpose for which they will be used.

1. *Understand historical patterns to inform future expectations* – understanding the past drivers of improvements in mortality can provide insight as to what will happen in the future and help to inform modelling decisions to be in line with those expectations.
2. *Determine the granularity of assumptions given the availability of data and the purpose for which the assumptions will be used* – assumptions may vary for different target groups, and the appropriate granularity will depend in part on the purpose for which the assumptions are used.
3. *Allow for flexibility to adapt assumptions where appropriate for their purpose* – whether to require the use of standard assumptions or to allow them to be adjusted to specific populations will depend in part on the purpose for which the assumptions are used.
4. *Be open to innovative approaches* – in some contexts, standard approaches to modelling mortality may not be possible or may be greatly improved by using emerging techniques.

Establishing baseline mortality assumptions

It is necessary to establish baseline mortality assumptions that reflect the current mortality levels of the target population.

5. *Calibrate assumptions for baseline mortality on data that is as similar as possible to the target population* – mortality levels vary significantly across population groups and the population(s) chosen to calibrate the model should reflect the characteristics of the target population.
6. *Graduate baseline mortality considering available data and the desired fit and smoothness* – the appropriate graduation model should reflect the expected pattern of mortality across ages.
7. *Consider the expected pattern of mortality when extrapolating assumptions to the oldest ages* – different models can lead to a continued increase in mortality by age or to a plateau in mortality rates.
8. *Set the maximum age of the mortality table to ensure that assumptions will apply to all members of the target population* – it should not be set at an age below the oldest living person in the target population.

Developing assumptions for future mortality improvements

It is necessary to establish mortality improvement assumptions that reflect the future expected decreases in mortality over time.

9. *Account for future mortality improvements in a way that reflects reasonable expectations* – mortality improvement assumptions should ideally vary across ages and over time.
10. *Choose a projection model compatible with future expectations taking into account the trade-off between transparency and complexity* – the choice should consider whether improvements are expected to converge to a long-term rate and should also aim for parsimony.
11. *Calibrate mortality improvement assumptions on a stable population representative of the target population* – trends cannot be accurately measured on a population that has experienced significant demographic change over the period or that has been subject to a major policy shock or shift.

Ensuring internal consistency

The final mortality tables should be in line with analysis and expectations.

12. *Ensure coherency across different ages and groups* – mortality tables should reflect the expected relationship of mortality rates for different populations.
13. *Be transparent regarding modelling decisions* – modelling decisions and judgement applied should be clearly disclosed and justified.

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Notes

[1] Based on standard mortality tables in OECD member countries where available.

[2] Jeanne Calment of France died in 1997 at the age of 122 years and 164 days.

[3] Based on standard mortality tables for pensioners or annuitants in OECD member countries, where available.

Mortality and the Provision of Retirement Income

This report analyses the development of mortality assumptions to build mortality tables to better protect retirement income provision. Mortality assumptions are necessary to ensure the sustainability of lifetime incomes. It explores considerations and traditional approaches for developing mortality tables, as well as provides an international overview of longevity trends and drivers over the last several decades, including the impact of the COVID-19 pandemic. The report also details the standard mortality tables developed across OECD member countries and offers guidelines to assist regulators and supervisors in assessing whether the mortality assumptions and tables used in the context of retirement income provision are appropriate.

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