The *Causes* and the *Consequences* of Growing Life Expectancy Shortfalls

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Abstract

Life expectancy stagnation—the lack of improvement in life expectancy over time—and life expectancy divergence—the widening of an existing life expectancy gap—are both warning signs that population health is not developing as well as it could. Most demographic research has used a *stagnation* perspective to understand recent life expectancy trends in high-income countries. This dissertation argues that a within-country approach risks overlooking critical mortality dynamics that are unique to the population experiencing life expectancy stagnation. It proposes to complement within-country analysis of life expectancy stagnation with between-country analysis of life expectancy divergence. In three empirical studies, this dissertation identifies the *causes* of recent life expectancy trends in the United States of America (USA) and the United Kingdom (UK) relative to other high-income countries before, during, and after the COVID-19 pandemic, and quantifies the *consequences* of this life expectancy divergence for population composition. Using demographic decomposition, **Chapter 2** identifies the age groups and causes of death that contributed to the decreasing life expectancy advantage or increasing life expectancy disadvantage of England and Wales relative to other European countries in the period 2010–2019. **Chapter 3** identifies the age groups and causes of death that contributed to life expectancy divergence between the USA and the UK and better-performing peer countries during the COVID-19 pandemic. **Chapter 4** considers the *consequences* of the growing life expectancy shortfall of the USA. Using counterfactual methods, it estimates the number of children that were never born because the USA consistently experienced higher mortality than its peers. Across the three chapters, the proposed *divergence* approach points to critical population dynamics in the USA and the UK that had previously gone unnoticed with a *stagnation* approach. Thus, this dissertation argues that the joint application of the two approaches should become more common practice in demographic analysis.

Contents

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Chapter 1
Introduction[1]

Chapter word count: 6,170

1.1. Problem statement

During the second half of the twentieth century, humanity became accustomed to continuous improvements in life expectancy (Oeppen & Vaupel, 2002). However, widespread slowdowns in mortality improvements shortly before the COVID-19 pandemic dashed optimism that steep gains in life expectancy would continue in the near future (Raleigh, 2019). In addition to stagnation, several countries saw their relative position in international life expectancy rankings decline (Leon et al., 2019; Woolf, 2023). The subsequent arrival of the COVID-19 pandemic in 2020 even resulted in global life expectancy *losses*—in many cases the greatest seen since World War II—and created further life expectancy divergence between countries due to its heterogeneous impact (Schöley et al., 2022).

Figure 1-1 shows changes in life expectancy at birth in 37 countries (hereafter also "low-mortality countries") for which data are available in the Human Mortality Database (HMD, 2025) for the pre-pandemic years 2010 and 2019. The arrow tails indicate life expectancy in 2010, while the arrow heads indicate life expectancy in 2019. Shorter arrows therefore indicate smaller life expectancy improvements. The light blue arrows are ordered in descending order by their level of life expectancy in 2010. The two dark blue arrows at the

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[1] Parts of this chapter are joint work with Jennifer Beam Dowd and have been published as: Polizzi, A., & Dowd, J. B. (2024). Working-age mortality is still an important driver of stagnating life expectancy in the United States. *Proceedings of the National Academy of Sciences*, *121*(4), e2318276121. https://doi.org/10.1073/pnas.2318276121.

top of the graph represent the two countries that are the focus of this dissertation: the United States of America (USA) and the United Kingdom (UK).

The USA stands out as the country with the smallest life expectancy improvements—less than half a year over a ten-year period. The UK's status as a life expectancy laggard is also evident from Figure 1-1, with improvements of just over one year in the decade 2010–2019, performing better only than Canada, Greece, New Zealand, and the USA. Among the 37 countries in Figure 1-1, the USA and the UK respectively ranked 29th and 22nd in 2019—respectively down two and three ranks when compared with their positions in 2010.

Following the logic of Figure 1-1, Figure 1-2 shows changes in life expectancy at birth in 25 Human Mortality Database countries with available data in 2019 and 2021, focusing on the most severe period of the COVID-19 pandemic (Schöley et al., 2022). Compared to Figure 1-1, the set of countries is reduced because data through 2021 are not yet available for all countries in the Human Mortality Database, pointing to a general problem with delays in data reporting that I discuss in more detail in Chapter 5.

Figure 1-2 highlights the heterogeneous effects of the COVID-19 pandemic on life expectancy trajectories in low-mortality countries. While some countries, such as Australia, New Zealand, and the Republic of Korea, had experienced (small) improvements in life expectancy by 2021, several countries had experienced life expectancy losses compared to 2019. These losses are represented by arrows pointing to the left and were particularly large in Central and Eastern European countries—Bulgaria (-3.7 years), Poland (-2.3 years), and Czechia (-2.0 years). However, the USA and the UK also ranked among the countries with the largest life expectancy losses, -2.5 years (second-largest losses) and -0.9 years (fifth-largest losses), respectively. Combined with their smaller life expectancy improvements in the pre-pandemic period, the 2021 life expectancy gaps between the USA and the UK and peer countries were the worst seen in decades.

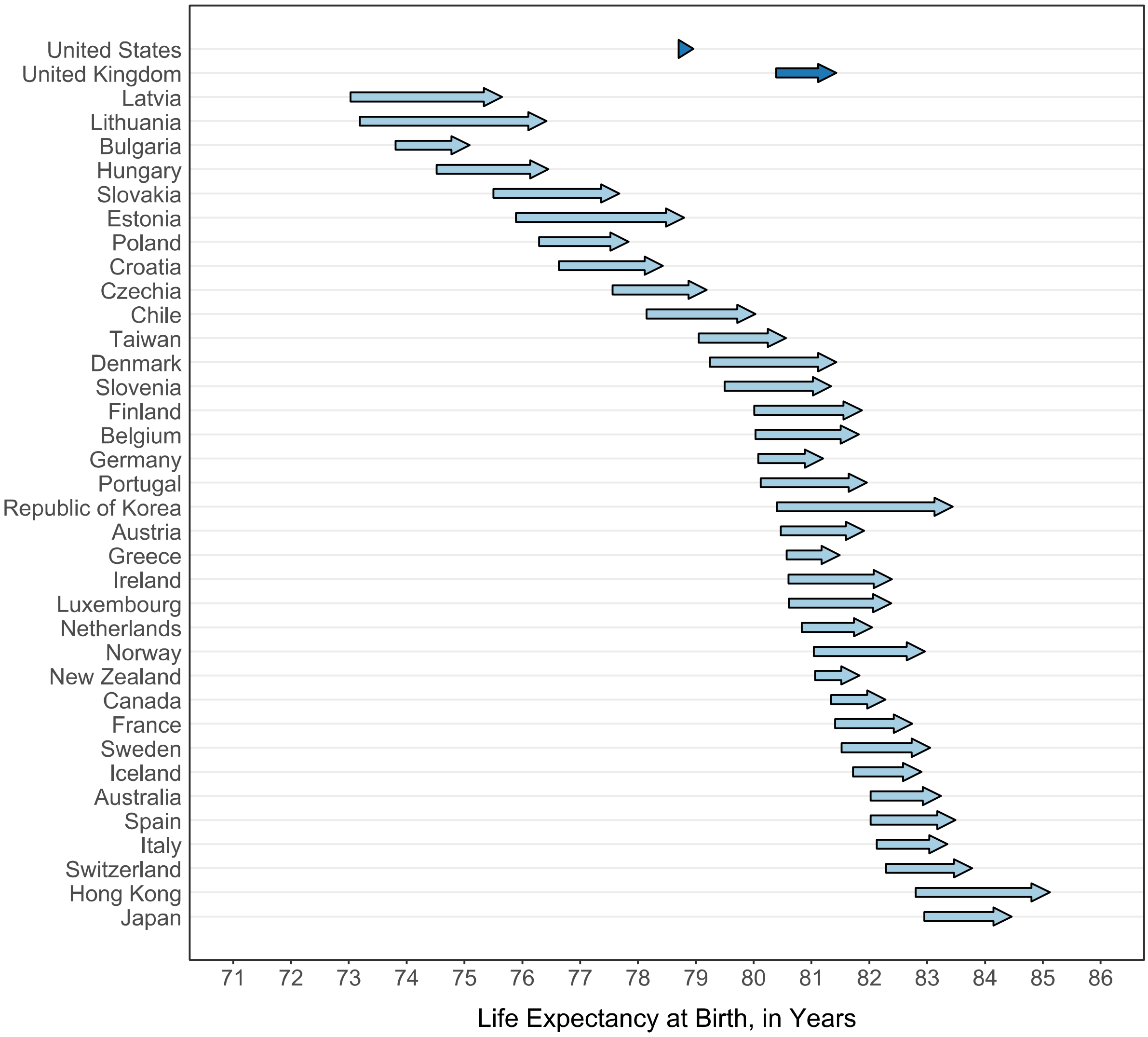

Figure 1-1. Life expectancy changes in Human Mortality Database countries, 2010–2019. *Source*: Human Mortality Database (HMD, 2025).

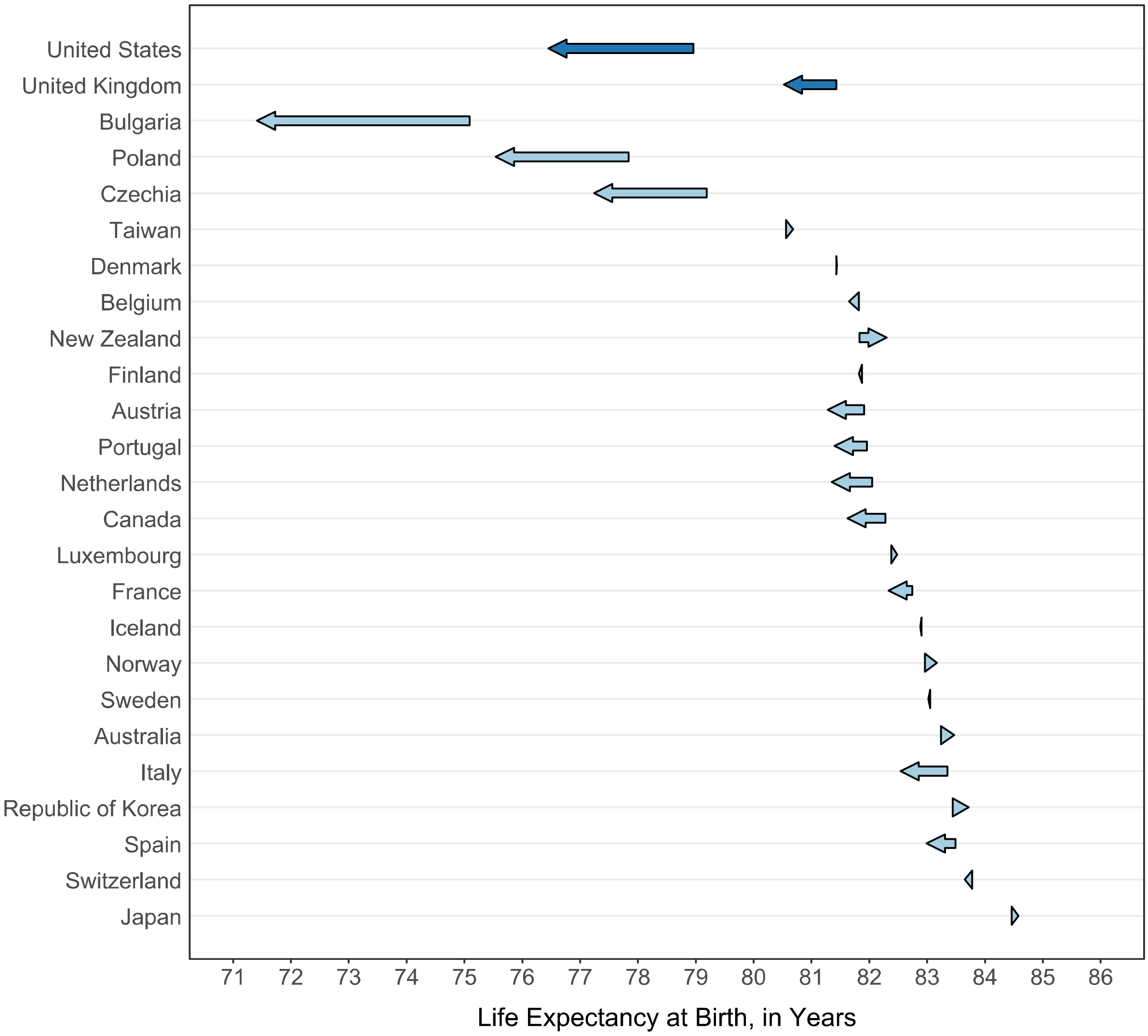

Figure 1-2. Life expectancy changes in Human Mortality Database countries, 2019–2021. *Source*: Human Mortality Database (HMD, 2025).

This dissertation uses high-quality demographic data and state-of-the-art demographic methods to examine the *causes* and the *consequences* of the widening life expectancy gaps between the USA and the UK and other low-mortality countries before, during, and after the COVID-19 pandemic. Most research on recent mortality dynamics has focused on changes in life expectancy within individual countries over time, or on life expectancy gaps between countries at a given point in time. **This dissertation combines these two perspectives and asks why life expectancy gaps between countries have widened and what the consequences are for population composition.** Specifically, this dissertation aims to provide answers to two main research questions (see Box 1-1) that were formulated based on a review of the demographic literature (see section 1.2). This review suggested that external, substance-related, and cardiometabolic mortality at working and reproductive ages have played a key role in the growing life expectancy shortfall of the USA and the UK, with a possible additional effect of COVID-19 mortality from 2020 onwards.

Box 1-1. Main research questions investigated in this dissertation.

1. A) How have external and substance-related mortality, cardiometabolic mortality, and COVID-19 mortality contributed to the growing life expectancy shortfall of the USA and the UK before, during, and after the COVID-19 pandemic?

   B) Which age groups drive the influence of external and substance-related mortality and cardiometabolic mortality on life expectancy divergence?

   C) What is the contribution of alcohol, drug, and suicide mortality ("deaths of despair") to the life expectancy divergence of the USA and the UK from other low-mortality countries?
2. How did the growing life expectancy divergence between the USA and the UK and other low-mortality countries affect population-level birth outcomes?

1.2. Definition of key terms and approach

The central tenet of this dissertation is that the *causes* and the *consequences* of life expectancy *stagnation* are not synonymous with those of life expectancy *divergence*, where "divergence" refers to a growing life expectancy *shortfall*.

For the purposes of this dissertation, life expectancy *stagnation* is defined as a lack of increase in life expectancy over time, such as the one seen for the USA in Figure 1-1 (Mehta et al., 2020). A life expectancy *shortfall*, or life expectancy *gap*, refers to a life expectancy in a population that is lower than in a (group of) peer population(s) (Ho, 2022). While I will be using the terms *shortfall* and *gap* interchangeably in the remainder of this dissertation, I prefer the term *shortfall* for its normative connotation (Sen, 1995). It invokes the idea that the population in question should, in theory, have the means necessary to reach a life expectancy level equal to the peer population(s) (Hosseinpoor et al., 2012). This implies that the benchmark is chosen such that it does not unfairly exaggerate (or understate) the shortfall. For example, previous studies have compared life expectancy trends in England and Wales to the median of a group of high-income countries (Leon et al., 2019); or used mortality conditions in European countries (Preston & Vierboom, 2021) or other wealthy nations (Bor et al., 2023) as a benchmark to estimate excess deaths in the USA. This latter research defines “early death” as the deaths in a given population that would not have occurred under the mortality conditions of another population (Bor et al., 2023).

A focus on life expectancy shortfalls is concerned with explaining life expectancy gaps at a given point in time in terms of variation in age- and cause-of-death-specific mortality rates using so-called “decomposition” methods (Preston et al., 2001), which will be explained below. This focus on shortfalls is perhaps the most widely used approach in demographic analysis. In contrast, a focus on life expectancy divergences takes life expectancy gaps at an earlier time point as given and asks about the *causes* and the *consequences* of a further widening of the mortality shortfall (National Research Council, 2011).

For example, when applied to Figure 1-1, a *shortfall* perspective would ask why the arrows for the USA, the UK, and other low-mortality countries start at different positions; whereas a *divergence* perspective would ask why the arrows for the USA and the UK are shorter than for other Human Mortality Database countries. Or, when applied to Figure 1-2, a *divergence* perspective could ask why the arrows for the USA and the UK are pointing to the left but pointing to the right for Australia and New Zealand. Thus, the *divergence* perspective is mainly concerned with mortality *trends*, not mortality *levels*. The study of life expectancy divergences has been aided by recent innovations in demographic decomposition, such as the contour decomposition method (Jdanov et al., 2017), which will be discussed in Chapter 2.

1.3. Review of the literature

1.3.1. Stagnation vs. divergence

A focus on life expectancy divergence provides new insights into mortality dynamics compared to a focus on life expectancy stagnation. Consider the following exchange between Abrams et al. (2023) and Polizzi and Dowd (2024), recently published in the *Proceedings of the National Academy of Sciences*. In their article, "The 'double jeopardy' of midlife and old age mortality trends in the United States," Abrams et al. (2023) asked which age groups were responsible for the slowdown in life expectancy improvements in the USA after about 2010. They estimated how high remaining USA life expectancy at age 25 would have been in 2019 if the rates of mortality improvement (ROMI) observed during the period 2000–2009 had continued through 2019. For context, 2000–2009 was a decade in which the USA still experienced fairy large life expectancy gains. ROMI are indicators of the relative change in mortality over a given period of time, calculated as the annual percentage change in age-specific mortality rates.

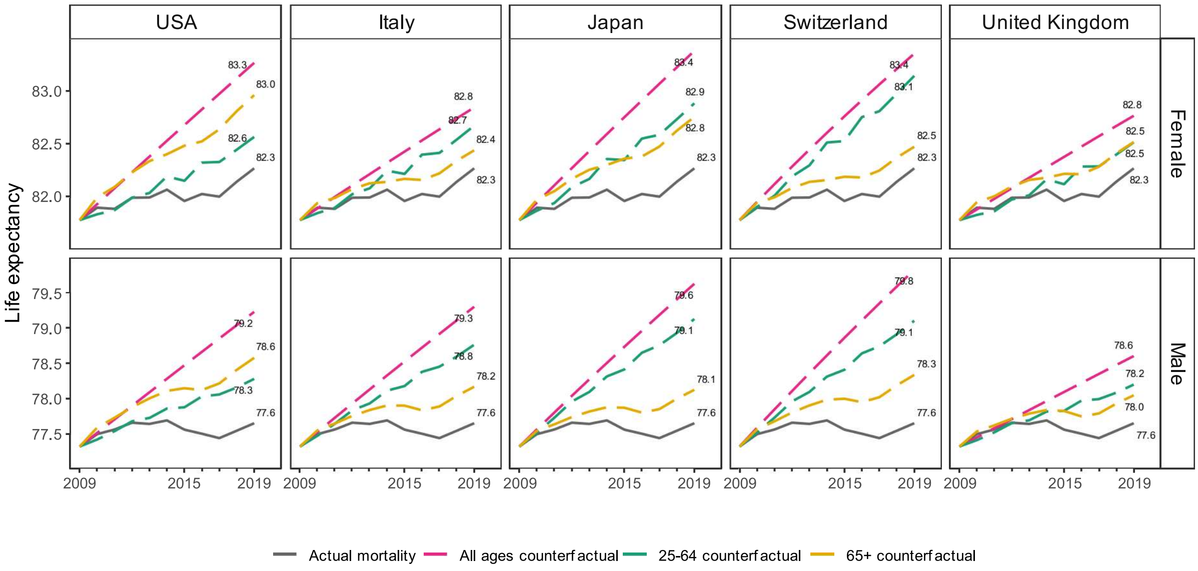

Figure 1-3. Observed and counterfactual life expectancy conditional on survival to age 25 in the USA, 2009–2019. *Note*: The USA panels assume continuation of USA 2000–2009 ROMI. The remaining panels assume that country-specific 2010–2019 ROMI would have applied in the USA. *Source*: Polizzi and Dowd (2024).

The leftmost column in Figure 1-3, taken from Polizzi and Dowd (2024), replicates the results of the Abrams et al. study. The solid line represents the actual USA life expectancy trajectory between 2009 and 2019. The dashed lines represent various counterfactual scenarios of mortality change. For example, consider the panel for males. Assuming that USA mortality change at ages 25–64 had continued at the ROMI observed in 2000–2009—but mortality rates at ages 65+ had changed as they actually did in 2010–2019—the USA would have gained 0.7 additional years of life expectancy by 2019 (difference between green line and solid line). In contrast, if the 2000–2009 ROMI at ages 65 and over had continued through 2019—but mortality rates at ages 25–64 had changed as they actually did in 2010–2019—the USA would have gained one additional year of life expectancy (yellow line – solid line). If all ages 25 and over had continued to change as in 2000–2009, the additional life expectancy gain would have been 1.6 years (red line – solid line). Since the age group 65+ accounted for most of the counterfactual gain in life expectancy, Abrams et al. (2023) concluded that “the adverse mortality trend at retirement ages […] has […] been more consequential to the US[A] life expectancy stagnation since 2010”. This is in contrast to most research that focuses on rising USA working-age mortality as the cause of the stagnation, as discussed below.

In my response to the article, “Working-age mortality is still an important driver of stagnating life expectancy in the United States,” I questioned the exclusive within-country perspective of the Abrams et al. study (Polizzi & Dowd, 2024). Instead of asking how USA life expectancy would have developed if the 2000–2009 ROMI had applied through 2019, I asked what would have happened if the USA had experienced the 2010–2019 ROMI of other countries. In practice, this meant changing the focus on stagnation in the Abrams et al. study to a focus on life expectancy divergence. The remaining four columns in Figure 1-3 show the results of my own counterfactual estimations. The presentation follows the logic of the original study, with the dashed lines now representing the hypothetical USA life expectancy trajectories if the 2010–2019 ROMI of Italy, Japan, Switzerland, or the UK had applied.

Consider the “Male” panel in the “Switzerland” column of Figure 1-3 as an example. If working-age (25–64) mortality in the USA had changed at the rate of Switzerland over the period 2010–2019, USA life expectancy would have been 1.5 years higher than it actually was in 2019, bringing the arrowheads of the USA and Switzerland closer together in Figure 1-1. In contrast, changing retirement-age (65+) mortality at the Swiss ROMI would have resulted in 0.7 additional years of life expectancy. Thus, working-age mortality explained most of the counterfactual convergence between the USA and Switzerland, though the difference between the working-age and retirement-age counterfactuals in Figure 1-3 was less pronounced when applying the UK ROMI to the USA.

Because of this variation across countries, I repeated the counterfactual analysis using ROMI from other Human Mortality Database countries, finding that the counterfactual life expectancy gains from changing working-age mortality usually exceeded those from changing retirement-age mortality (16 out of 32 counterfactuals for females, 28 out of 32 counterfactuals for males). These additional analyses are shown in the Supplementary Information to this Introduction, along with a detailed explanation of the data and methods used for the counterfactual estimations in Polizzi and Dowd (2024). Based on the alternative set of counterfactuals, the study concluded that "rising working-age mortality may still play a more important role" (Polizzi & Dowd, 2024) than retirement-age mortality—at least when considering the USA's growing life expectancy shortfall from other countries, instead of its life expectancy stagnation compared to an earlier decade. The findings by Polizzi and Dowd (2024) are in line with a recent study by Ho (2022), who found that mortality at ages 25–64 explained a larger share of the life expectancy gap between the USA and the average of 17 comparison countries in 2018 vs. 2008. In contrast, the share of the life expectancy gap explained by mortality differences at ages 65+ increased by only a small amount or even decreased between 2008 and 2018.

Why does working-age mortality explain most of the USA's life expectancy divergence from other countries but less of its life expectancy stagnation over time? To understand this potentially counterintuitive result, consider Figure 1-4, also taken from Polizzi and Dowd (2024), which directly shows the age-specific ROMI of the USA, Italy, Japan, Switzerland, and the UK in the two decades 2000–2009 (represented by bars) and 2010–2019 (represented by lines). These are the inputs of the counterfactual life expectancy projections shown in Figure 1-3. In Figure 1-4, negative ROMI (in red) represent worsening mortality, while positive ROMI (in blue) represent improving mortality. Starting with the USA panel, we can see that the country experienced large improvements in retirement-age mortality in the decade 2000–2009, as well as some smaller improvements in the decade 2010–2019. Among working ages, mortality mostly stagnated in the decade 2000–2009, as shown by the short positive or negative bars. In contrast, working-age mortality increased strongly in the decade 2010–2019, as shown by the negative lines.

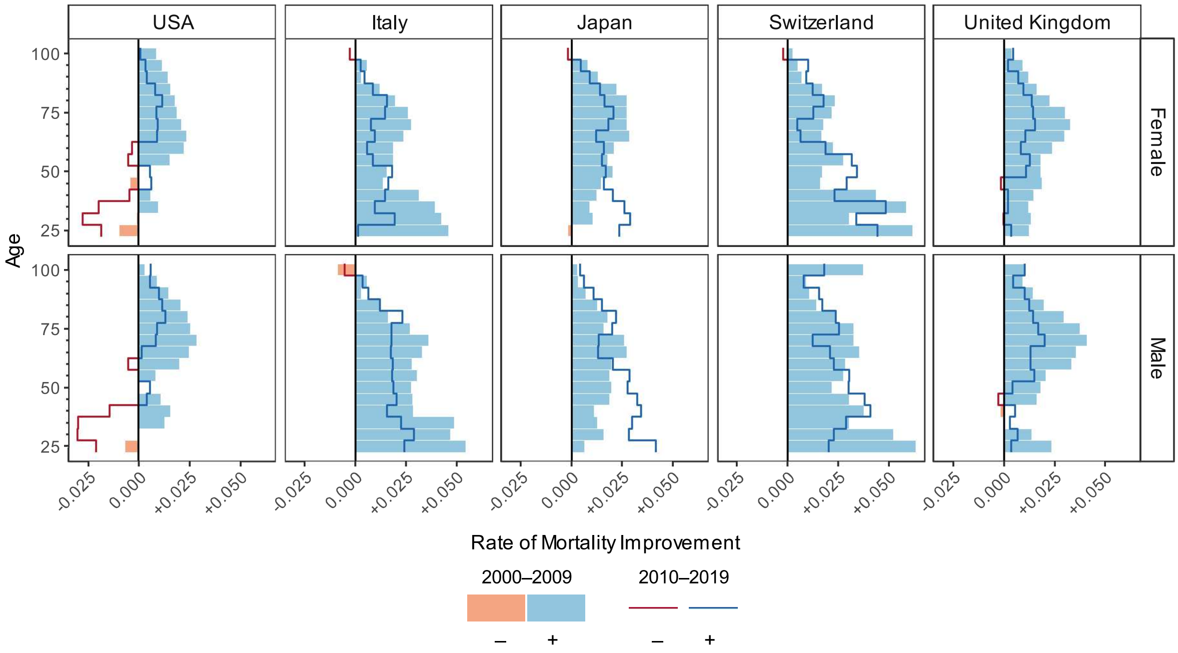

Figure 1-4. ROMI by 5-year age groups in the USA, Italy, Japan, Switzerland, and the UK, 2000–2009 and 2010–2019. *Source*: Polizzi and Dowd (2024).

Two factors need to be considered when trying to make sense of the results for the within-USA counterfactual by Abrams et al. (2023): (1) the size of the mortality change, represented by the distance between the lines and the bars; (2) the age where the change occurred. In the USA, while the distance between the lines and the bars sometimes appeared larger at some working ages, notable—and sustained—differences between the lines and the bars were also visible at retirement ages, where death rates are usually largest. Thus, the absolute change in death rates between the observed and counterfactual scenarios in the

Abrams et al. study may have well ended up being larger at retirement ages, making this the more important age group for life expectancy *stagnation*.

Turning to the *divergence* perspective, the relevant comparison is instead between the USA ROMI and the peer country ROMI in the decade 2010–2019. In Figure 1-4, these are the lines in the USA panel and the lines in the peer country panels. For reference, the figure also shows ROMI for the peer countries in 2000–2009, represented by the bars. Among the peer countries, retirement-age mortality improved in 2010–2019, resulting in positive ROMI. Overall, mortality improvements at retirement ages also slowed down in peer countries, with patterns similar to the USA. In contrast, working-age mortality often improved strongly in the peer countries, creating large distances between the (negative) USA lines and the (positive) peer country lines at those ages—usually much larger than the distance between the USA lines and bars. These larger gaps offset the overall lower mortality rates at working ages, making working ages more important for life expectancy *divergence*.

Of course, the *stagnation* and *divergence* perspectives need not result in different conclusions about the relative importance of different age groups. In the case of the USA, the fact that mortality improvements among retirement ages uniformly slowed across high-income countries means that the age group 65+ played an important role for stagnation but not divergence. In contrast, USA mortality at working ages performed consistently poorly over the two decades 2000–2009 and 2010–2019, but improvements in the peer countries were fairly stable. This means that the age group 25–64 was less important for life expectancy stagnation than for life expectancy divergence.

The exchange between Abrams et al. (2023) and Polizzi and Dowd (2024) highlights the value—and necessity—of considering a cross-country mortality perspective *in addition to* a within-country one. Both stagnation and divergence are warning signs that mortality is not developing as well as it could—albeit using different types of benchmarks. Thus, the *stagnation* and *divergence* perspectives are complementary to each other and often point to different conclusions about *causes* and *consequences*.

1.3.2. Causes of death and ages at death

External and substance-related mortality. In the USA, rising deaths from alcohol, drug overdose, and suicide have received widespread attention. These three causes of death—a subset of all external and substance-related deaths—are often collectively referred to as "deaths of despair." This term is based on the hypothesis that the three causes of death are all related to recent deteriorations of social life and economic opportunity in the USA and resulting feelings of "despair," especially among middle-aged white Americans (Case & Deaton, 2021). The "deaths of despair" hypothesis has been challenged on the grounds that the three causes of death—alcohol, drugs, and suicide—follow distinct temporal, geographical, and sex-specific trends—suggesting differences in aetiology—and that recent increases in these causes of death have also been registered in minority populations and across a broader group of working ages—suggesting other relevant drivers than "despair" (Masters et al., 2018; Simon & Masters, 2021; Tilstra et al., 2021). Nevertheless, the aggregation of the three causes of death into one "despair" category has been rapidly adopted in international analyses (e.g., Lübker & Murtin, 2025), thereby masking country-specific idiosyncrasies in cause-of-death trends and their underlying drivers. While alcohol, drug, and suicide mortality have all increased in the USA (Angus et al., 2023), trends in the three causes combined have been driven by drug deaths (Masters et al., 2018). This suggests a need to primarily understand the role of drug-related mortality in the life expectancy stagnation of the USA and its divergence from other countries, where trends in external and substance-related mortality were more favorable before the pandemic (Dowd et al., 2024).

Since the late 1970s, the USA has seen an exponential increase in the number of deaths from drug overdoses (Jalal et al., 2018). This increase in drug-related deaths has been the result of multiple overlapping drug epidemics—most recently, the opioid epidemic, which started with the mass prescription of opioid-based pain killers at the end of the 1990s and was followed by a significant rise in (lethal) heroin and fentanyl consumption in the 2010s (see Simon & Masters, 2024 for an overview). Between 2003 and 2013, changes in drug-related mortality explained on average 19% (men) and 34% (women) of the widening life expectancy gap between the USA and 17 high-income countries (Ho, 2019). In the years leading up to the COVID-19 pandemic, additional large increases in alcohol, drug, and suicide mortality were registered in the USA (Angus et al., 2023). **This could mean that the relative contribution of drug-related mortality to life expectancy divergence is now even higher. In addition, pre-pandemic increases in alcohol and suicide mortality in the USA would suggest that the combined impact of external and substance-related mortality on the life expectancy shortfall from other countries could be much larger.**

Compared with other high-income countries, the UK had relatively low mortality from several external and substance-related causes, such as homicide, suicide, and traffic accidents—although some increases were observed before the COVID-19 pandemic (Dowd et al., 2024). Pre-pandemic trends in alcohol mortality remained largely flat in the UK, whereas mortality from drug overdoses and other external causes of death strongly increased (Dowd et al., 2024). However, there has been notable heterogeneity in alcohol, drug, and suicide mortality trends between the four constituent nations of the UK (Angus et al., 2023): England, Wales, Northern Ireland, and Scotland—highlighting again that the concept of “deaths of despair” does not effectively capture causes of death with a common aetiology. Prior to the pandemic, increases in drug-related mortality were particularly pronounced in Scotland (Angus et al., 2023). Like in the USA, notable increases have been seen for deaths involving opioids, such as prescription opioids and heroin, but also deaths involving other illegal drugs, such as cocaine and benzodiazepines (Office for National Statistics, 2023). Alcohol-related mortality showed different trends in the four UK countries, with stable (England and Wales), fluctuating (Northern Ireland), and decreasing (Scotland) pre-pandemic trends (Angus et al., 2023). In contrast, suicide mortality generally started to increase across the UK around 2015 (Angus et al., 2023).

Overall, drug-related mortality in the UK has tended to peak at working ages (25–64), whereas alcohol-related mortality has usually peaked at higher ages, and suicide mortality has had a less distinct age pattern (Angus et al., 2023)—suggesting that “deaths of despair” are also not merely a working-age phenomenon. **To what extent external and substance-related deaths contributed to the pre-pandemic life expectancy divergence of the UK from peer countries, and whether this influence was primarily concentrated in working ages, has not been sufficiently investigated yet.**

Cardiometabolic mortality. Besides external and substance-related mortality, the USA and the UK have also seen internationally exceptional trends in cardiometabolic mortality—comprising deaths from both cardiovascular diseases (CVD) and metabolic diseases (Ho & Hendi, 2024). Prior to the pandemic, cardiometabolic mortality in the USA ranked near the bottom internationally, while the UK held a relatively favorable position (Ho & Hendi, 2024). However, in addition to slowdowns in CVD mortality improvements during the decade 2010–2019 (Lopez & Adair, 2019), the USA and the UK experienced rising metabolic mortality before the pandemic (Ho & Hendi, 2024). These unfavorable trends in cardiometabolic mortality have been hypothesized to be linked, at least in part, to rising obesity rates (Acosta et al., 2022; McCartney et al., 2022).

Compared with rising external and substance-related mortality, slowing improvements in cardiometabolic mortality in the USA and the UK were a more important driver of the countries' pre-pandemic life expectancy stagnation (e.g., Mehta et al., 2020). For example, slowing improvements in mortality from CVD, diabetes, and kidney disease accounted for over 70% (USA) and nearly 70% (UK) of the slowdown in improvements in age-standardized mortality between 2000–2011 and 2011–2019—in contrast to changes in mortality from drug use disorders and injuries, which accounted for only 6% (USA) and 2% (UK) of the slowdown (Murphy & Grundy, 2022).

On the one hand, the slowdown in improvements in cardiometabolic mortality implies a shrinking international advantage (UK) or increasing disadvantage (USA) for this cause of death and may therefore also be a potential source of divergence in life expectancy. On the other hand, slowing improvements in cardiometabolic mortality may be a more general trend (Lopez & Adair, 2019), which would then contribute little to life expectancy divergence. **However, to what extent cardiometabolic mortality contributed to the pre-pandemic life expectancy divergence of the USA and the UK from other peer countries has not been sufficiently investigated yet.**

COVID-19 mortality. Many countries experienced large increases in deaths in 2020 and 2021 due to COVID-19. However, in many countries, it became clear early on that excess deaths—deaths above an expected baseline based on pre-pandemic trends—exceeded the number of deaths with COVID-19 on the death certificate (Msemburi et al., 2023). The fact that estimated excess deaths exceeded recorded COVID-19 deaths implies (a) underreporting of COVID-19 deaths—which were then recorded as due to other causes of death—and/or (b) a true increase in deaths from other causes above and beyond what was expected based on past trends.

The two explanations for excess non-COVID-19 mortality are not mutually exclusive. For example, between March 2020 and December 2022, the largest number of excess deaths in the USA was observed for CVD mortality, at over 100,000 (Degtiareva et al., 2024). In the USA, non-COVID-19 causes of death accounted for about 20% of the total mortality burden associated with COVID-19 in the first year of the pandemic, with about half of this burden attributable to circulatory diseases (Luck et al., 2023). In addition, Paglino et al. (2024) found that increases in registered COVID-19 deaths were usually preceded or accompanied by increases and followed by decreases in natural-cause non-COVID-19 excess deaths. This temporal pattern does not align well with explanations attributing natural-cause non-COVID-19 excess deaths to healthcare strains, as increases in natural-cause non-COVID-19 excess deaths would have most likely *followed* peaks in registered COVID-19 deaths in this case (Paglino et al., 2024). This suggests that many of the excess CVD deaths during the pandemic were, in fact, unregistered COVID-19 deaths. On the other hand, admission and treatment of acute cardiovascular diseases, such as heart attacks and strokes, decreased in many countries during the pandemic, suggesting a large burden of untreated

CVD and a true increase in CVD mortality (Ball et al., 2020; Hoyer et al., 2020; Kiss et al., 2021).

The importance of these two mechanisms may have also varied internationally and across causes of death. For example, underreporting of COVID-19 deaths is generally less of a concern for non-natural causes of death, such as external and substance-related mortality. During the COVID-19 pandemic, alcohol and drug mortality generally increased in the USA and UK, while suicide mortality generally remained stable or decreased slightly (Angus et al., 2023). **Taken together, COVID-19 mortality and deaths registered as not due to COVID-19—including cardiometabolic and external and substance-related deaths—may have played an important role in the additional life expectancy divergence of the USA and the UK during the pandemic.**

1.3.3. Consequences *of growing life expectancy shortfalls*

Most mortality research is concerned with the c*auses* of life expectancy shortfalls, stagnations, or divergences. One of the dominant approaches in this line of research is the use of demographic decomposition or counterfactual methods to identify the age–cause-of-death combinations responsible for existing, widening, or narrowing life expectancy gaps. For instance, using counterfactual methods, Polizzi and Dowd (2024) showed that working-age mortality is largely responsible for the recent life expectancy divergence between the USA and other Human Mortality Database countries. In a similar vein, decomposition work has found that working-age mortality accounts for a large part of the USA life expectancy shortfall at any given time point (Ho, 2013, 2022; Ho & Preston, 2010).

Most mortality research uses population health indicators that remove the confounding information introduced by the age structure of a population. For example, period life expectancy at birth is the hypothetical mean age at death if a newborn experienced the age-specific death rates observed at a given time (Preston et al., 2001). This is different from estimating the actual mean age of all decedents at that time, which would be largely influenced by the mortality conditions in the more populous age groups. Removing the confounding effects of age structure means that mortality conditions can be more reliably compared across time and populations. However, age-standardized indicators can make it difficult to convey information about the magnitude of the *consequences* of mortality divergences on the population. Thus, some recent research has moved toward directly estimating the *consequences* of long-term mortality divergences without adjusting for age structure. For example, several studies have estimated the number of deaths that could have been avoided if the USA had followed the more favorable mortality trajectories of its peer countries (Bor et al., 2023, 2024; Preston & Vierboom, 2021), i.e., if the USA had experienced no mortality divergence. Bor et al. (2023) estimated that more than 600,000 people (around half aged less than 65 years) would have survived in 2019 alone if the USA had experienced the better mortality conditions of the average of 21 other wealthy nations in that year.

Most research on the *consequences* of mortality shortfalls for population composition has focused narrowly on estimating “excess mortality,” thereby treating death in a vacuum. Going beyond an estimation of excess deaths, some research in the field of “kinship demography” (Alburez-Gutierrez et al., 2022) has estimated how many people have lost a family member to a drug overdose (Schlüter et al., 2024) or SARS-CoV-2 infection (Snyder et al., 2022), acknowledging that a death has ripple effects on the social and family network of the decedent.

The kin loss literature typically starts from the existing kinship networks affected by kin death. But the early death of people at younger ages, more specifically at reproductive ages (15–49), can affect kinship networks in an often-overlooked way—by taking away an individual's chance to have (additional) children. In this way, early mortality may prevent family networks from developing in the first place. This argument is linked to recent demographic research on "lineage extinction" (Kolk & Skirbekk, 2022) and connects to the long tradition of fertility research under the "population renewal" framework (Sharpe & Lotka, 1911). As opposed to traditional fertility research, which assumes guaranteed survival until the end of the reproductive period, the population renewal framework extends widely used fertility indicators, such as the total fertility rate (TFR), by a survival term. Thus, age-standardized indicators used in the population renewal framework, such as the net reproduction rate (NRR) or the reproduction survival ratio (RSR), focus on the amount or share of "potential fertility" that "survives the effects of mortality" among potential parents (Shryock et al., 1998). To explicitly account for the effects of age structure on forgone birth outcomes, previous studies have used a counterfactual approach to estimate the number of Americans that "literally owe their lives to health progress" (White & Preston, 1996) or that "could be alive […] had mortality in the United States […] been the lowest possible at the time" (Muszyńska & Rau, 2009). For example, Muszyńska and Rau (2009) estimated that more than 700,000 additional children could have been born in the year 2000 alone if the USA had had the highest life expectancy recorded in each year of the 20th century. **However, the consequences of the recent divergence in USA life expectancy, particularly the increase in reproductive-age mortality, for birth outcomes have not been examined.**

1.3.4. Summary

Many high-income countries saw slower life expectancy improvements in the decade 2010–2019 compared to the preceding decade 2000–2009. For some countries, such as the USA and the UK, improvements were several magnitudes smaller than for their peer countries. Together, these trends led to a reshuffling of international life expectancy rankings: While the USA dropped from 27th to 29th place among 37 Human Mortality Database countries, the UK lost three places and ranked 22nd in 2019. The decade 2010–2019 showed that, even over a short period of only ten years, life expectancies can evolve in dramatically different ways across countries. In 2020 and 2021, the COVID-19 pandemic caused a drastic increase in mortality worldwide, with much larger losses in life expectancy and slower recoveries in the USA and the UK than in other Human Mortality Database countries, further manifesting their status as international life expectancy laggards.

The existing demographic literature suggests that external, substance-related, and cardiometabolic mortality in working and reproductive ages have played a key role in the recent life expectancy divergence of the USA and the UK, with a possible additional effect of COVID-19 mortality from 2020 onwards. At the population level, the widening mortality gaps have had potentially devastating and long-lasting consequences, with many early deaths and never-born children due to avoidable high mortality.

1.4. This dissertation

This dissertation provides a much-needed assessment of the widening life expectancy gaps between the USA and the UK and other low-mortality countries before, during, and after the COVID-19 pandemic. Guided by the two main research questions formulated in Box 1-1, the three empirical chapters of this dissertation identify the *causes* (Chapters 2 and 3) and the *consequences* (Chapter 4) of the life expectancy divergence between the USA and the UK and their peer countries using high-quality demographic data and state-of-the-art demographic methods.

1.4.1. Data

For this dissertation, I combine publicly available secondary population-level data from three main data sources: (1) the Human Mortality Database, (2) the World Health Organization Mortality Database, and (3) the United Nations World Population Prospects. The **Human Mortality Database** is a project at the Max Planck Institute for Demographic Research, the University of California, Berkeley, and the French Institute for Demographic Studies. It provides high-quality death and population estimates by age, sex, and calendar year for several low-mortality populations. In addition, the Human Mortality Database provides estimated life tables, including life expectancy at birth (see Figure 1-1). The **World Health Organization Mortality Database** compiles death counts by age, sex, and cause as reported by World Health Organization member states using the International Classification of Diseases. Finally, the **United Nations World Population Prospects** provide annual population estimates since 1950 for more than 200 populations. These include estimates of deaths and population by age and sex, births by age of mother, and life tables. In addition, the database provides projections of these estimates until 2100.

1.4.2. Methods

To quantify the *causes* and the *consequences* of growing life expectancy shortfalls, this dissertation makes use of state-of-the-art demographic decomposition methods and counterfactual population projection methods. **Demographic decomposition methods** take the difference in demographic summary measures—such as life expectancy—between two populations and disaggregate this difference into age- and/or cause-of-death specific contributions. These contributions are additive and sum to the total life expectancy difference (Preston et al., 2001). Decomposition methods make it possible to identify the age groups and/or causes of death that are most important in explaining (changes in) life expectancy gaps, allowing for the formulation of hypotheses about factors that influence differential disease occurrence.

Counterfactual population projections use mortality rates, fertility rates, and migration rates or counts to project an initial population by age and sex forward in time under two scenarios: (1) a baseline scenario in which the initial population is subjected to the mortality, fertility, and migration conditions actually observed in the population; and (2) a counterfactual scenario in which the initial population is subjected to counterfactual demographic conditions, such as the conditions observed in other populations (Muszyńska & Rau, 2009; White & Preston, 1996). The difference in demographic indicators between the two scenarios, such as the number of live births, represents the population *consequences* of differences in demographic conditions.

<table>
<tr><th></th><th colspan="2">Causes</th><th colspan="2">Consequences</th></tr>
<tr><th></th><th>USA</th><th>UK</th><th>USA</th><th>UK</th></tr>
<tr><td>Pre-pandemic</td><td colspan="2" rowspan="2">Chapter 2
Chapter 3</td><td colspan="2" rowspan="2">Chapter 4</td></tr>
<tr><td>Pandemic</td></tr>
</table>

Figure 1-5. Schematic overview of the empirical chapters of this dissertation.

1.4.3. Dissertation outline

The remainder of this dissertation is structured as follows: **Chapter 2** focuses on England and Wales, two of the four constituent nations of the UK, and identifies the age groups and causes of death that contributed to the decreasing life expectancy advantage or increasing life expectancy disadvantage relative to other European countries in the period 2010–2019 using demographic decomposition. **Chapter 3** compares the period immediately before (2015–2019) and during (2019–2022) the COVID-19 pandemic. Using demographic decomposition, it identifies the age groups and causes of death that contributed to the change in life expectancy within countries in each time period. An **Addendum to Chapter 3** uses these decomposition results to identify the contributions of external and substance-related mortality, cardiometabolic mortality, and COVID-19 mortality to the life expectancy stagnation in the USA and the UK during the COVID-19 pandemic, as well as the life expectancy divergence between the USA and the UK and better-performing peer countries before and during the pandemic. **Chapter 4** considers the *consequences* of the widening life expectancy gap between the USA and high-income peer countries. Using counterfactual population projections, it estimates the number of children that were not born in the USA ("missing births") because the country consistently experienced higher mortality than its peers. Finally, **Chapter 5** summarizes and discusses the three empirical chapters, highlighting potential areas for future research. Figure 1-5 provides a schematic overview of the three empirical chapters along three axes: *causes* vs. *consequences*, USA vs. UK, pre-pandemic vs. pandemic.

1.5. Supplementary Information

1.5.1. Data and methods

For Figures 1-1 and 1-2, I used values for life expectancy at birth for all countries with available data for the years 2010 and 2019 (Figure 1-1) and 2019 and 2021 (Figure 1-2) in the Human Mortality Database (HMD, 2025), version 12 December 2024.

For the calculations underlying Figures 1-3 and 1-4, Polizzi and Dowd (2024) used female and male death and exposures counts by single year of age (0–110+) from the Human Mortality Database (HMD, 2025), version 06 October 2023, for the USA and all countries with available data for at least 2010 and 2019. They discarded death and exposure counts below age 25, and aggregated death and exposure counts above age 100 to form a new open-ended age group. Countries with zero death or exposure counts for at least one age in any of the two years were excluded, leaving 32 countries for the counterfactual analysis: Australia, Austria, Belgium, Bulgaria, Canada, Chile, Croatia, Czechia, Denmark, Finland, France, Germany, Greece, Hong Kong, Hungary, Ireland, Italy, Japan, Latvia, Lithuania, Netherlands, New Zealand, Norway, Poland, Portugal, Republic of Korea, Slovakia, Spain, Sweden, Switzerland, Taiwan, United Kingdom.

For each country–sex combination, the authors first expressed changes in age-specific mortality rates over the periods 2000–2009 and/or 2010–2019 using an exponential growth equation with a constant rate r: $m(t) = m(0) \times e^{rt}$ (Rau et al., 2018), where $m(t)$ is the age-specific mortality rate in the final year, 2009 or 2019, and $m(0)$ is the age-specific mortality rate in the base year, 2000 or 2010. In both cases, $t = 9$. Polizzi and Dowd (2024) obtained r by rearranging the growth equation as follows: $r = \frac{\ln\left(\frac{m(9)}{m(0)}\right)}{9}$. Next, they estimated counterfactual life expectancy trajectories in the USA for the period 2010–2019. They started with the above growth equation, where *m(0)* now represents the observed age-specific mortality rate in the USA in 2009. For the leftmost panel in Figure 1-3, the authors replaced *r* in the growth equation with the USA value for the period 2000–2009 and successively set *t* to values from 1 (for counterfactual age-specific mortality rates in 2010) to 10 (for counterfactual age-specific mortality rates in 2019) to obtain new values of *m(t)*. For the remaining panels, they replaced *r* in the growth equation with the peer country values for the period 2010–2019 and varied *t* as described above.

Polizzi and Dowd (2024) estimated three counterfactual scenarios: (a) *25–64 counterfactual*, where they applied counterfactual *r* values to working ages only and left all other mortality rates at their observed values at time *t*; (b) *65+ counterfactual*, where they applied counterfactual *r* values to retirement ages only and left all other mortality rates at their observed values at time *t*; (c) *all ages counterfactual*, where they applied counterfactual *r* values to working ages and retirement ages. They calculated life expectancy conditional on survival to age 25 in each year using standard procedures (Preston et al., 2001).

For Figure 1-4, the authors aggregated death and exposure counts to derive mortality rates for five-year age groups (25–29, 30–34, …, 90–94, 95–99, 100+) and calculated *r* for each age group. To ensure that mortality improvements (i.e., decreasing mortality rates) received positive values, they multiplied *r* by –1 to obtain so-called “rates of mortality improvement” (Rau et al., 2018), that is: $-r$ = ROMI.

1.5.2. Figures

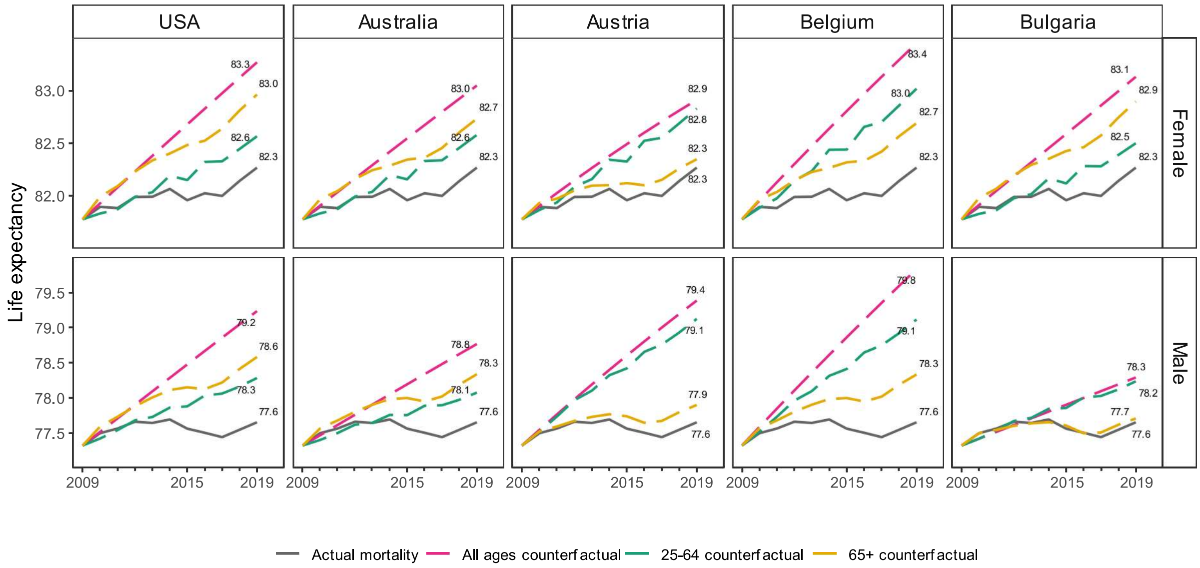

Figure 1-S1. Observed and counterfactual life expectancy conditional on survival to age 25 in the USA, 2009–2019. *Note*: The USA panels assume continuation of USA 2000–2009 ROMI. The remaining panels assume that country-specific 2010–2019 ROMI would have applied in the USA. *Source*: Polizzi and Dowd (2024).

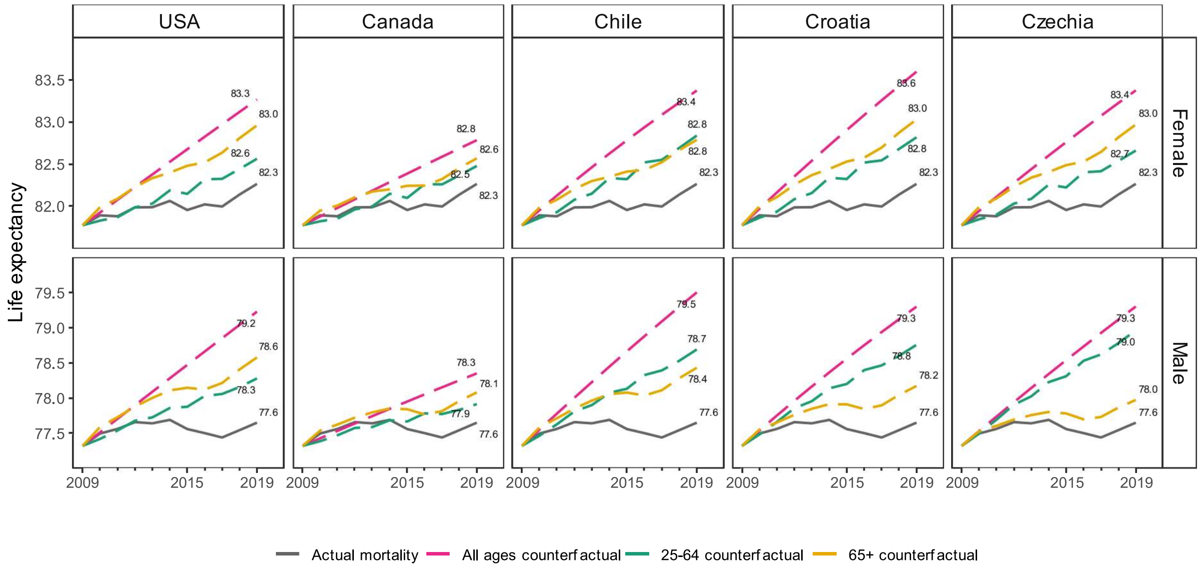

Figure 1-S2. Observed and counterfactual life expectancy conditional on survival to age 25 in the USA, 2009–2019. *Note*: The USA panels assume continuation of USA 2000–2009 ROMI. The remaining panels assume that country-specific 2010–2019 ROMI would have applied in the USA. *Source*: Polizzi and Dowd (2024).

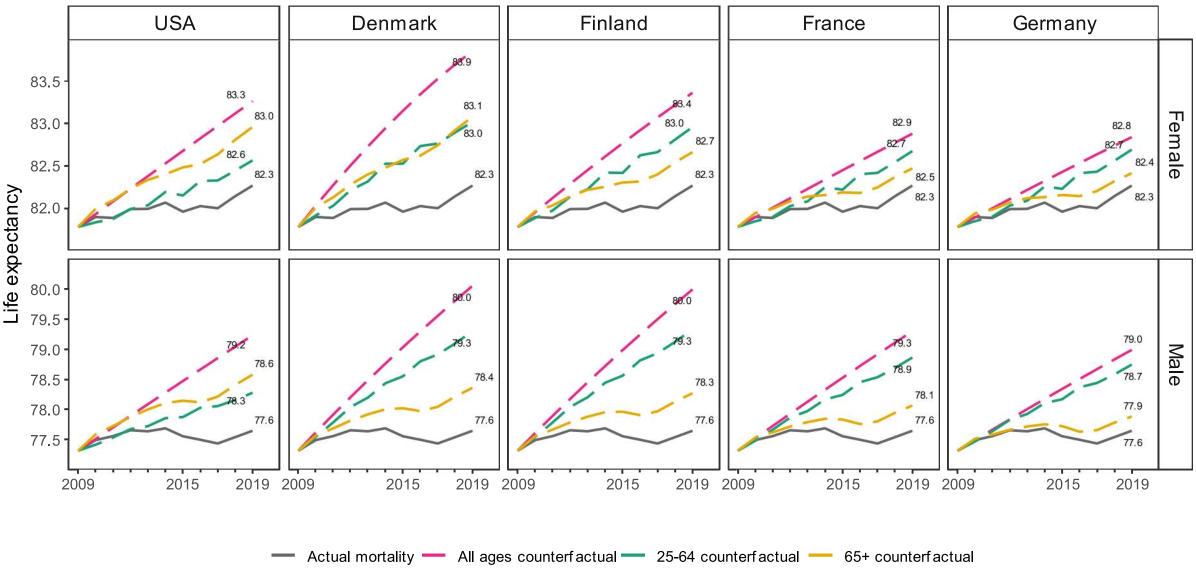

Figure 1-S3. Observed and counterfactual life expectancy conditional on survival to age 25 in the USA, 2009–2019. *Note*: The USA panels assume continuation of USA 2000–2009 ROMI. The remaining panels assume that country-specific 2010–2019 ROMI would have applied in the USA. *Source*: Polizzi and Dowd (2024).

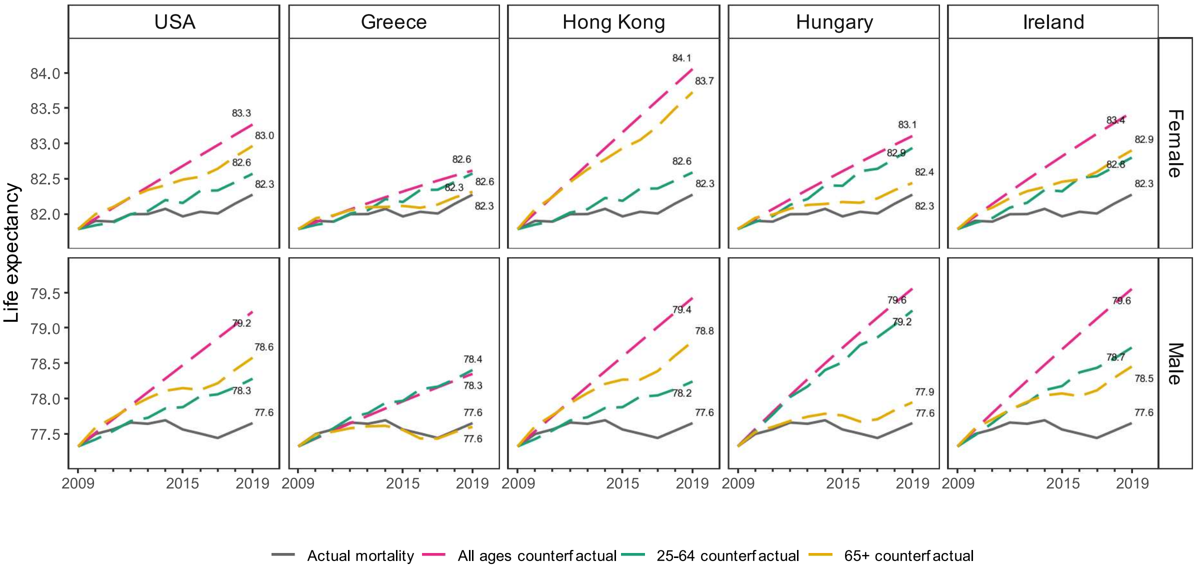

Figure 1-S4. Observed and counterfactual life expectancy conditional on survival to age 25 in the USA, 2009–2019. *Note*: The USA panels assume continuation of USA 2000–2009 ROMI. The remaining panels assume that country-specific 2010–2019 ROMI would have applied in the USA. *Source*: Polizzi and Dowd (2024).

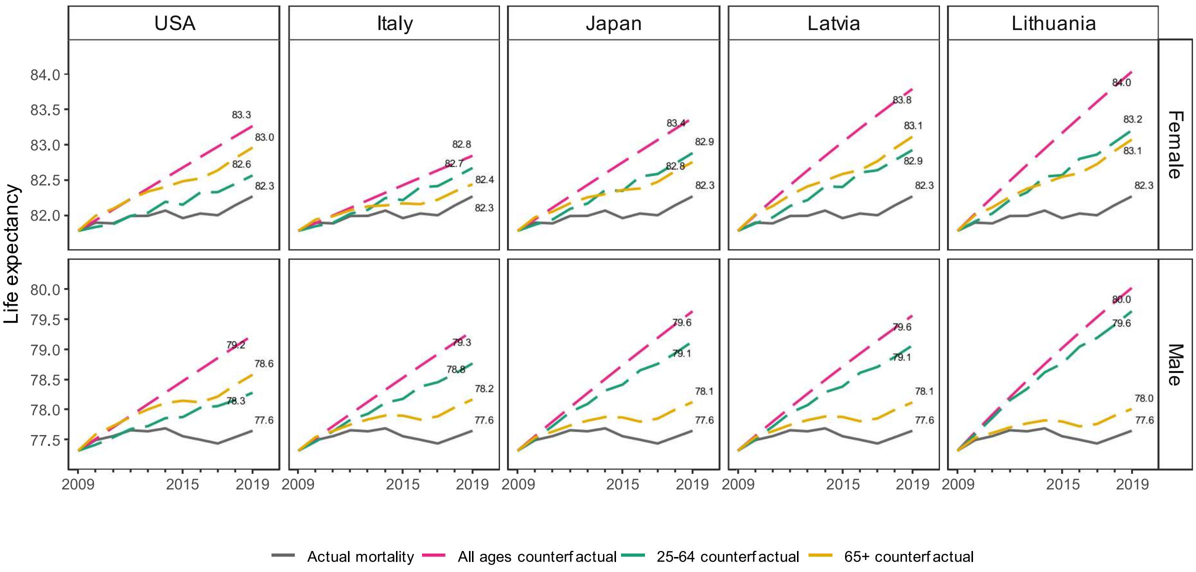

Figure 1-S5. Observed and counterfactual life expectancy conditional on survival to age 25 in the USA, 2009–2019. *Note*: The USA panels assume continuation of USA 2000–2009 ROMI. The remaining panels assume that country-specific 2010–2019 ROMI would have applied in the USA. *Source*: Polizzi and Dowd (2024).

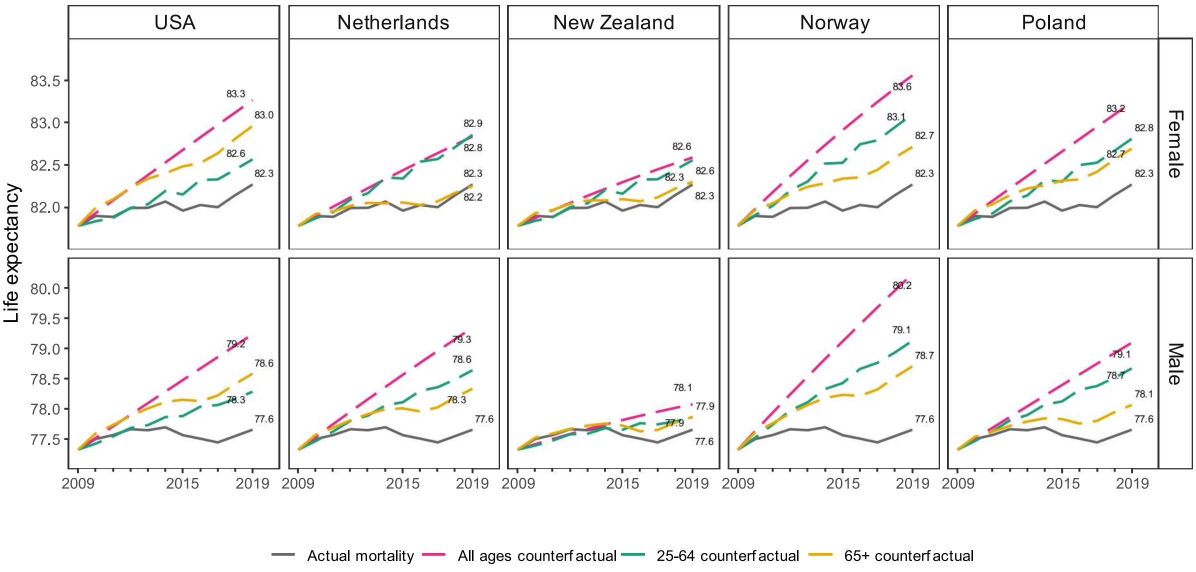

Figure 1-S6. Observed and counterfactual life expectancy conditional on survival to age 25 in the USA, 2009–2019. *Note*: The USA panels assume continuation of USA 2000–2009 ROMI. The remaining panels assume that country-specific 2010–2019 ROMI would have applied in the USA. *Source*: Polizzi and Dowd (2024).

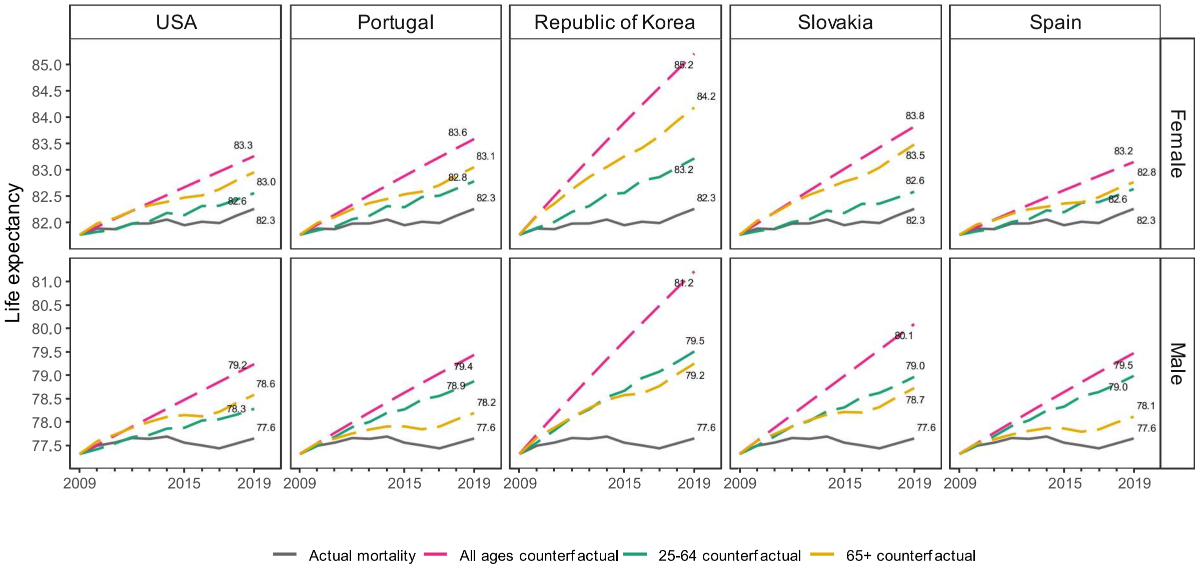

Figure 1-S7. Observed and counterfactual life expectancy conditional on survival to age 25 in the USA, 2009–2019. *Note*: The USA panels assume continuation of USA 2000–2009 ROMI. The remaining panels assume that country-specific 2010–2019 ROMI would have applied in the USA. *Source*: Polizzi and Dowd (2024).

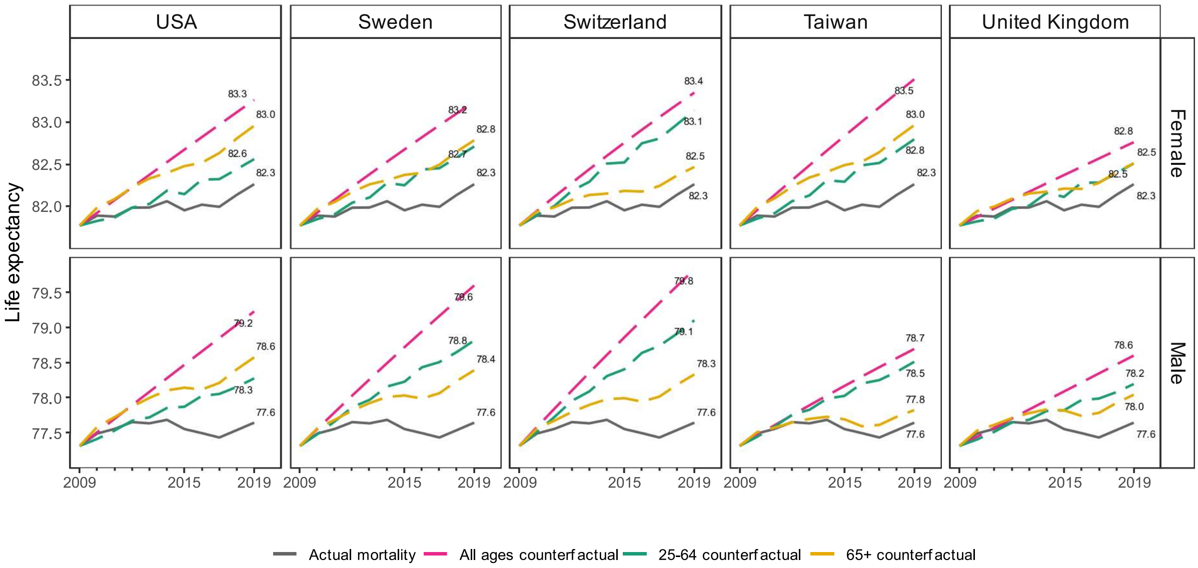

Figure 1-S8. Observed and counterfactual life expectancy conditional on survival to age 25 in the USA, 2009–2019. *Note*: The USA panels assume continuation of USA 2000–2009 ROMI. The remaining panels assume that country-specific 2010–2019 ROMI would have applied in the USA. *Source*: Polizzi and Dowd (2024).

References

Abrams, L. R., Myrskylä, M., & Mehta, N. K. (2023). The “double jeopardy” of midlife and old age mortality trends in the United States. *Proceedings of the National Academy of Sciences*, *120*(42), e2308360120. https://doi.org/10.1073/pnas.2308360120

Acosta, E., Mehta, N., Myrskylä, M., & Ebeling, M. (2022). Cardiovascular mortality gap between the United States and other high life expectancy countries in 2000–2016. *The Journals of Gerontology: Series B*, *77*(Supplement_2), S148–S157. https://doi.org/10.1093/geronb/gbac032

Alburez-Gutierrez, D., Barban, N., Caswell, H., Kolk, M., Margolis, R., Smith-Greenaway, E., Song, X., Verdery, A. M., & Zagheni, E. (2022). Kinship, demography, and inequality: Review and key areas for future development. *SocArXiv*. https://doi.org/10.31235/osf.io/fk7x9

Angus, C., Buckley, C., Tilstra, A. M., & Dowd, J. B. (2023). Increases in ‘deaths of despair’ during the COVID-19 pandemic in the United States and the United Kingdom. *Public Health*, *218*, 92–96. https://doi.org/10.1016/j.puhe.2023.02.019

Ball, S., Banerjee, A., Berry, C., Boyle, J. R., Bray, B., Bradlow, W., Chaudhry, A., Crawley, R., Danesh, J., Denniston, A., Falter, F., Figueroa, J. D., Hall, C., Hemingway, H., Jefferson, E., Johnson, T., King, G., Lee, K. K., McKean, P., … Wyatt, M. (2020). Monitoring indirect impact of COVID-19 pandemic on services for cardiovascular diseases in the UK. *Heart*, *106*(24), 1890–1897. https://doi.org/10.1136/heartjnl-2020-317870

Bor, J., Raquib, R., Himmelstein, D., Woolhandler, S., & Stokes, A. C. (2024). Causes of excess deaths in the US relative to other wealthy nations, 1999-2020: A population autopsy. *medRxiv*. https://doi.org/10.1101/2024.07.26.24311071

Bor, J., Stokes, A. C., Raifman, J., Venkataramani, A., Bassett, M. T., Himmelstein, D., & Woolhandler, S. (2023). Missing Americans: Early death in the United States—1933–2021. *PNAS Nexus*, *2*(6), pgad173. https://doi.org/10.1093/pnasnexus/pgad173

Case, A., & Deaton, A. (2021). *Deaths of despair and the future of capitalism*. Princeton, NJ, & Oxford, UK: Princeton University Press.

Degtiareva, E., Tilstra, A. M., Schöley, J., Kashyap, R., & Dowd, J. B. (2024). Cause-specific excess mortality in the US during the COVID-19 pandemic. *medRxiv*. https://doi.org/10.1101/2024.03.05.24303783

Dowd, J. B., Doniec, K., Zhang, L., & Tilstra, A. (2024). US exceptionalism? International trends in midlife mortality. *International Journal of Epidemiology*, *53*(2), dyae024. https://doi.org/10.1093/ije/dyae024

HMD. (2025). *Human Mortality Database* [Dataset]. Max Planck Institute for Demographic Research (Germany), University of California, Berkeley (USA), and French Institute for Demographic Studies (France). Available at www.mortality.org.

Ho, J. Y. (2013). Mortality under age 50 accounts for much of the fact that US life expectancy lags that of other high-income countries. *Health Affairs*, *32*(3), 459–467. https://doi.org/10.1377/hlthaff.2012.0574

Ho, J. Y. (2019). The contemporary American drug overdose epidemic in international perspective. *Population and Development Review*, *45*, 7–40. https://doi.org/10.1111/padr.12228

Ho, J. Y. (2022). Causes of America's lagging life expectancy: An international comparative perspective. *The Journals of Gerontology: Series B*, *77*(Supplement_2), S117–S126. https://doi.org/10.1093/geronb/gbab129

Ho, J. Y., & Hendi, A. S. (2024). Inequalities in life expectancy and cardiometabolic disease mortality across and within high-income countries. *Cell Metabolism*, *36*(2), 224–228. https://doi.org/10.1016/j.cmet.2023.11.002

Ho, J. Y., & Preston, S. H. (2010). US mortality in an international context: Age variations. *Population and Development Review*, *36*(4), 749–773. https://doi.org/10.1111/j.1728-4457.2010.00356.x

Hosseinpoor, A. R., Harper, S., Lee, J. H., Lynch, J., Mathers, C., & Abou-Zahr, C. (2012). International shortfall inequality in life expectancy in women and in men, 1950–2010. *Bulletin of the World Health Organization*, *90*(8), 588–594. https://doi.org/10.2471/BLT.11.097378

Hoyer, C., Ebert, A., Huttner, H. B., Puetz, V., Kallmünzer, B., Barlinn, K., Haverkamp, C., Harloff, A., Brich, J., Platten, M., & Szabo, K. (2020). Acute stroke in times of the COVID-19 pandemic. *Stroke*, *51*(7), 2224–2227. https://doi.org/10.1161/STROKEAHA.120.030395

Jalal, H., Buchanich, J. M., Roberts, M. S., Balmert, L. C., Zhang, K., & Burke, D. S. (2018). Changing dynamics of the drug overdose epidemic in the United States from 1979 through 2016. *Science*, *361*(6408), eaau1184. https://doi.org/10.1126/science.aau1184

Jdanov, D. A., Shkolnikov, V. M., Van Raalte, A. A., & Andreev, E. M. (2017). Decomposing current mortality differences into initial differences and differences in trends: The contour decomposition method. *Demography*, *54*(4), 1579–1602. https://doi.org/10.1007/s13524-017-0599-6

Kiss, P., Carcel, C., Hockham, C., & Peters, S. A. E. (2021). The impact of the COVID-19 pandemic on the care and management of patients with acute cardiovascular disease: A systematic review. *European Heart Journal - Quality of Care and Clinical Outcomes*, *7*(1), 18–27. https://doi.org/10.1093/ehjqcco/qcaa084

Kolk, M., & Skirbekk, V. (2022). Fading family lines- women and men without children, grandchildren and great-grandchildren in 19th, 20th and 21st Century Northern Sweden. *Advances in Life Course Research*, *53*, 100481. https://doi.org/10.1016/j.alcr.2022.100481

Leon, D. A., Jdanov, D. A., & Shkolnikov, V. M. (2019). Trends in life expectancy and age-specific mortality in England and Wales, 1970–2016, in comparison with a set of 22 high-income countries: An analysis of vital statistics data. *The Lancet Public Health*, *4*(11), e575–e582. https://doi.org/10.1016/S2468-2667(19)30177-X

Lopez, A. D., & Adair, T. (2019). Is the long-term decline in cardiovascular-disease mortality in high-income countries over? Evidence from national vital statistics. *International Journal of Epidemiology*, *48*(6), 1815–1823. https://doi.org/10.1093/ije/dyz143

Lübker, C., & Murtin, F. (2025). Educational inequalities in deaths of despair in 14 OECD countries: A cross-sectional observational study. *Journal of Epidemiology and Community Health*, *79*(2), 75. https://doi.org/10.1136/jech-2024-222089

Luck, A. N., Stokes, A. C., Hempstead, K., Paglino, E., & Preston, S. H. (2023). Associations between mortality from COVID-19 and other causes: A state-level analysis. *PLOS ONE*, *18*(3), e0281683. https://doi.org/10.1371/journal.pone.0281683

Masters, R. K., Tilstra, A. M., & Simon, D. H. (2018). Explaining recent mortality trends among younger and middle-aged White Americans. *International Journal of Epidemiology*, *47*(1), 81–88. https://doi.org/10.1093/ije/dyx127

McCartney, G., Walsh, D., Fenton, L., & Devine, R. (2022). *Resetting the course for population health. Evidence and recommendations to address stalled mortality* *improvements in Scotland and the rest of the UK*. Glasgow, Scotland: Glasgow Centre for Population Health / University of Glasgow. https://www.gcph.co.uk/publications/1036_resetting_the_course_for_population_health

Mehta, N. K., Abrams, L. R., & Myrskylä, M. (2020). US life expectancy stalls due to cardiovascular disease, not drug deaths. *Proceedings of the National Academy of Sciences*, *117*(13), 6998–7000. https://doi.org/10.1073/pnas.1920391117

Msemburi, W., Karlinsky, A., Knutson, V., Aleshin-Guendel, S., Chatterji, S., & Wakefield, J. (2023). The WHO estimates of excess mortality associated with the COVID-19 pandemic. *Nature*, *613*, 130–137. https://doi.org/10.1038/s41586-022-05522-2

Murphy, M., & Grundy, E. (2022). Slowdown in mortality improvement in the past decade: A US/UK comparison. *The Journals of Gerontology: Series B*, *77*(Supplement_2), S138–S147. https://doi.org/10.1093/geronb/gbab220

Muszyńska, M. M., & Rau, R. (2009). Falling short of highest life expectancy: How many Americans might have been alive in the twentieth century? *Population and Development Review*, *35*(3), 585–603.

National Research Council. (2011). *Explaining divergent levels of longevity in high-income countries*. Washington, DC: The National Academies Press. https://doi.org/10.17226/13089

Oeppen, J., & Vaupel, J. W. (2002). Broken limits to life expectancy. *Science*, *296*(5570), 1029–1031. https://doi.org/10.1126/science.1069675

Office for National Statistics. (2023). *Deaths related to drug poisoning in England and Wales: 2022 registrations*.

https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/bulletins/deathsrelatedtodrugpoisoninginenglandandwales/2022registrations

Paglino, E., Lundberg, D. J., Wrigley-Field, E., Zhou, Z., Wasserman, J. A., Raquib, R., Chen, Y.-H., Hempstead, K., Preston, S. H., Elo, I. T., Glymour, M. M., & Stokes, A. C. (2024). Excess natural-cause mortality in US counties and its association with reported COVID-19 deaths. *Proceedings of the National Academy of Sciences*, *121*(6), e2313661121. https://doi.org/10.1073/pnas.2313661121

Polizzi, A., & Dowd, J. B. (2024). Working-age mortality is still an important driver of stagnating life expectancy in the United States. *Proceedings of the National Academy of Sciences*, *121*(4), e2318276121. https://doi.org/10.1073/pnas.2318276121

Preston, S. H., Heuveline, P., & Guillot, M. (2001). *Demography: Measuring and modeling population processes*. Malden, MA: Blackwell Publishers.

Preston, S. H., & Vierboom, Y. C. (2021). Excess mortality in the United States in the 21st century. *Proceedings of the National Academy of Sciences*, *118*(16), e2024850118. https://doi.org/10.1073/pnas.2024850118

Raleigh, V. S. (2019). Trends in life expectancy in EU and other OECD countries: Why are improvements slowing? *OECD Health Working Papers*, *108*. https://doi.org/10.1787/223159ab-en

Rau, R., Bohk-Ewald, C., Muszyńska, M. M., & Vaupel, J. W. (2018). Surface plots of rates of mortality improvement. In R. Rau, C. Bohk-Ewald, M. M. Muszyńska, & J. W. Vaupel (Eds.), *Visualizing mortality dynamics in the lexis diagram* (pp. 43–67). Springer International Publishing. https://doi.org/10.1007/978-3-319-64820-0_6

Schlüter, B.-S., Alburez-Gutierrez, D., Bibbins-Domingo, K., Alexander, M. J., & Kiang, M. V. (2024). Youth experiencing parental death due to drug poisoning and firearm violence in the US, 1999-2020. *JAMA*, *331*(20), 1741–1747. https://doi.org/10.1001/jama.2024.8391

Schöley, J., Aburto, J. M., Kashnitsky, I., Kniffka, M. S., Zhang, L., Jaadla, H., Dowd, J. B., & Kashyap, R. (2022). Life expectancy changes since COVID-19. *Nature Human Behaviour*, *6*, 1649–1659. https://doi.org/10.1038/s41562-022-01450-3

Sen, A. (1995). *Inequality reexamined*. Oxford, England: Oxford University Press. https://doi.org/10.1093/0198289286.001.0001

Sharpe, F. R., & Lotka, A. J. (1911). A problem in age-distribution. *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science*, *21*(124), 435–438. https://doi.org/10.1080/14786440408637050

Shryock, H. S., Siegel, J. S., & Stockwell, E. G. (1998). *The methods and materials of demography* (Condensed ed., [15. print.]). New York: Academic Press.

Simon, D. H., & Masters, R. K. (2021). Do deaths of despair move together? County-level mortality changes by sex and urbanization, 1990–2017. *American Journal of Epidemiology*, *190*(6), 1169–1171. https://doi.org/10.1093/aje/kwab015

Simon, D. H., & Masters, R. K. (2024). Institutional failures as structural determinants of suicide: The opioid epidemic and the Great Recession in the United States. *Journal of Health and Social Behavior*. https://doi.org/10.1177/00221465231223723

Snyder, M., Alburez-Gutierrez, D., Williams, I., & Zagheni, E. (2022). Estimates from 31 countries show the significant impact of COVID-19 excess mortality on the incidence of family bereavement. *Proceedings of the National Academy of Sciences*, *119*(26), e2202686119. https://doi.org/10.1073/pnas.2202686119

Tilstra, A. M., Simon, D. H., & Masters, R. K. (2021). Trends in “deaths of despair” among working-aged White and Black Americans, 1990–2017. *American Journal of Epidemiology*, *190*(9), 1751–1759. https://doi.org/10.1093/aje/kwab088

White, K. M., & Preston, S. H. (1996). How many Americans are alive because of twentieth-century improvements in mortality? *Population and Development Review*, *22*(3), 415–429. https://doi.org/10.2307/2137714

Woolf, S. H. (2023). Falling behind: The growing gap in life expectancy between the United States and other countries, 1933–2021. *American Journal of Public Health*, *113*(9), 970–980. https://doi.org/10.2105/AJPH.2023.307310

Chapter 2

Why is life expectancy in England and Wales falling behind? A cause-of-death decomposition approach[1]

Chapter word count: 8,084

2.1. Abstract

Life expectancy in England and Wales has diverged from its high-income peers since 2011, raising concerns that the country may become an international laggard like the United States of America (USA). Using the contour method, we decompose gaps in male and female life expectancy between England and Wales and 20 individual high-income countries in 2019 into: (a) pre-existing differences in age- and cause-specific death rates in 2011; and (b) diverging trends in these rates in 2011–19. Focusing on trends, we find that external mortality at young-to-middle ages, cardiometabolic mortality at middle-to-older ages, and dementia mortality at older ages contributed most to life expectancy gaps. Although England and Wales and the USA shared adverse trends in cardiometabolic and external mortality, England and Wales experienced larger life expectancy gains. Our findings underscore the urgency of the mortality trends in England and Wales to avoid life expectancy from falling behind further.

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[1] This chapter is joint work with Andrea M. Tilstra, Luyin Zhang, and Jennifer Beam Dowd.

2.2. Introduction

After decades of steady progress, mortality improvements in many high-income countries slowed considerably in the period 2010–19 (Djeundje et al., 2022; Murphy et al., 2019; Raleigh, 2019). In Europe, this slowdown was particularly pronounced in the United Kingdom (Minton et al., 2020, 2023), where mortality improvements began to level off in 2011 (Murphy & Grundy, 2022), especially for males (Walsh, Dundas, et al., 2022). Thus far, there is little agreement on the mechanisms underlying the slowing mortality improvements in the United Kingdom (Hiam et al., 2023; Public Health England, 2018).

Since 2011, the slowing mortality improvements in England and Wales, two of the four constituent countries of the United Kingdom (UK), have contributed to widening life expectancy gaps with other high-income countries (Leon et al., 2019). In 2011, male life expectancy at birth in England and Wales outperformed the United States (USA) and many other high-income countries in Northern, Western, and Southern Europe, as shown by the blue arrow tails in Figure 2-1. In contrast, female life expectancy in England and Wales was already lower than in many peer countries, as shown by the red arrow tails in Figure 2-1. By 2019, both male (0.8 years) and female (0.6 years) life expectancy in England and Wales had only shown small improvements compared to the peer countries (1.4 and 0.9 years, on average, respectively) and ranked worse than in 2011, as indicated by the blue and red arrow heads in Figure 2-1.

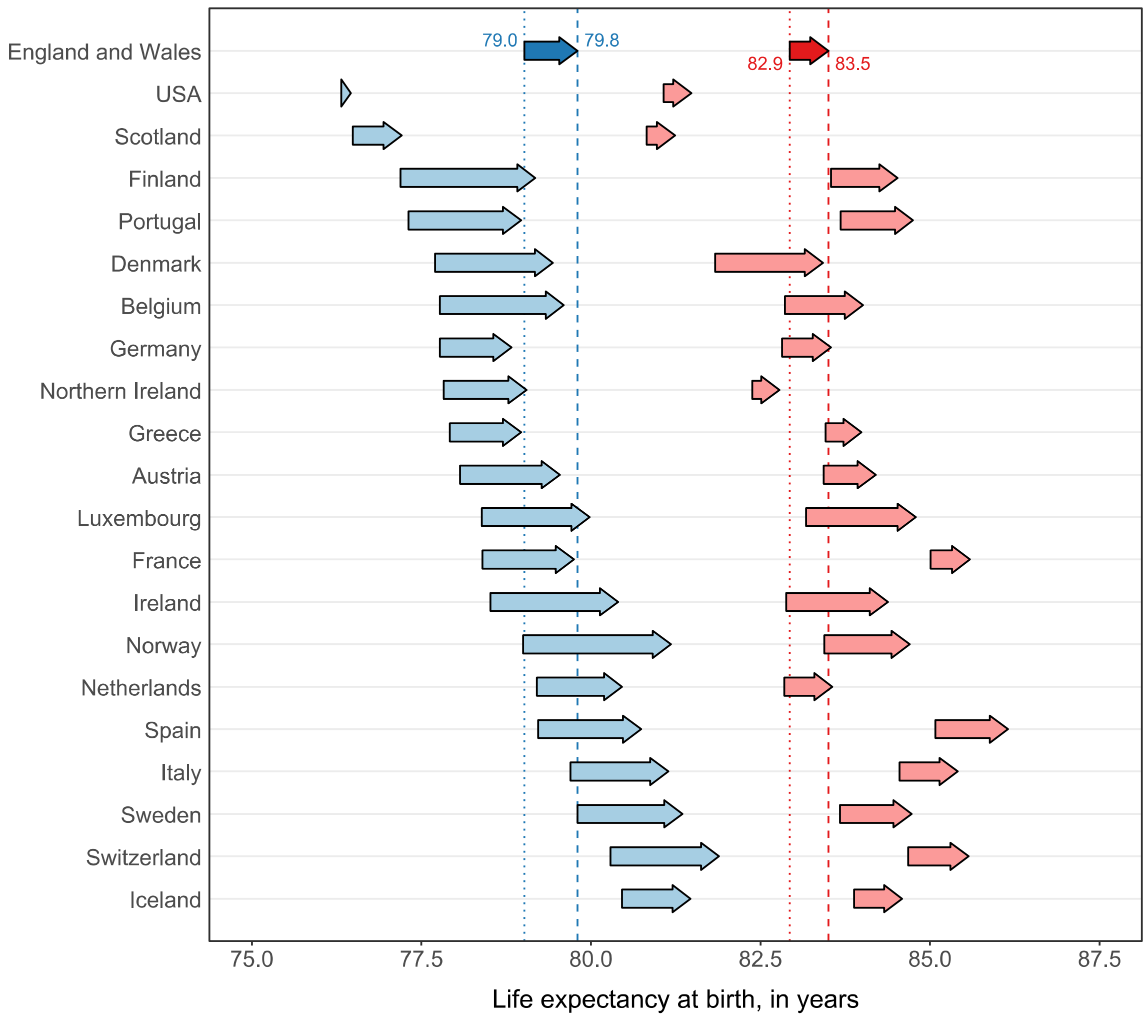


Figure 2-1. Male (blue) and female (red) life expectancy at birth in England and Wales and 20 high-income countries in 2011 (tail of arrow) and 2019 (head of arrow). *Note:* Dotted lines: England and Wales life expectancy in 2011. Dashed lines: England and Wales life expectancy in 2019. Male life expectancy in England and Wales ranked 7th and 10th in 2011 and 2019, respectively. Female life expectancy ranked 13th and 17th in 2011 and 2019, respectively. *Source:* Human Mortality Database.

The USA's mortality divergence from peer countries has informed much of our current understanding of international life expectancy shortfalls (Dowd, Doniec, et al., 2024; Ho, 2022; Woolf, 2023). "Deaths of despair" (Case & Deaton, 2015)—deaths from alcohol, drugs, and suicide—have dominated the narrative about the lack of improvements in USA longevity, but other evidence suggests that slowing improvements in cardiovascular and metabolic mortality are a more significant contributor to the USA life expectancy stagnation (Masters et al., 2018; Mehta et al., 2020). In addition, both working- and retirement-age mortality have meaningfully contributed to widening life expectancy gaps between the USA and other high-income countries (Abrams et al., 2023; Polizzi & Dowd, 2024), with drug-related and cardiometabolic mortality playing an important role in this divergence (Acosta et al., 2022; Ho, 2019).

Is England and Wales following in the footsteps of the USA, or do different mechanisms explain its life expectancy divergence from European peer countries? Most existing research has focused on the slowing life expectancy improvements within England and Wales over time, with cardiovascular disease, dementia, drug, and influenza mortality hypothesized to be responsible for the stagnating trends. While current evidence supports the contributing role of cardiovascular disease and drug-related mortality to life expectancy stagnation over time within England and Wales (McCartney, Walsh, et al., 2022), the factors contributing to its life expectancy divergence from other countries may be different (Polizzi & Dowd, 2024). Many other European countries also experienced slowing mortality improvements after 2010. Whether these smaller slowdowns were qualitatively similar to those in England and Wales or reflected different age and cause of death patterns is not sufficiently known (Minton et al., 2023).

An earlier study found that slower mortality improvements at ages 15 and above in England and Wales over the period 2011–16 contributed to its increasing life expectancy shortfall compared to the median among 22 high-income countries (Leon et al., 2019). Due to methodological constraints, this earlier analysis was restricted to all-cause mortality. In addition, the life expectancy benchmark in this earlier study was calculated from median age-specific death rates across all peer countries. This median mortality profile may deviate from the mortality profiles of individual countries, raising the question of whether the earlier findings for England and Wales depend on the specific comparison country chosen. We build on the study by Leon et al. in three ways: (a) by extending the observation period to 2019; (b) by comparing England and Wales to 20 individual high-income countries; (c) by including an analysis by age and cause of death. This extended analysis allows a more detailed answer to the question of why life expectancy in England and Wales is increasingly falling behind other high-income countries.

2.3. Data

We used all-cause mortality rates by sex, year, and age group (0, 1–4, 5–9, 10–14, …,100–104, 105–109, 110+) from the Human Mortality Database (HMD, 2024) and retrieved death counts by sex, year, age group (0, 1–4, 5–9, 10–14, …, 85+/95+), and International Classification of Diseases version 10 (ICD-10) code from the World Health Organization Mortality Database (WHO MD, 2024) for England and Wales and 20 high-income countries: Austria (country code AT), Belgium (BE), Denmark (DK), Finland (FI), France (FR), Germany (DE), Greece (GR), Iceland (IS), Ireland (IE), Italy (IT), Luxembourg (LU), Netherlands (NL), Northern Ireland (GB-NIR), Norway (NO), Portugal (PT), Scotland (GB-SCO), Spain (ES), Sweden (SE), Switzerland (CH), and USA (US). We used data for the period 2011–2019, except for countries with more limited data availability including Greece (2014–2019) and Norway (2011–2016). We excluded Central and Eastern European countries because of their distinct mortality trajectories (Aburto & van Raalte, 2018).

We focused on six causes of death that have been the focus of recent research on the stagnating life expectancy in England and Wales (Heath et al., 2018; Hiam et al., 2024; Ho & Hendi, 2018; Marshall et al., 2019; McCartney, Walsh, et al., 2022; Murphy et al., 2019;

Public Health England, 2018; Raleigh, 2024), with all remaining causes grouped into a "residual" category: (1) cardiometabolic diseases (ICD-10 codes E00–E88 and I00–I69), (2) external and substance-related deaths (F10–F19, K70–K74, and V01–Y89), hereafter "external" deaths, for brevity, (3) dementia (F01, F03, G30, and G31), (4) lung cancer (C33–C34), (5) all other cancers (C00–C32 and C37–D48), and (6) respiratory diseases (J00–J99). We combined cardiovascular and metabolic deaths because of common underlying risk factors, such as obesity (Ho & Hendi, 2024). However, we separately analyzed lung cancer deaths due to strong international variation in smoking trends (Janssen, 2021). The Supplementary Information shows changes in the share of cardiometabolic deaths that are cardiovascular vs. metabolic deaths (Figure 2-S1); and changes in the share of cancer deaths that are deaths from lung cancer vs. other cancers (Figure 2-S2).

In 2019, the six causes of death respectively accounted for 84 and 86 percent of all deaths among females and males in England and Wales (Figure 2-S3). For each age–sex category, we proportionally redistributed ill-defined causes of death (R00–R94 and R96–R99) across the seven cause-of-death categories used in our analysis.

2.4. Methods

We generated a new open-ended age category for the HMD life tables by dividing life table deaths above age 95 (ℓ_{95}) by life table exposures above age 95 (T_{95}). We then aligned WHO MD age groups with the new HMD age groups using penalized composite link models (Rizzi et al., 2015) and calculated the age-specific share of deaths attributable to each cause. Finally, we derived age- and cause-specific mortality rates by multiplying the aligned WHO MD cause-of-death shares by the new HMD all-cause mortality rates and calculated life expectancy at birth following standard procedures (Preston et al., 2001).

We decomposed life expectancy gaps between England and Wales and each of the 20 comparison countries into contributions by age and cause of death using the contour decomposition method (Jdanov, 2024; Jdanov et al., 2017, 2024). In short, our decomposition approach estimates the contribution to the life expectancy difference between two countries at the end of the observation period, usually 2019, from (a) pre-existing mortality differences at the beginning of the observation period, usually 2011; and (b) differential mortality trends over the observation period, usually 2011–19. In our results, we focus on contributions by (a) cause of death, summed across all age groups; and (b) age group, summed across all causes of death, where we distinguish between "childhood" (ages 0–14), "early working ages" (15–44), "late working ages" (45–64), and "retirement ages" (65+). We used R version 4.4.2 (R Core Team, 2024) for our analysis, and relied on the packages *furrr* (Vaughan & Dancho, 2022), *ggh4x* (van den Brand, 2024), *gggenes* (Wilkins, 2023), *HMDHFDplus* (Riffe, 2023), *tidyverse* (Wickham, 2023), and *ungroup* (Pascariu et al., 2024) for data handling, analysis, and visualization.

2.5. Results

2.5.1. Changes in life expectancy gaps

Figure 2-2 shows changes in female (top panel) and male (bottom panel) life expectancy gaps between England and Wales and all comparison countries in 2011–19 (except Greece [2014–19] and Norway [2011–16]) in months. This summarizes the mortality data used in our contour decompositions below. For each panel, the countries are ordered according to the size of the life expectancy gap in 2011.

In Figure 2-2, we distinguish between six patterns of change. Downward-pointing arrows indicate that the life expectancy gap between England and Wales and a given comparison country became worse for England and Wales in 2011–19 (i.e., "decreasing advantage," "emerging disadvantage," or "increasing disadvantage"). For example, the downward arrow for Denmark in the female panel indicates that the life expectancy advantage of England and Wales decreased from 13.1 months to 1 month, while the downward arrow for Portugal in the female panel indicates that the life expectancy disadvantage of England and Wales increased from 9.1 to 15.0 months. In contrast, upward-pointing arrows indicate that the life expectancy gap became more favorable for England and Wales (i.e., "decreasing disadvantage", "emerging advantage," or "increasing advantage"). For example, the upward arrow for Greece in the female panel indicates that the life expectancy disadvantage of England and Wales decreased from 8.7 to 5.7 months, while the upward arrow for Scotland in the female panel indicates that the life expectancy advantage of England and Wales increased from 25.2 to 26.9 months. The pattern "emerging advantage" was not observed in our data.

The dominant pattern for females was a smaller improvement in life expectancy at birth in England and Wales compared to other countries, as seen by the large number of downward arrows. Only five life expectancy gaps became more favorable for England and Wales (France, Greece, Northern Ireland, USA, and Scotland). Relative deterioration was the norm for male life expectancy gaps as well, except for the increasing advantages over Scotland and the USA. Overall, life expectancy divergences were larger for males compared to females, as shown by the longer arrows in the male panel.

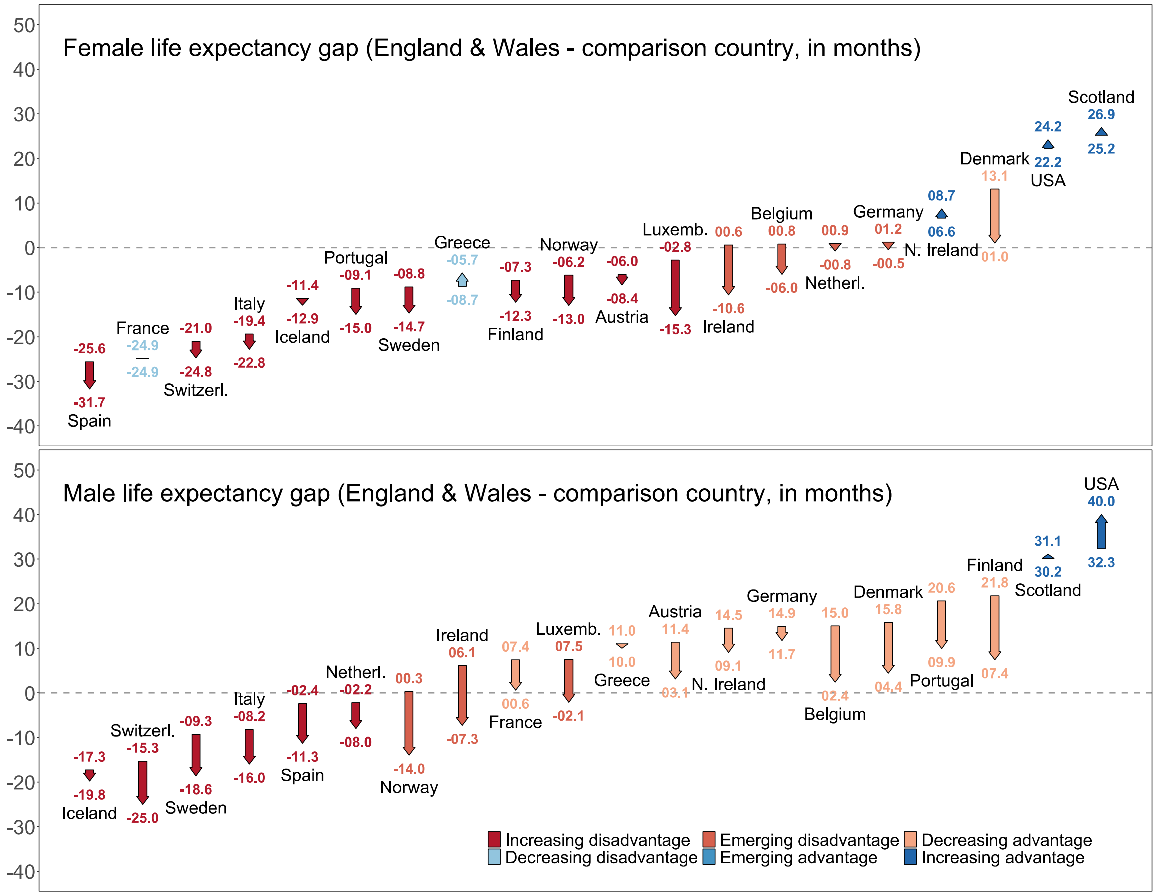


Figure 2-2. Changes in female (top panel) and male (bottom panel) life expectancy gaps between England and Wales and 20 high-income countries, in months. *Note*: Observation period 2011–19, except Greece (2014–19) and Norway (2011–16). “Advantage” and “disadvantage” are from the perspective of England and Wales. *Source*: Authors’ calculations based on data from the Human Mortality Database.

2.5.2. Decomposition results for life expectancy gaps in 2019

Causes of death. Figure 2-3 shows the results of the contour decomposition for the gap in female (top panel) and male (bottom panel) life expectancy between England and Wales and each comparison country in 2019 by cause of death in months. Like in Figure 2-2, peer countries are ordered from left to right according to the size of the total life expectancy gap in 2011. The arrow heads indicate how much of the 2019 life expectancy gaps between England and Wales and the peer countries was due to differences in cause-specific death rates in 2019. This contribution from mortality differences in 2019 is then further split into contributions from (a) differences in cause-specific death rates that already existed in 2011, represented by the tail of the arrows, and (b) diverging trends in cause-specific death rates in 2011–19, represented by the length and direction of the arrows. For example, in 2019, females in England and Wales had lower cardiometabolic mortality than Danish females, corresponding to 0.6 months of life expectancy (head of arrow in Figure 2-3a). These 0.6 months can then be split into 4.2 months due to lower cardiometabolic mortality in England and Wales vs. Denmark at baseline in 2011, and -3.6 months due to a "decreasing advantage" of England and Wales over Denmark with respect to cardiometabolic mortality in 2011–19. The value of -3.6 months on the trend component means that without recent trends in cardiometabolic mortality in both England and Wales and Denmark, their 2019 gap in female life expectancy would have been 3.6 months greater, i.e., 4.6 months instead of just 1 month (see Figure 2-2). For each cause of death in Figure 2-3, the six categories of change ("increasing disadvantage," "emerging disadvantage," "decreasing advantage," "decreasing disadvantage," "emerging advantage," "increasing advantage") were determined by comparing the contributions from mortality differences in 2011 (tail of arrow) and 2019 (head of arrow).

For both females and males, most arrows in the “cardiometabolic” panel started above zero, indicating that England and Wales had better levels of cardiometabolic mortality than most countries in 2011. By 2019, cardiometabolic mortality in England and Wales was much closer to the European average, with most remaining advantages reduced to just a few months of life expectancy. We observed a similar pattern of “decreasing advantages” for external mortality, especially among males.

In 2011, females in England and Wales ranked close to last for mortality from the remaining four causes of death—dementia, lung cancer, other cancers, and respiratory diseases. For dementia mortality, these mortality disadvantages generally increased further over time, whereas they generally decreased for lung cancer mortality and, to some extent, respiratory mortality. Gaps in mortality from other cancers showed mixed trends, with some becoming more favorable for England and Wales (“decreasing disadvantage,” “increasing advantage”) and some becoming less favorable (“decreasing advantage,” “emerging disadvantage,” “increasing disadvantage”).

Males in England and Wales also ranked close to last for dementia and respiratory mortality in 2011. These gaps usually became worse for England and Wales (“decreasing advantage,” “emerging disadvantage,” “increasing disadvantage”) or remained relatively stable. In contrast, males in England and Wales had among the lowest lung cancer mortality in 2011, which largely remained true over time. Males in England and Wales ranked in the middle for other cancers at baseline, with most gaps becoming less favorable over time

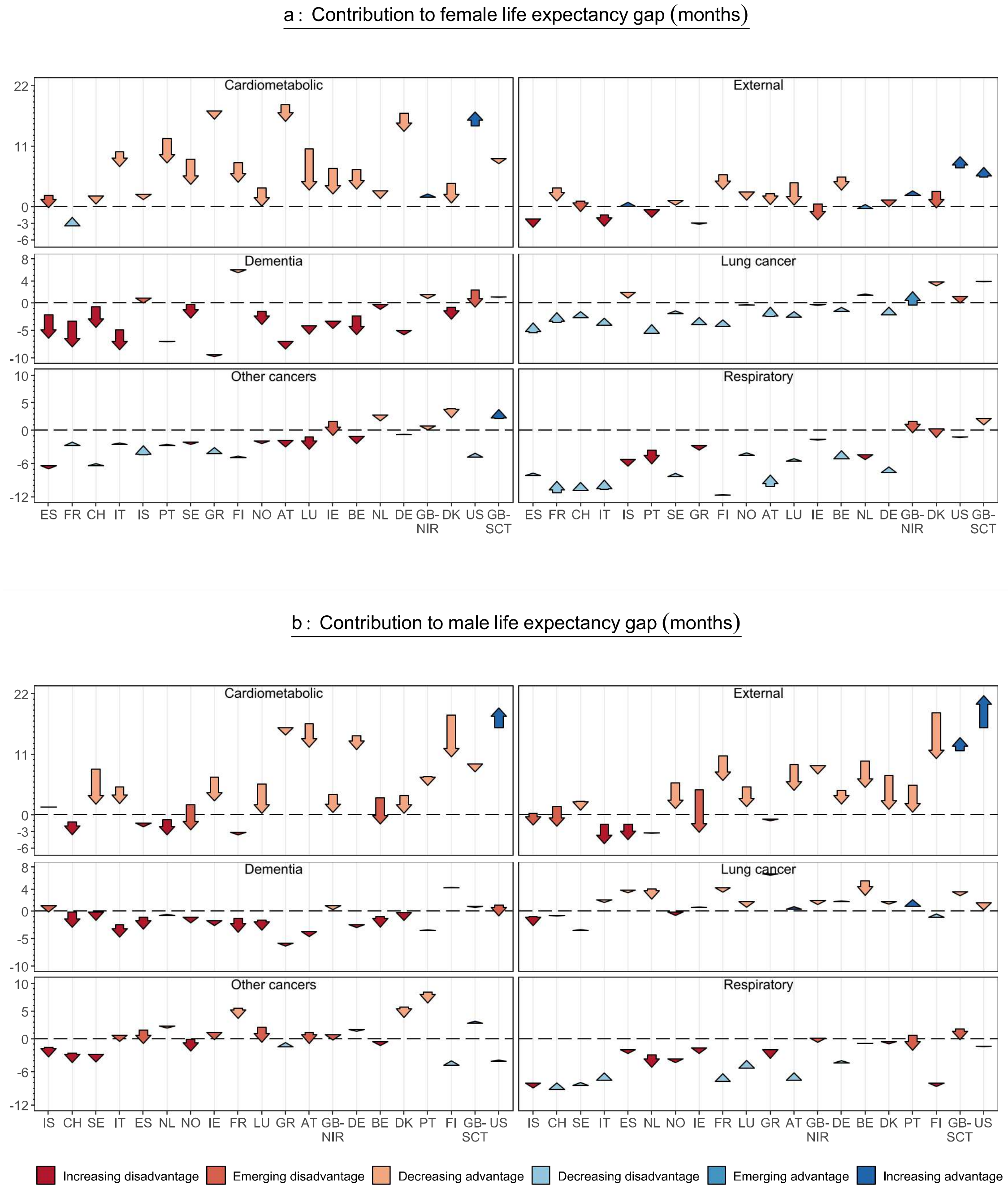


Figure 2-3. Contributions (in months) from mortality differences in 2011 (tail of arrow) and mortality trends between 2011–19 (length and direction of arrow) to female (top panel) and male (bottom panel) life expectancy gaps between England and Wales and each high-income country in 2019, by cause of death. *Note:* See the note in Figure 2-2 for exceptions in the observation period. “Advantage” and “disadvantage” are from the perspective of England and Wales. *Source*: Authors’ calculations based on data from the Human Mortality Database and the World Health Organization Mortality Database.

Figure 2-4 shows only the trend contributions from the contour decomposition, corresponding to the length of the arrows in Figure 2-3. By centering the arrows from

Figure 2-3 around the zero line, Figure 2-4 removes information on initial mortality differences, allowing us to focus on whether mortality gaps changed unfavorably ("decreasing advantage," "emerging disadvantage," or "increasing disadvantage") or favorably ("decreasing disadvantage," "emerging advantage," or "increasing advantage") for England and Wales. The bar colors in Figure 2-4 represent different causes of death. Similar to Figures 2-2 and 2-3, the peer countries are listed on the vertical axis according to the size of the total life expectancy gap in 2011.

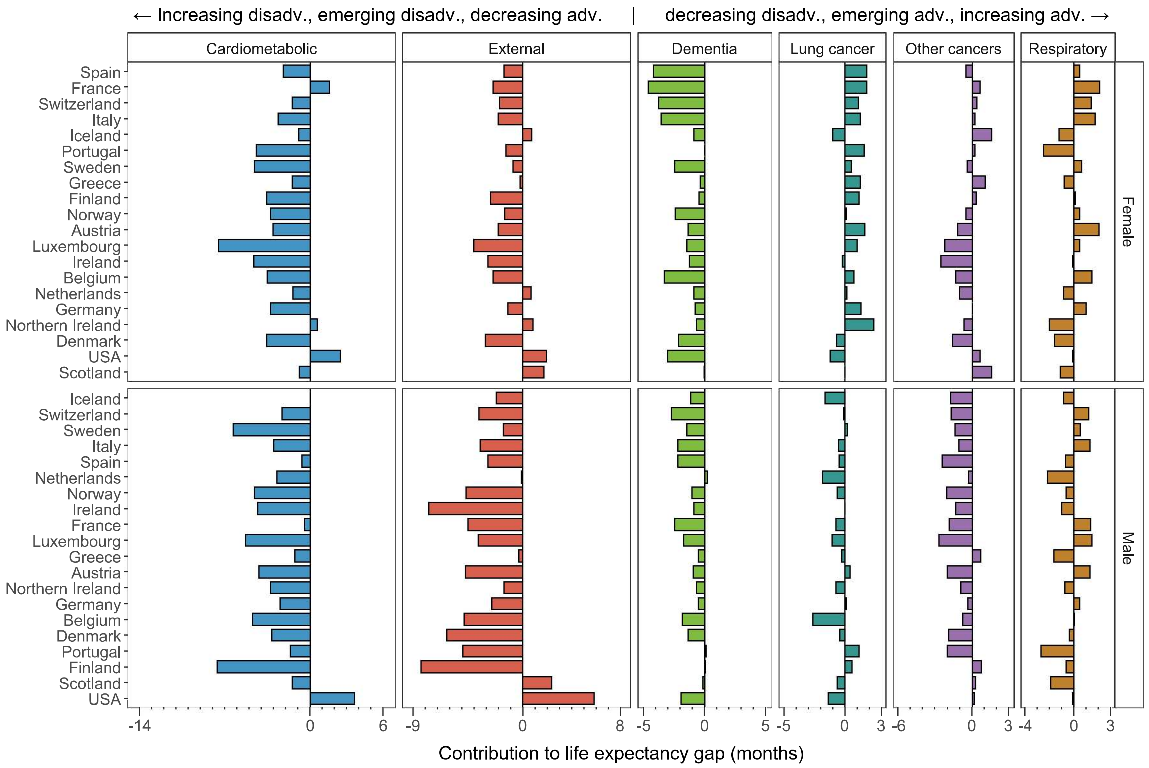


Figure 2-4. Contributions (in months) from mortality trends between 2011–19 to female (top row) and male (bottom row) life expectancy gaps between England and Wales and each high-income country in 2019, by cause of death. *Note:* See the note in Figure 2-2 for exceptions in the observation period. "Advantage" and "disadvantage" are from the perspective of England and Wales. *Source*: Authors' calculations based on data from the Human Mortality Database and the World Health Organization Mortality Database.

Figure 2-4 serves to facilitate interpretation of Figure 2-5, which further breaks down the contributions from mortality trends into their country-specific components. Lighter shades represent contributions from mortality trends in England and Wales, while darker shades represent contributions from mortality trends in the peer countries. The sum of the lighter and darker bars in Figure 2-5 is equal to the bars in Figure 2-4 and the length of the arrows in Figure 2-3. Dark bars to the left of zero mean that mortality in the peer country improved, whereas light bars to the left of zero mean that mortality in England and Wales worsened. Conversely, dark bars to the right of zero mean that mortality in the peer country worsened, whereas light bars to the right of zero mean that mortality in England and Wales improved. Building on the previous example, cardiometabolic mortality among females in England and Wales improved in 2011–19 (light blue bar pointing to the right), increasing the life expectancy gap with Denmark by roughly 5 months. However, among Danish females, cardiometabolic mortality also improved (dark blue bar pointing to the left), reducing the life expectancy gap with England and Wales by roughly 9 months. Together, the contributions from the country-specific mortality trends net out to -3.6 months, which is equal to the trend component in Figures 2-3 and 2-4. Contributions for England and Wales, i.e., the light bars within each cause-of-death panel, are of similar length, except where the period of observation differs (i.e., Greece and Norway).

Figure 2-5 shows that mortality from cardiometabolic diseases and other cancers generally improved in all countries (i.e., dark bars to the left of zero and light bars to the right of zero), but typically less so in England and Wales. In contrast, mortality from external causes decreased in most comparison countries (i.e., dark bars to the left of zero) but *increased* in England and Wales (i.e., light bars to the left of zero). Most high-income countries saw increases in mortality from dementia (i.e., dark bars to the right of zero and light bars to the left of zero), which were more extreme for England and Wales. Finally, lung cancer and respiratory mortality showed sex-specific patterns. Among males, these causes typically improved across countries (i.e., dark bars to the left of zero and light bars to the right of zero), but less in England and Wales. Females in England and Wales generally saw improvements in these causes (i.e., light bars to the right of zero), while they worsened in some peer countries (i.e., dark bars to the right of zero), resulting in the mixed net trends shown in Figure 2-4.

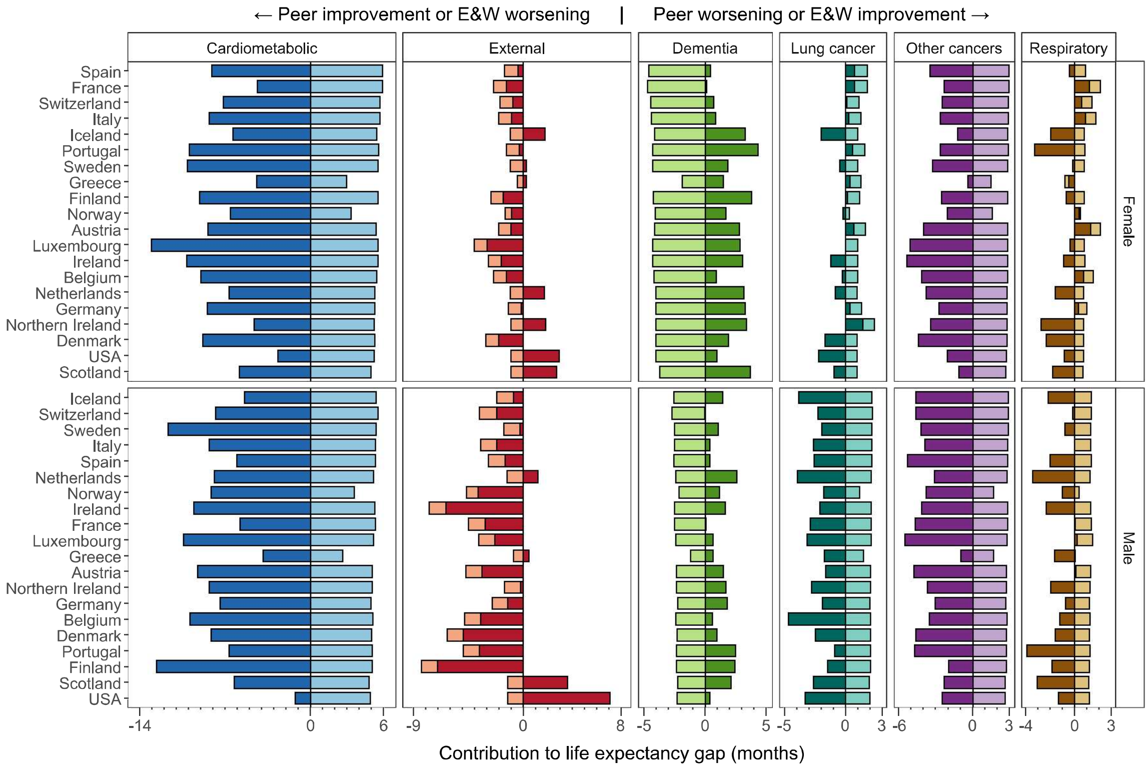


Figure 2-5. Contributions (in months) from mortality trends between 2011–19 in England and Wales (lighter shade) and each high-income country (darker shade) to female (top row) and male (bottom row) life expectancy gaps in 2019, by cause of death. *Note:* See the note in Figure 2-2 for exceptions in the observation period. *Source*: Authors' calculations based on data from the Human Mortality Database and the World Health Organization Mortality Database.

Causes of death and age groups. In the Supplementary Information (Figures 2-S4 to 2-S7), we further break down the cause-specific contributions from Figure 2-3 by age group for females and males. These Figures show that the mortality trends in cardiometabolic mortality were predominantly driven by ages 65+. However, unfavorable mortality trends for England and Wales in cardiometabolic mortality were also visible in the age group 45–

64. By 2019, England and Wales still outperformed most countries in cardiometabolic mortality at ages 65+ but ranked near the bottom for ages 45–64.

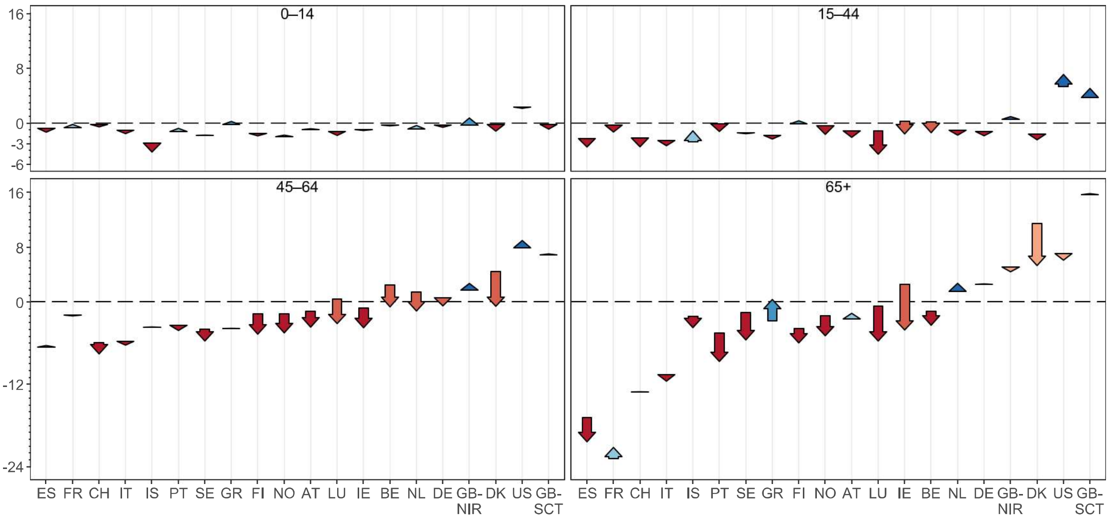
Trends in external mortality were predominantly driven by working ages (15–64). Particularly concerning were the unfavorable mortality trends for England and Wales among males aged 15–44, with several emerging disadvantages. Consequently, by 2019, males in England and Wales ranked worse than average for external mortality in early working ages.

Finally, contributions from trends in dementia mortality were entirely driven by ages 65+. In contrast, trends in cancer and respiratory mortality were driven by both late working and retirement ages (45+). While mortality trends for these causes were generally worse for England and Wales for ages 45–64, for ages 65+, the trends were more mixed. The exception was female lung cancer mortality, which consistently showed favorable trends for England and Wales, especially in the age group 65+.

Residual causes of death. In the Supplementary Information (Figure 2-S8), we show contributions to the 2019 life expectancy gaps for the residual cause-of-death category. In most country comparisons, mortality in the residual category changed in favor of England and Wales ("decreasing disadvantage," "emerging advantage," "increasing advantage"). These relatively favorable mortality trends in the residual category appeared across most age groups and prevented England and Wales life expectancy from falling behind even further.

Age groups. Analogous to Figure 2-3, Figure 2-6 displays age-group-specific contributions (again in months) to the 2019 life expectancy gap between England and Wales and the comparator countries based on the contour decompositions for females (top panel) and males (bottom panel). In 2011, England and Wales generally had a small mortality disadvantage in childhood (ages 0–14) that changed only little in 2011–19. This was also true for female mortality in early working ages (15–44). In contrast, male mortality at ages 15–44 in England and Wales started in the middle of the pack and worsened by 2019.

a : Contribution to female life expectancy gap (months)



b : Contribution to male life expectancy gap (months)

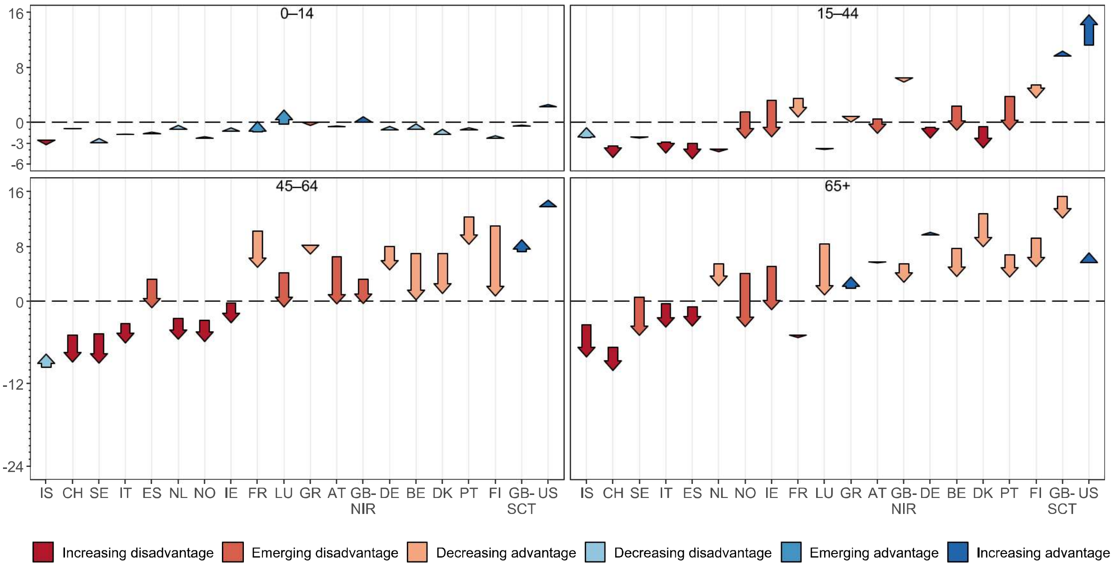


Figure 2-6. Contributions (in months) from mortality differences in 2011 (tail of arrow) and mortality trends between 2011–19 (length and direction of arrow) to female (top panel) and male (bottom panel) life expectancy gaps between England and Wales and each high-income country in 2019, by age group. *Note:* See the note in Figure 2-2 for exceptions in the observation period. “Advantage” and “disadvantage” are from the perspective of England and Wales. *Source*: Authors’ calculations based on data from the Human Mortality Database and the World Health Organization Mortality Database.

In 2011, female mortality at ages 45+ in England and Wales already ranked poorly. By 2019, most of the mortality gaps had worsened. The large female mortality disadvantage of England and Wales in retirement-age mortality in 2011 and 2019 compared to countries such as Spain, France, and Switzerland were particularly noteworthy, amounting to more than one year of life expectancy. In contrast, male mortality in 2011 at ages 45 and older ranked favorably compared to most peer countries. However, by 2019, these gaps worsened for England and Wales, falling closer to the middle of the rankings.

Analogous to Figure 2-4, Figure 2-7 shows the trend contributions to the life expectancy gap in 2019 by age group.

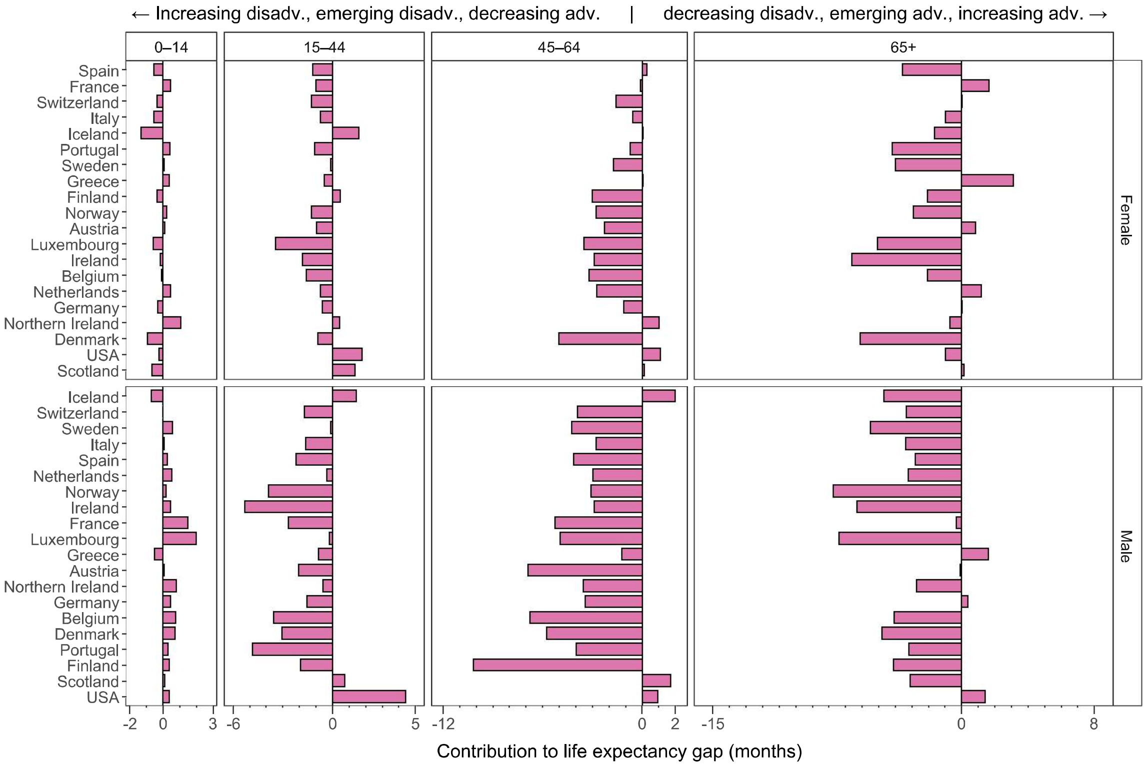


Figure 2-7. Contributions (in months) from mortality trends between 2011–19 to female (top row) and male (bottom row) life expectancy gaps between England and Wales and each high-income country in 2019, by age group. *Note:* See the note in Figure 2-2 for exceptions in the observation period. “Advantage” and “disadvantage” are from the perspective of England and Wales. *Source*: Authors’ calculations based on data from the Human Mortality Database and the World Health Organization Mortality Database.

Figure 2-7 serves to facilitate interpretation of Figure 2-8, which shows that the net negative trend contributions generally came from smaller mortality improvements in England and Wales (lighter bar shade pointing to the right) than in the comparator countries (darker bar shade pointing to the left), especially for males. Particularly noteworthy is the virtual absence of mortality improvements in early working ages (15–44) and the much smaller mortality improvements in late working ages (45–64) in England and Wales. Mortality improved more at retirement ages (65+) in England and Wales but still more slowly than in the peer countries, resulting in the net negative trends shown in Figure 2-7.

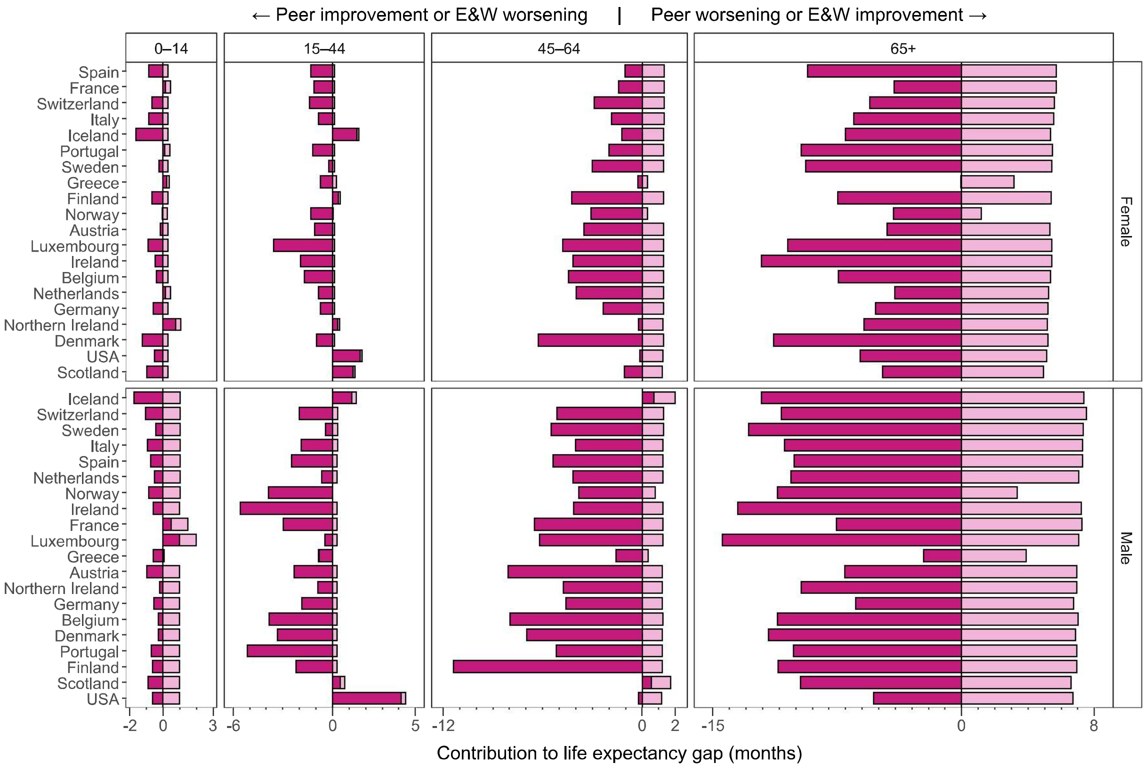


Figure 2-8. Contributions (in months) from mortality trends between 2011–19 in England and Wales (lighter shade) and each high-income country (darker shade) to female (top row) and male (bottom row) life expectancy gaps in 2019, by age group. *Note:* See the note in Figure 2-2 for exceptions in the observation period. *Source*: Authors' calculations based on data from the Human Mortality Database and the World Health Organization Mortality Database.

2.5.3. Comparison with the USA

The life expectancy disadvantage of the USA compared to England and Wales grew over the period 2011–19 (Figure 2-2), despite smaller increases in dementia mortality and larger improvements in lung cancer mortality (Figures 2-3 to 2-5). Mortality from cardiometabolic diseases improved much less in the USA, and mortality from external causes increased more than in England and Wales. Consequently, working-age mortality increased (ages 15–44) or stagnated (ages 45–64) in the USA (Figures 2-6 to 2-8). For retirement-age mortality (ages 65+), patterns differed between females (larger USA improvements) and males (smaller USA improvements).

2.6. Summary

Life expectancy is a key barometer of overall population welfare, reflecting the cumulative effects of the broader social, economic, and environmental conditions in which people live. While stagnation and reversals in life expectancy in the USA have garnered significant attention in recent years, slowing mortality improvements in England and Wales have also raised alarm bells. Male life expectancy in England and Wales in 2011 was higher than in many other high-income countries. However, the slower improvements in England and Wales meant that life expectancy advantages over most other countries have shrunk, whereas existing disadvantages have widened. Female life expectancy in England and Wales already ranked comparatively low in 2011 and lost further ground over the period 2011–19.

Previously, the causes of death contributing to the recent life expectancy divergence between England and Wales and other high-income countries were not fully understood. Building on an earlier study (Leon et al., 2019), we applied state-of-the-art decomposition methods to high-quality mortality data to better understand recent life expectancy changes in England and Wales vis-à-vis its peers. The contour decomposition approach allowed us to quantify the contribution of recent mortality trends to current life expectancy gaps, net of the contribution of baseline mortality differentials. Thus, our study addressed the question of changing gaps in life expectancy *between* England and Wales and other high-income countries. This complements existing research focusing on the causes of slowdowns in mortality improvements *within* England and Wales over time (Murphy & Grundy, 2022). While some overlap in the explanatory mechanisms can be expected, these are distinct research questions that warrant their own research designs (Abrams et al., 2023; Polizzi & Dowd, 2024).

Overall, the life expectancy divergence of England and Wales was more pronounced for males compared to females. This finding is consistent with previous studies that found the slowdown in mortality improvements within England to be much stronger among males vs. females (Walsh, Dundas, et al., 2022). Consistent with Leon et al., our decomposition results suggest that all age groups except for childhood (ages 0–14) contributed meaningfully to life expectancy divergences between England and Wales and other high-income countries. This reflected both smaller (age groups 45–64 and 65+) and stagnating (ages 15–44) mortality improvements in England and Wales. In contrast, most age groups in the high-income peer countries saw consistent mortality improvements during 2011–19. Thus, by 2019, mortality in England and Wales had become closer to the peer average (males) or fallen even further behind the peer average (females).

These age-specific patterns are directly linked to changes in cause-specific mortality in England and Wales compared to the peer countries. Less favorable trends for England and

Wales were generally seen for: (a) external mortality at young and middle ages (15–64), except when compared with Scotland and the USA; (b) mortality from cardiometabolic diseases at middle and older ages (45+), except when compared with the USA; (c) male lung cancer mortality at late working ages (45–64); (d) and (e) female and male mortality from other cancers and respiratory diseases at late working ages (45–64); and finally, (f) dementia mortality at older ages (65+), especially among females. More favorable trends for England and Wales compared to peers were rare and generally seen for (a) female lung cancer mortality at middle and older ages (45+) and male lung cancer mortality at retirement ages (65+); (b) female and male mortality from other cancers and respiratory diseases at retirement ages (65+); (c) female and male mortality from residual causes of death across all age groups, but mostly at retirement ages (65+).

2.7. Discussion

2.7.1. External mortality

External causes of death are one example of how the shift from a within-country to a cross-country perspective strongly influences conclusions about drivers of life expectancy stagnation or divergence. While trends within England and Wales over time suggest that rising external mortality has offset improvements in other causes of death by only one or two months, strong improvements in some other countries, such as Ireland and Finland, mean that differential trends in external mortality have contributed up to eight months to the life expectancy disadvantage of England and Wales vs. its peers. Consistent with our findings, Dowd et al. (2024) documented worsening mortality among ages 25–64 in the UK compared to high-income peers from 1990–2019, particularly for drug-related deaths. England and Wales has recently seen sharp rises in deaths from drug misuse, especially deaths involving opioids, cocaine, and benzodiazepines (Office for National Statistics, 2023). Also consistent with our results, drug-related mortality in midlife has increased dramatically in Scotland, with mortality rates for some age–sex groups even exceeding levels in the USA (Dowd et al., 2023). Compared to high-income peers, the UK had relatively low mortality due to transport accidents, suicide, and homicide mortality, though some increases were visible in recent years, including among other external causes of death (Dowd, Doniec, et al., 2024).

2.7.2. Cardiometabolic mortality

Our finding that smaller improvements in cardiometabolic mortality contributed to the mortality divergence of England and Wales are consistent with observations of slowing cardiovascular mortality improvements across high-income countries (Lopez & Adair, 2019). The UK saw large annual reductions in cardiovascular mortality of around five percent per year in 2001–10, which declined to around four percent per year during 2010–15, and further to around two percent in 2014–15 (Lopez & Adair, 2019). This slowing trend was even more pronounced for the age group 35–74 (Lopez & Adair, 2019). Some data even suggest an increase in cardiovascular mortality in the UK between 2016 and 2017 (Lopez & Adair, 2019). Analyses using more fine-grained cause-of-death coding than was possible with our decomposition approach suggest that improvements in England have slowed particularly for heart disease and stroke mortality (Public Health England, 2018). Slowing improvements in coronary heart disease in the UK were mostly visible below age 54 (Nichols et al., 2013), and slowing improvements in stroke mortality were concentrated among certain stroke types (Shah et al., 2019). While UK death rates from cardiometabolic disease were low compared to peers in 2011, continued large improvements in countries with lower cardiometabolic mortality, such as Switzerland or Spain, suggest that slowing improvements in England and Wales are not due to floor effects (Ho & Hendi, 2024).

Two potential explanations for slowing improvements in cardiometabolic mortality in the UK are (a) limited remaining gains from reductions in smoking; and (b) the accumulating impact of the obesity epidemic (Acosta et al., 2022; Lopez & Adair, 2019). The UK was one of the first countries to undergo the smoking transition, as seen by changes in peak smoking prevalences across cohorts, i.e., the maximum proportion of individuals within a cohort who were smokers at the same time. Peak smoking prevalence was highest in the male birth cohorts of the 1910s, at over 80 percent, and in the female cohorts of the 1920s, at around 50 percent (Christopoulou, 2015). In other countries, such as Germany and Spain, men born in the 1940s and 1950s and women born in the 1950s and 1960s had the highest peak smoking prevalence (Christopoulou & Önder, 2015; Decicca et al., 2015; Vogt et al., 2017). Different cohort smoking patterns in England and Wales and its peer countries translate into different amounts of period life expectancy lost to smoking. Based on 2014 data, Janssen (2021) estimated that men in the UK could gain nearly two years of life expectancy by eliminating smoking-attributable mortality, surpassing only Sweden, Iceland, Norway, Switzerland, Finland, and Ireland. For women, the potential gain in life expectancy in the UK was also close to two years, the third-largest value in Janssen's sample of 30 European countries. Our results highlight the later smoking transition of most European peer countries compared to England and Wales, with lung cancer mortality still improving rapidly for men and worsening for women in the peer countries. Although further improvements in cardiometabolic and lung cancer mortality could still be achieved by reducing smoking in England and Wales (see Acosta et al., 2022 for evidence from the USA), recent stabilization in cohort smoking trends mean that these reductions may not be realized. In other high-income countries, declines in peak smoking prevalence can still be expected in future cohorts of men and women based on recent trends (Christopoulou & Önder, 2015; Decicca et al., 2015).

Rising obesity levels may have—at least in part—offset expected improvements in cardiovascular mortality from smoking reductions (Lopez & Adair, 2019). The obesity epidemic has become a common explanation for the recent lack of improvements in cardiovascular disease mortality in the USA (Mehta et al., 2020; Preston et al., 2018), where adult obesity (BMI ≥30) levels before the COVID-19 pandemic were as high as 42% (Stierman et al., 2021). In England, adult obesity prevalence in 1993–2019 increased from 16% to 31% (Moody, 2020), levels that are lower than in the USA but higher than in most of Europe (World Health Organization Regional Office for Europe, 2022). Obesity levels in England have increased almost continuously across birth cohorts, particularly among those born between the mid-1970s and the mid-1990s (Opazo Breton & Gray, 2023). Besides the acute risk of obesity for diabetes and cardiovascular disease, this means that younger cohorts are spending more years of their lives obese on average, potentially contributing to longer-term trends in risk. Thus, the UK's forerunner position in the obesity epidemic (Janssen et al., 2020) could be a factor in the diverging mortality trends between England and Wales and other European countries. While associations between obesity and mortality are challenging to estimate (Stokes & Preston, 2016), an analysis by Walsh et al. (2022) suggests that in the 2017–19 period, up to about 20% (males) and 35% (females) of the discrepancy between observed mortality rates and expected mortality rates (based on a linear extrapolation of trends in 1991–2010) among 35-to-89-year-olds in England could be due to changes in the BMI distribution between the mid-1990s and the late 2000s.

2.7.3. Cancer mortality

Cancer (including lung cancer) has overtaken cardiovascular disease as the most common cause of death in the UK—in 2011 for men and in 2014 for women (Wilson et al., 2017). We find that slower improvements in mortality from non-lung cancers have contributed meaningfully to the widening mortality gap between England and Wales and other high-income countries, particularly for males. Yet, cancer mortality has so far received little attention in the literature on life expectancy stagnation in England and Wales (e.g., Public Health England, 2018). In the UK, declines in cancer mortality started decelerating in the 1990s (Wilson et al., 2017). Between 2001–11 and 2011–19, cancer mortality, including lung-cancer, contributed just below 15% to the total slowdown in mortality improvements in the UK (Murphy & Grundy, 2022). Improvements in ten-year survival for all cancers combined in the UK have slowed since 2010, and cancer survival is lagging behind comparable countries (Cancer Research UK, 2024). In addition, compared to the early 1990s, mortality rates for liver, skin, and oral cancer have increased among men aged 35–69 in the UK (Shelton et al., 2024). Similarly, among women aged 35–69, mortality rates for liver, oral, pancreas, and uterine cancer have grown in the past 30 years. Compared to 2001–11, mortality improvements in breast cancer and colon and rectum cancer in 2011–19 have also slowed down or reversed in the UK (Murphy & Grundy, 2022). Among other risk factors, increases or slowdowns in improvements in liver, uterine, breast, and colorectal cancer mortality rates could potentially be linked to rising overweight and obesity in the UK (Shelton et al., 2024). While we still lack a good understanding of the pace of improvements in other cancer sites and the potential causes of slowdowns in cancer mortality improvements, our results suggest that cancer mortality may be a meaningful contributor to the life expectancy shortfall of England and Wales compared to other high-income countries.

2.7.4. Respiratory mortality

Previous reports by Public Health England and the UK's Office for National Statistics emphasized the role of seasonal influenza in the stagnating life expectancy trends in England and Wales, pointing to an increase in excess winter deaths between 2014 and 2015 (Hiam et al., 2024; Murphy, 2021). Because influenza may be underreported on death certificates, we followed earlier studies and investigated trends in respiratory mortality more broadly (Ho & Hendi, 2018). However, our decomposition results show that contributions of trends in respiratory diseases to the life expectancy gap between England and Wales and other countries are generally small and mixed in direction. Both males and females in England and Wales saw further improvements in respiratory mortality across the period 2011–19 and sometimes larger gains than in other countries. Thus, our findings support work questioning the role of influenza in longer-term life expectancy stagnation, since influenza deaths constitute a small share of all deaths and there has been a longer-term decline in influenza deaths (Murphy, 2021).

2.7.5. Dementia mortality

Our finding that England and Wales saw larger increases in dementia mortality contradicts trends in dementia incidence in England and Wales. While a recent study using an algorithm-based dementia case definition found that dementia incidence in England and Wales declined between 2002 and 2008 and increased again between 2008 and 2016 (Chen et al., 2023), this U-shaped time trend has been attributed to the use of inconsistent dementia definitions in the original study (Ahmadi-Abhari & Kivimäki, 2024). A reanalysis of the same data source using a consistent case definition concluded that dementia incidence has, in fact, continuously declined over the first two decades of the twenty-first century (Ahmadi-Abhari & Kivimäki, 2024). Simultaneously, the proportion of GP patients with a dementia diagnosis has increased (Donegan et al., 2017), especially following the introduction of the National Dementia Strategy for England in 2009. Thus, the disproportionately fast increase in the use of dementia as underlying cause of death in England and Wales appears to be mainly attributable to a rise in dementia awareness (Murphy & Grundy, 2022) and changes to the cause-of-death coding algorithms in 2011 and 2014 (McCartney, Walsh, et al., 2022), which contributed to substantial overreporting of dementia as an underlying cause of death (Adair et al., 2023).

Recent increases in reported dementia death rates have also been documented in other countries with declining dementia incidence (Farina et al., 2022). Over the period 2006–17, deaths in Australia and the USA with dementia listed as a multiple cause of death have seen an increasing use of dementia as the underlying cause of death (Adair et al., 2022). Simultaneously, the use of cardiovascular disease as underlying cause of death decreased. These changes in certification practices and dementia reporting suggest that the contribution of trends in dementia mortality to life expectancy gaps between England and Wales and other high-income countries may be overestimated in our study. In addition, if major causes of death at older ages, such as cardiometabolic and respiratory diseases, have become more likely to be coded as dementia over time, improvements in these causes may have been even smaller than they appeared in our results (Adair et al., 2022; Murphy et al., 2019).

2.7.6. Macro-level drivers of mortality trends

Other studies have documented widespread slowdowns in mortality improvements in high-income countries, with England and Wales showing relatively strong mortality deceleration in the decade 2010–19. Our results suggest that England and Wales mainly differs from other high-income countries in the magnitude of mortality improvements or deteriorations rather than the pattern of ages and causes. With few exceptions, such as lung cancer mortality among females and external-cause mortality among both females and males, the direction of mortality changes in England and Wales and other high-income countries were broadly similar. Thus, shared drivers of international slowdowns in life expectancy improvements may have been exacerbated by factors specific to England and Wales (Minton et al., 2023). Austerity—reductions in government spending to achieve debt reduction following the 2007–08 financial crisis (Stuckler et al., 2017)—has been proposed as a potential cause of adverse mortality trends in England and Wales (Walsh & McCartney, 2025). Internationally, austerity was found to be associated with worse mortality outcomes (McCartney, McMaster, et al., 2022; Rajmil & Fernández de Sanmamed, 2019). While the UK was not the only country to implement austerity measures, it had one of Europe's largest austerity packages and was among a small group of countries in our sample that reduced public spending on social protection (Reeves et al., 2013). Reductions were achieved though changes in benefit generosity and eligibility (Griffiths, 2020) as well as through funding cuts to local governments, which are responsible for the provision of social care and public health, among other factors (Gray & Barford, 2018). Simultaneously, increases in healthcare expenditure have considerably slowed in the UK from 2009 onwards, compared with other high-income countries (Papanicolas et al., 2019). Within the UK, spending cuts were most severe among the most deprived areas (Currie et al., 2019; Gray & Barford, 2018; Griffiths, 2020).

Most work on the association between austerity and mortality in England and Wales has studied variation at the subnational level using macro-level data. For example, at the local level in the UK, cuts to social security, social care, public health, and healthcare expenditure were associated with worse mortality (Alexiou et al., 2021; Martin et al., 2021; Seaman et al., 2024), including higher older-age mortality (Loopstra et al., 2016; Watkins et al., 2017), suicide mortality (Barr et al., 2016), and drug overdoses (Friebel et al., 2022; Koltai et al., 2021). However, empirical evidence is not yet sufficient to conclude that the specific austerity package implemented in England and Wales can fully or partially explain its diverging mortality trends from those in other high-income countries that also implemented austerity measures, through which mechanisms the effect of austerity operates, and to which causes of death this applies.

2.7.7. Strengths, limitations, and further research

While our cause-of-death analysis is a major strength of our study, the computationally intensive algorithm used for our decompositions means that we had to restrict our analysis to a smaller set of broad causes of death, limiting our ability to analyze more specific causes. Causes of death not falling into our broad categories were assigned to the 'residual' category, which includes a variety of less common causes of death. This residual category comprised about 13 percent (females) and 12 percent (males) of total deaths in England and Wales in 2019. Nonetheless, our analysis focused on the main causes of death highlighted in recent discourse on the life expectancy stagnation in England and Wales. Thus, our study paints a comprehensive picture of diverging life expectancy trends in England and Wales vs. other high-income countries and lays a foundation for understanding determinants of mortality that are both similar and different across countries. Existing comparative work on international mortality trends has focused primarily on the mortality disadvantage of the USA, potentially overlooking concerning trends in other countries that are also seeing stagnating or rising mortality, such as England and Wales. While there are some similarities in the narratives used to explain life expectancy trends in

England and Wales and the USA, such as the obesity epidemic and so-called “deaths of despair,” there are important differences between the USA and England and Wales. Mortality trends in England and Wales are still much better than in the USA, where cardiometabolic disease mortality barely improved from 2011 to 2019 and external-cause mortality soared due to the opioid crisis. England and Wales also experienced distinct mortality trends that should be examined further, including significant increases in dementia mortality, particularly among females. In addition to the USA and England and Wales, life expectancy slowdowns in other European countries, such as France, Germany, and the Netherlands, have been noted. The COVID-19 pandemic, which started after our period of analysis, led to life expectancy losses across many high-income countries, including from mortality not attributed to COVID-19 (Polizzi et al., 2025). By 2023, life expectancy in many countries had still not returned to pre-pandemic levels (Huang et al., 2024). Whether we are entering a period of more generalized life expectancy stagnation in high-income countries and how life expectancy trajectories will develop in the post-pandemic period will be an important question to monitor (Dowd, Polizzi, et al., 2024).

Our findings suggest important areas for future research. First, future work should examine cohort differences in lifetime exposures when evaluating the role of obesity in international cardiometabolic mortality trends. In addition, cross-country comparisons of changes in cardiometabolic risk factors such as management of high blood pressure and cholesterol may help shed light on the slowing mortality improvements both within England and Wales as well as in relation to other high-income nations. Second, future research could preferably use multiple cause of death data to determine how changes in dementia mortality have contributed to life expectancy changes among high-income countries, better accounting for changes in dementia coding and reporting practices. Third, our analysis suggests that a deeper examination of cross-country differences in sex-specific mortality trends could yield additional insights. In absolute terms, life expectancy in England and Wales has fallen behind more for males vs. females, although female life expectancy ranked worse initially. How this increasing male disadvantage reflects sex differences in population health risk factors such as obesity should be explored further. Finally, given evidence that the stagnation in life expectancy in England and Wales has hit the most deprived areas hardest, with some parts of the population experiencing rising all-cause mortality (Walsh, Dundas, et al., 2022), future research should investigate how widening social inequalities in mortality by cause of death have contributed to the life expectancy divergence of England and Wales from other countries.

2.8. Conclusion

Mortality trends reflect a combination of short- and long-term mechanisms that are challenging to disentangle (Murphy et al., 2019). Period health shocks such as influenza and COVID-19 or rising drug overdose deaths call attention to short-term medical and policy remedies. Medium- and long-term determinants of mortality, including complex comorbidities related to the obesity epidemic, rising prevalence of mental health disorders and substance use, and long-term changes in economic and social policies, are more difficult to isolate but even more important to understand. Our analysis aimed to build the fact base for further hypothesis testing regarding the short- and long-term mechanisms underlying the diverging mortality trends in England and Wales. Additional comparative mortality work is needed to understand both differences and similarities in mortality patterns across countries and how these may relate to both micro and macro determinants of population health.

2.9. Acknowledgement

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2.11. Author contributions

Conceptualization: A.P. and J.B.D.; data preparation: A.P. and L.Z.; data analysis: A.P.; interpretation: A.P., A.M.T., J.B.D.; manuscript draft: A.P.; manuscript revision: A.P., A.M.T., L.Z., J.B.D.

2.12. Data availability

This study uses data from the Human Mortality Database (HMD) and the World Health Organization Mortality Database (WHO MD). Data from HMD are publicly available, under a Creative Commons license CC BY 4.0, from: *https://mortality.org*. Data from WHO MD are publicly available, for non-commercial purposes, from: *https://www.who.int/data/data-collection-tools/who-mortality-database*. R Code to carry out the contour decomposition is provided in Dmitry Jdanov's GitHub repository *cdecomp*, at: *https://github.com/djdanov/cdecomp*.

2.13. Supplementary Information

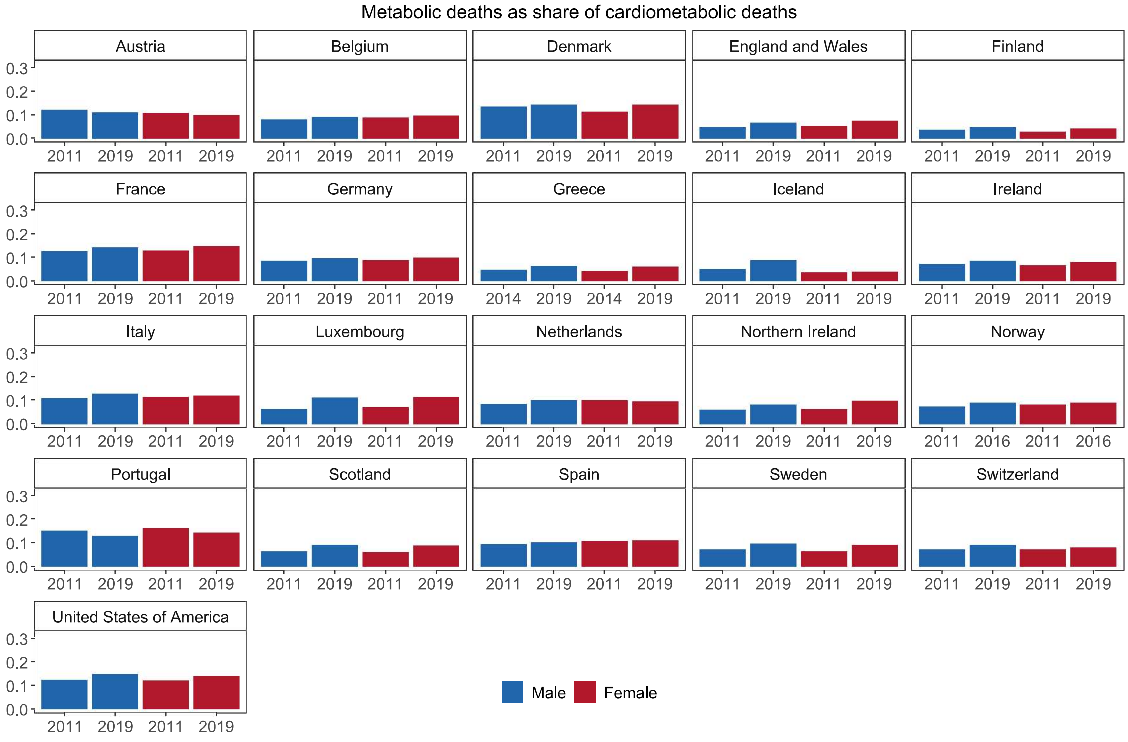


Figure 2-S1. Share of all cardiometabolic deaths that are metabolic deaths. *Source*: Authors' calculations based on data from the World Health Organization Mortality Database.

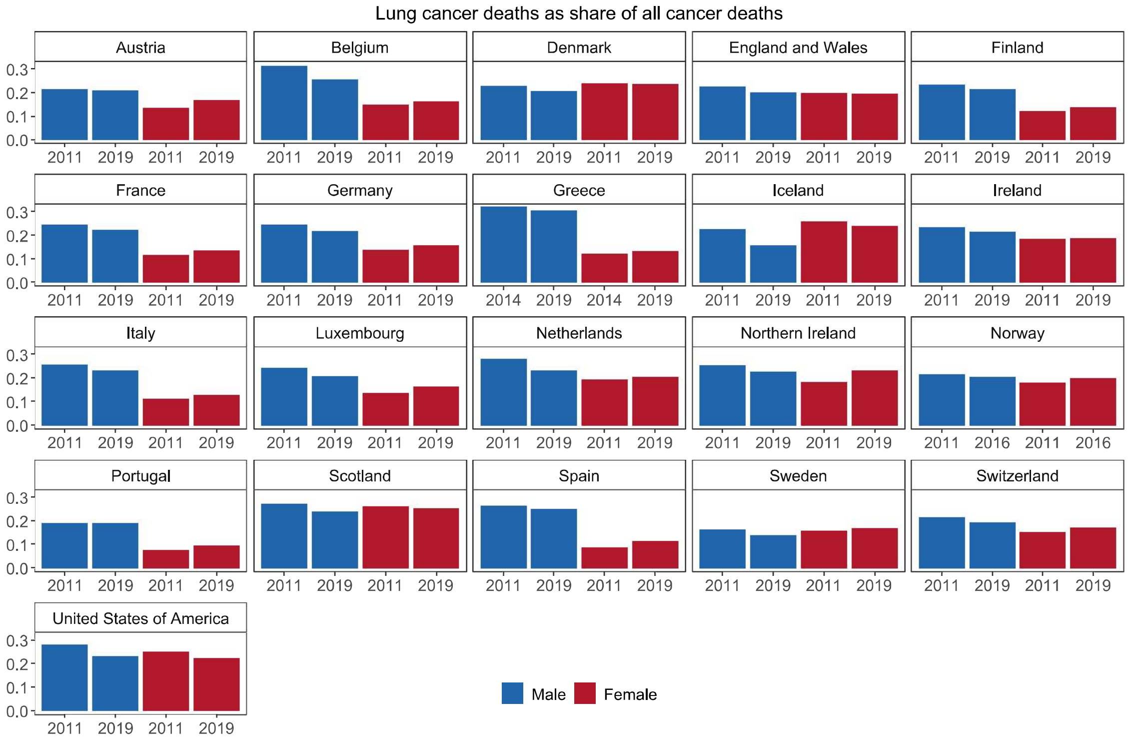


Figure 2-S2. Share of all cancer deaths that are lung cancer deaths. *Source*: Authors' calculations based on data from the World Health Organization Mortality Database.

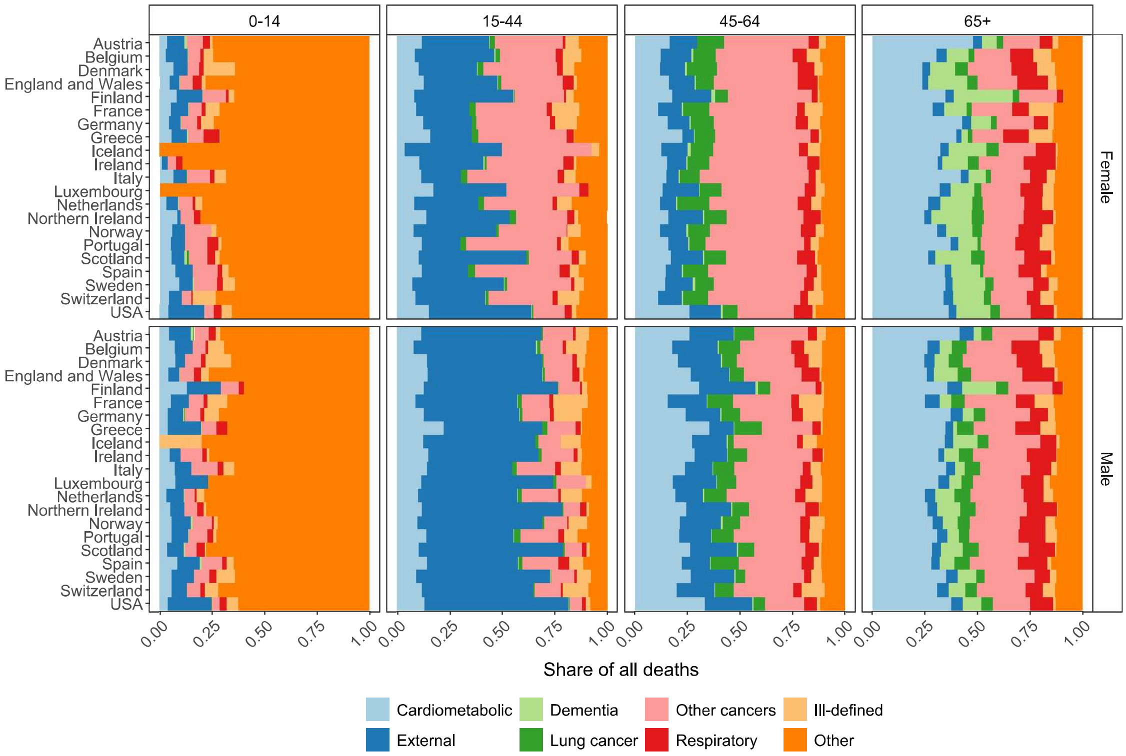
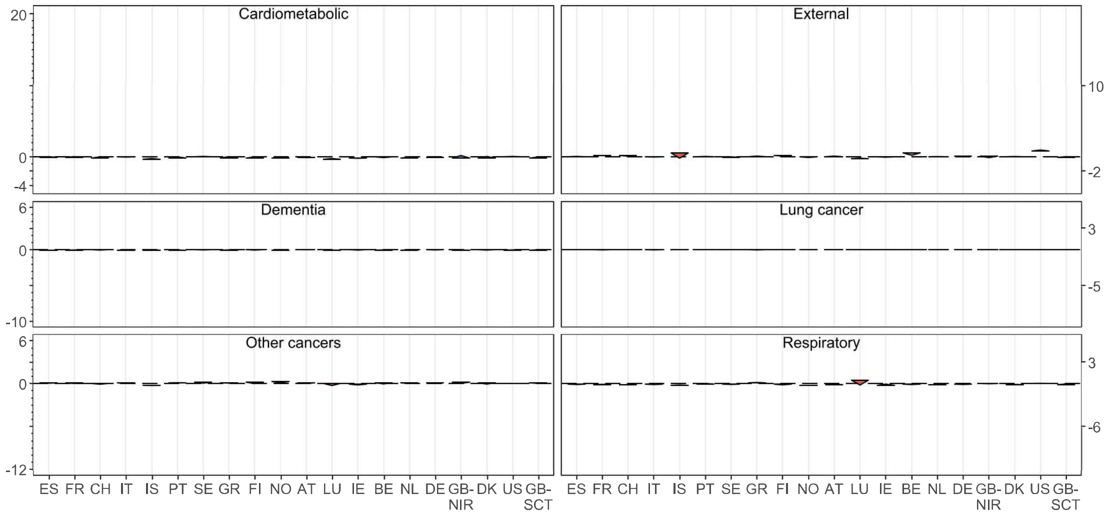


Figure 2-S3. Share of all deaths in 2019 attributable to eight causes of death, by age group. *Source*: Authors' calculations based on data from the World Health Organization Mortality Database.

a : Contribution to female life expectancy gap (months)



b : Contribution to male life expectancy gap (months)

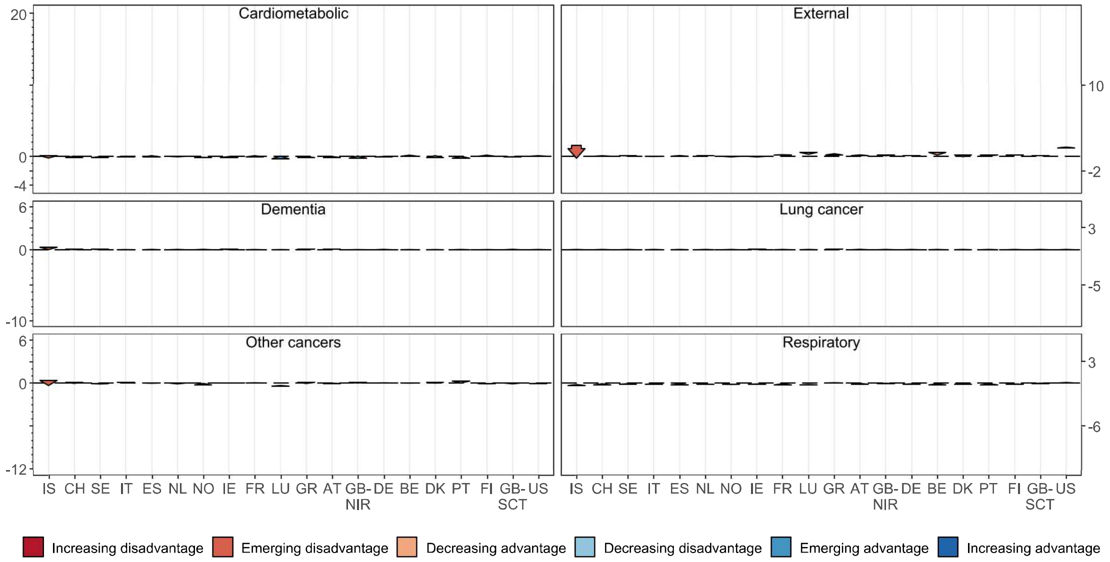
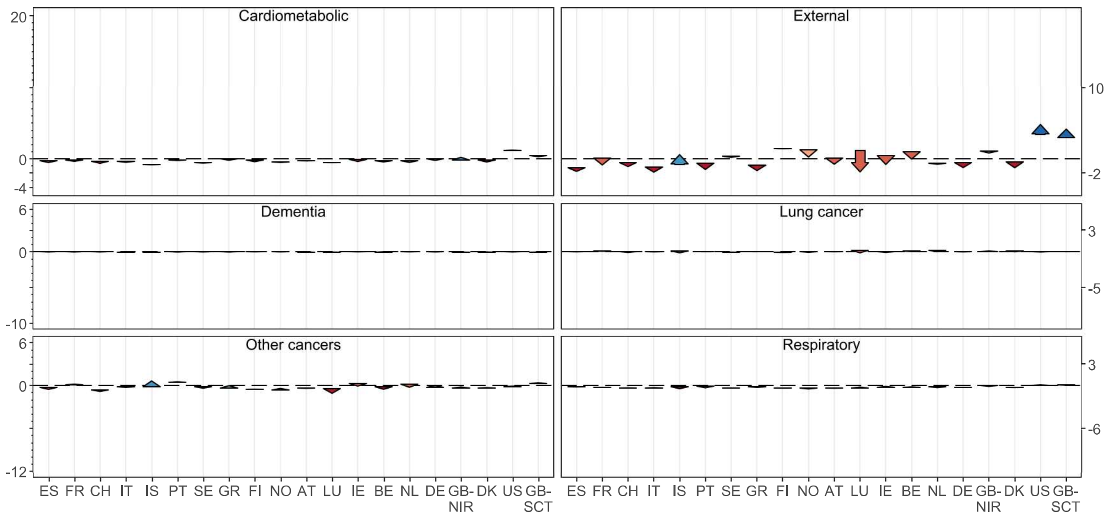


Figure 2-S4. Contributions (in months) from mortality differences in 2011 (tail of arrow) and mortality trends between 2011–19 (length and direction of arrow) to female (top panel) and male (bottom panel) life expectancy gaps between England and Wales and each high-income country in 2019, by cause of death, age group 0–14. *Note:* See the note in Figure 2-2 for exceptions in the observation period. “Advantage” and “disadvantage” are from the perspective of England and Wales. *Source*: Authors’ calculations based on data from the Human Mortality Database and the World Health Organization Mortality Database.

a : Contribution to female life expectancy gap (months)



b : Contribution to male life expectancy gap (months)

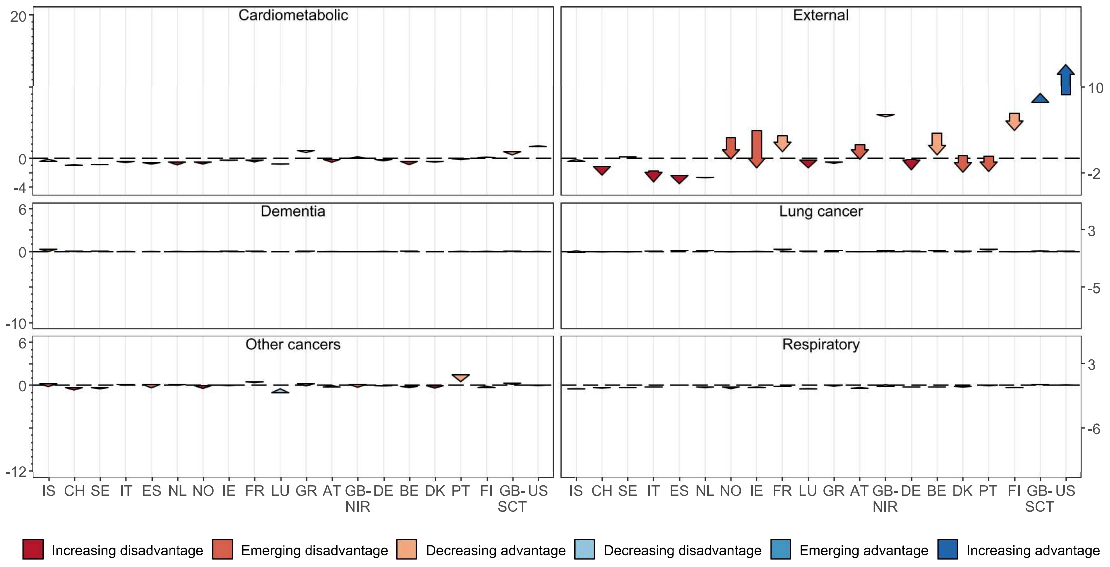
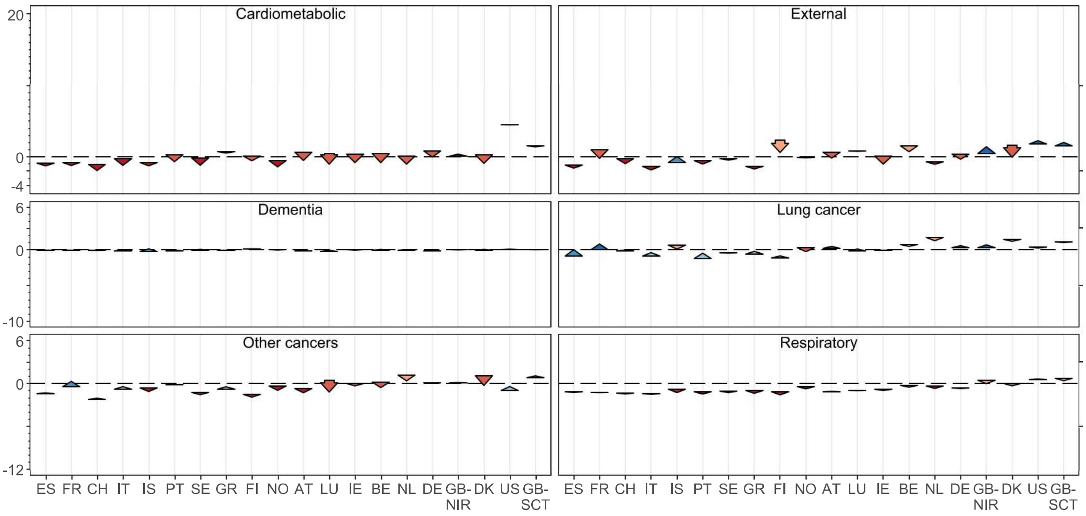


Figure 2-S5. Contributions (in months) from mortality differences in 2011 (tail of arrow) and mortality trends between 2011–19 (length and direction of arrow) to female (top panel) and male (bottom panel) life expectancy gaps between England and Wales and each high-income country in 2019, by cause of death, age group 15–44. *Note:* See the note in Figure 2-2 for exceptions in the observation period. "Advantage" and "disadvantage" are from the perspective of England and Wales. *Source*: Authors' calculations based on data from the Human Mortality Database and the World Health Organization Mortality Database.

a : Contribution to female life expectancy gap (months)



b : Contribution to male life expectancy gap (months)

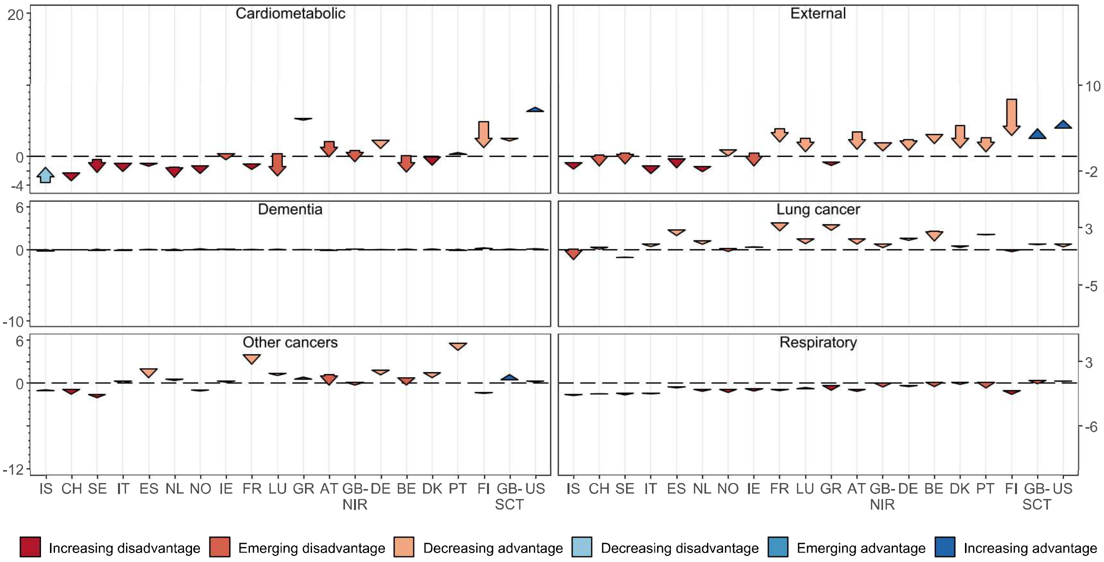
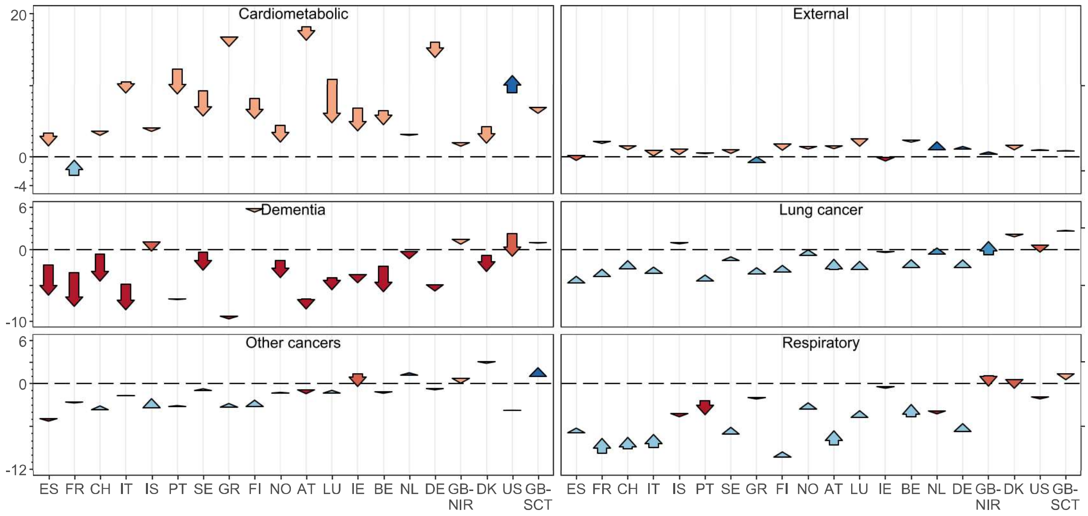


Figure 2-S6. Contributions (in months) from mortality differences in 2011 (tail of arrow) and mortality trends between 2011–19 (length and direction of arrow) to female (top panel) and male (bottom panel) life expectancy gaps between England and Wales and each high-income country in 2019, by cause of death, age group 45–64. *Note:* See the note in Figure 2-2 for exceptions in the observation period. "Advantage" and "disadvantage" are from the perspective of England and Wales. *Source*: Authors' calculations based on data from the Human Mortality Database and the World Health Organization Mortality Database.

a : Contribution to female life expectancy gap (months)



b : Contribution to male life expectancy gap (months)

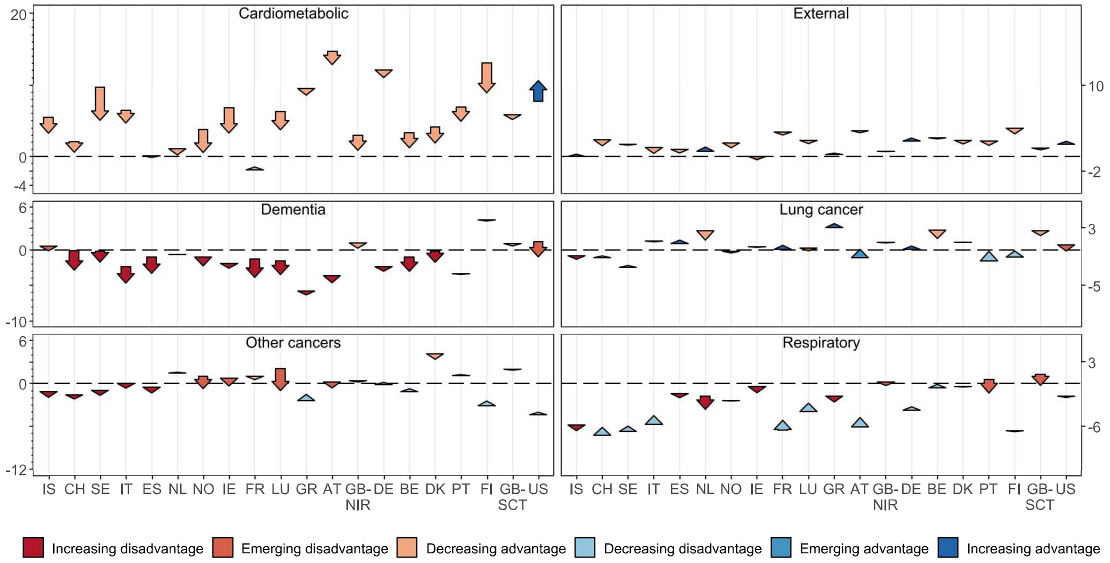
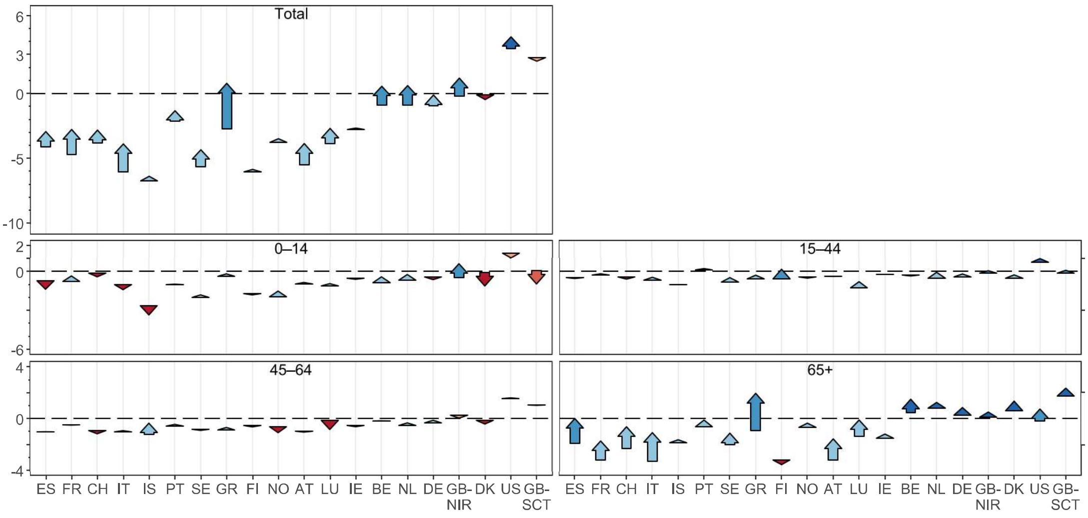


Figure 2-S7. Contributions (in months) from mortality differences in 2011 (tail of arrow) and mortality trends between 2011–19 (length and direction of arrow) to female (top panel) and male (bottom panel) life expectancy gaps between England and Wales and each high-income country in 2019, by cause of death, age group 65+. *Note:* See the note in Figure 2-2 for exceptions in the observation period. “Advantage” and “disadvantage” are from the perspective of England and Wales. *Source*: Authors’ calculations based on data from the Human Mortality Database and the World Health Organization Mortality Database.

a : Contribution to female life expectancy gap (months)



b : Contribution to male life expectancy gap (months)

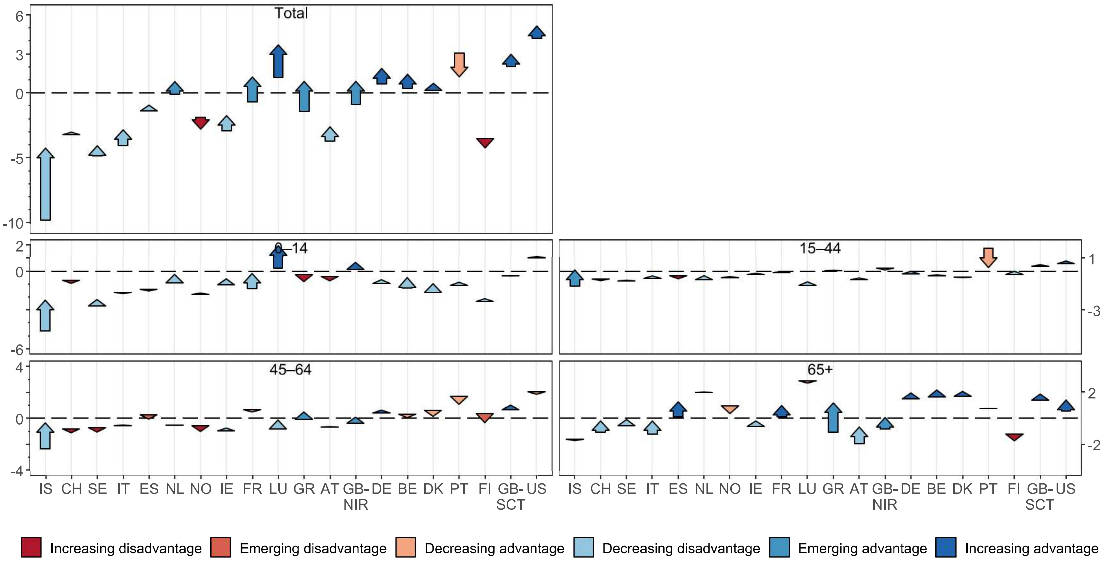


Figure 2-S8. Contributions (in months) from mortality differences in 2011 (tail of arrow) and mortality trends between 2011–19 (length and direction of arrow) to female (top panel) and male (bottom panel) life expectancy gaps between England and Wales and each high-income country in 2019, total and by age group, residual causes of death. *Note:* See the note in Figure 2-2 for exceptions in the observation period. "Advantage" and "disadvantage" are from the perspective of England and Wales. *Source*: Authors' calculations based on data from the Human Mortality Database and the World Health Organization Mortality Database.

References

Abrams, L. R., Myrskylä, M., & Mehta, N. K. (2023). The “double jeopardy” of midlife and old age mortality trends in the United States. *Proceedings of the National Academy of Sciences*, *120*(42), e2308360120. https://doi.org/10.1073/pnas.2308360120

Aburto, J. M., & van Raalte, A. (2018). Lifespan dispersion in times of life expectancy fluctuation: The case of Central and Eastern Europe. *Demography*, *55*(6), 2071–2096. https://doi.org/10.1007/s13524-018-0729-9

Acosta, E., Mehta, N., Myrskylä, M., & Ebeling, M. (2022). Cardiovascular mortality gap between the United States and other high life expectancy countries in 2000–2016. *The Journals of Gerontology: Series B*, *77*(Supplement_2), S148–S157. https://doi.org/10.1093/geronb/gbac032

Adair, T., Li, H., Temple, J., & Anstey, K. J. (2023). Large discrepancies in dementia mortality reported in vital statistics. The need for improved data to inform policy. *Alzheimer Disease & Associated Disorders*, *37*, 207–214. https://doi.org/10.1097/WAD.0000000000000562

Adair, T., Temple, J., Anstey, K. J., & Lopez, A. D. (2022). Is the rise in reported dementia mortality real? Analysis of multiple-cause-of-death data for Australia and the United States. *American Journal of Epidemiology*, *191*(7), 1270–1279. https://doi.org/10.1093/aje/kwac047

Ahmadi-Abhari, S., & Kivimäki, M. (2024). Do age-standardised dementia incidence rates really increase in England and Wales? *The Lancet Public Health*, *9*(3), e152–e153. https://doi.org/10.1016/S2468-2667(24)00019-7

Alexiou, A., Fahy, K., Mason, K., Bennett, D., Brown, H., Bambra, C., Taylor-Robinson, D., & Barr, B. (2021). Local government funding and life expectancy in England:

A longitudinal ecological study. *The Lancet Public Health*, *6*(9), e641–e647. https://doi.org/10.1016/S2468-2667(21)00110-9

Barr, B., Taylor-Robinson, D., Stuckler, D., Loopstra, R., Reeves, A., & Whitehead, M. (2016). 'First, do no harm': Are disability assessments associated with adverse trends in mental health? A longitudinal ecological study. *Journal of Epidemiology and Community Health*, *70*, 339–345. https://doi.org/10.1136/jech-2015-206209

Cancer Research UK. (2024). *Cancer in the UK: overview 2024*. Cancer Research UK.

Case, A., & Deaton, A. (2015). Rising morbidity and mortality in midlife among white non-Hispanic Americans in the 21st century. *Proceedings of the National Academy of Sciences*, *112*(49), 15078–15083. https://doi.org/10.1073/pnas.1518393112

Chen, Y., Bandosz, P., Stoye, G., Liu, Y., Wu, Y., Lobanov-Rostovsky, S., French, E., Kivimaki, M., Livingston, G., Liao, J., & Brunner, E. J. (2023). Dementia incidence trend in England and Wales, 2002–19, and projection for dementia burden to 2040: Analysis of data from the English Longitudinal Study of Ageing. *The Lancet Public Health*, *8*(11), e859–e867. https://doi.org/10.1016/S2468-2667(23)00214-1

Christopoulou, R. (2015). Smoking in the United Kingdom. In D. R. Lillard & R. Christopoulou (Eds.), *Life-course smoking behavior: Patterns and national context in ten countries* (pp. 43–56). New York, NY: Oxford University Press.

Christopoulou, R., & Önder, Z. (2015). Smoking by women in cross-country perspective. In D. R. Lillard & R. Christopoulou (Eds.), *Life-course smoking behavior: Patterns and national context in ten countries* (pp. 167–178). New York, NY: Oxford University Press.

Currie, J., Castillo, M. G., Adekanmbi, V., Barr, B., & O'Flaherty, M. (2019). Evaluating effects of recent changes in NHS resource allocation policy on inequalities in amenable mortality in England, 2007–2014: Time-series analysis. *Journal of Epidemiology and Community Health*, *73*, 162–167. https://doi.org/10.1136/jech-2018-211141

Decicca, P., McLeod, L., & Liu, F. (2015). Smoking by men in cross-country perspective. In D. R. Lillard & R. Christopoulou (Eds.), *Life-course smoking behavior: Patterns and national context in ten countries* (pp. 157–166). New York, NY: Oxford University Press.

Djeundje, V. B., Haberman, S., Bajekal, M., & Lu, J. (2022). The slowdown in mortality improvement rates 2011–2017: A multi-country analysis. *European Actuarial Journal*, *12*, 839–878. https://doi.org/10.1007/s13385-022-00318-0

Donegan, K., Fox, N., Black, N., Livingston, G., Banerjee, S., & Burns, A. (2017). Trends in diagnosis and treatment for people with dementia in the UK from 2005 to 2015: A longitudinal retrospective cohort study. *The Lancet Public Health*, *2*(3), e149–e156. https://doi.org/10.1016/S2468-2667(17)30031-2

Dowd, J. B., Angus, C., Zajacova, A., & Tilstra, A. M. (2023). Comparing trends in mid-life 'deaths of despair' in the USA, Canada and UK, 2001–2019: Is the USA an anomaly? *BMJ Open*, *13*, e069905. https://doi.org/10.1136/bmjopen-2022-069905

Dowd, J. B., Doniec, K., Zhang, L., & Tilstra, A. (2024). US exceptionalism? International trends in midlife mortality. *International Journal of Epidemiology*, *53*(2), dyae024. https://doi.org/10.1093/ije/dyae024

Dowd, J. B., Polizzi, A., & Tilstra, A. M. (2024). Progress stalled? The uncertain future of mortality in high-income countries. *Population and Development Review*. https://doi.org/10.1111/padr.12687

Farina, M. P., Zhang, Y. S., Kim, J. K., Hayward, M. D., & Crimmins, E. M. (2022). Trends in dementia prevalence, incidence, and mortality in the United States (2000–2016). *Journal of Aging and Health*, *34*(1), 100–108. https://doi.org/10.1177/08982643211029716

Friebel, R., Yoo, K. J., & Maynou, L. (2022). Opioid abuse and austerity: Evidence on health service use and mortality in England. *Social Science & Medicine*, *298*, 114511. https://doi.org/10.1016/j.socscimed.2021.114511

Gray, M., & Barford, A. (2018). The depths of the cuts: The uneven geography of local government austerity. *Cambridge Journal of Regions, Economy and Society*, *11*(3), 541–563. https://doi.org/10.1093/cjres/rsy019

Griffiths, S. (2020). The contracting state: Austerity and public services. In M. Guderjan, H. Mackay, & G. Stedman (Eds.), *Contested Britain: Brexit, Austerity and Agency* (pp. 19–32). Bristol, England: Bristol University Press. https://doi.org/10.2307/j.ctvz938gw.7

Heath, A. F., Kashyap, R., & Garratt, E. (2018). The fight against disease: Life expectancy, disease, and lifestyle. In A. F. Heath, E. Garratt, R. Kashyap, Y. Li, & L. Richards (Eds.), *Social Progress in Britain* (pp. 34–60). Oxford, England: Oxford University Press. https://doi.org/10.1093/oso/9780198805489.003.0003

Hiam, L., Dorling, D., & McKee, M. (2023). When experts disagree: Interviews with public health experts on health outcomes in the UK 2010–2020. *Public Health*, *214*, 96–105. https://doi.org/10.1016/j.puhe.2022.10.019

Hiam, L., McKee, M., & Dorling, D. (2024). Influenza: Cause or excuse? An analysis of flu’s influence on worsening mortality trends in England and Wales, 2010–19. *British Medical Bulletin*, *149*(1), 72–89. https://doi.org/10.1093/bmb/ldad028

HMD. (2024). *Human Mortality Database* [Dataset]. Max Planck Institute for Demographic Research (Germany), University of California, Berkeley (USA), and French Institute for Demographic Studies (France). Available at www.mortality.org (Version 26 February 2024).

Ho, J. Y. (2019). The contemporary American drug overdose epidemic in international perspective. *Population and Development Review*, *45*, 7–40. https://doi.org/10.1111/padr.12228

Ho, J. Y. (2022). Causes of America’s lagging life expectancy: An international comparative perspective. *The Journals of Gerontology: Series B*, *77*(Supplement_2), S117–S126. https://doi.org/10.1093/geronb/gbab129

Ho, J. Y., & Hendi, A. S. (2018). Recent trends in life expectancy across high income countries: Retrospective observational study. *BMJ*, *362*, k2562. https://doi.org/10.1136/bmj.k2562

Ho, J. Y., & Hendi, A. S. (2024). Inequalities in life expectancy and cardiometabolic disease mortality across and within high-income countries. *Cell Metabolism*, *36*(2), 224–228. https://doi.org/10.1016/j.cmet.2023.11.002

Huang, G., Guo, F., Liu, L., Taksa, L., Cheng, Z., Tani, M., Zimmermann, K. F., Franklin, M., & Silva, S. S. M. (2024). Changing impact of COVID-19 on life expectancy 2019–2023 and its decomposition: Findings from 27 countries. *SSM - Population Health*, *25*, 101568. https://doi.org/10.1016/j.ssmph.2023.101568

Janssen, F. (2021). The role of smoking in country differences in life expectancy across Europe, 1985–2014. *Nicotine & Tobacco Research*, *23*(1), 152–160. https://doi.org/10.1093/ntr/ntaa011

Janssen, F., Bardoutsos, A., & Vidra, N. (2020). Obesity prevalence in the long-term future in 18 European countries and in the USA. *Obesity Facts*, *13*(5), 514–527. https://doi.org/10.1159/000511023

Jdanov, D. (2024). *Cdecomp* [Computer software]. https://github.com/djdanov/cdecomp

Jdanov, D., Shkolnikov, V., & Jasilionis, D. (2024). Two-dimensional contour decomposition: Decomposing mortality differences into initial difference and trend components by age and cause of death. *Demographic Research*, *50*(41), 1223–1246. https://doi.org/10.4054/DemRes.2024.50.41

Jdanov, D., Shkolnikov, V., Van Raalte, A., & Andreev, E. (2017). Decomposing current mortality differences into initial differences and differences in trends: The contour decomposition method. *Demography*, *54*(4), 1579–1602. https://doi.org/10.1007/s13524-017-0599-6

Koltai, J., McKee, M., & Stuckler, D. (2021). Association between disability-related budget reductions and increasing drug-related mortality across local authorities in Great Britain. *Social Science & Medicine*, *284*, 114225. https://doi.org/10.1016/j.socscimed.2021.114225

Leon, D. A., Jdanov, D. A., & Shkolnikov, V. M. (2019). Trends in life expectancy and age-specific mortality in England and Wales, 1970–2016, in comparison with a set of 22 high-income countries: An analysis of vital statistics data. *The Lancet Public Health*, *4*(11), e575–e582. https://doi.org/10.1016/S2468-2667(19)30177-X

Loopstra, R., McKee, M., Katikireddi, S. V., Taylor-Robinson, D., Barr, B., & Stuckler, D. (2016). Austerity and old-age mortality in England: A longitudinal cross-local area analysis, 2007–2013. *Journal of the Royal Society of Medicine*, *109*(3), 109–116. https://doi.org/10.1177/0141076816632215

Lopez, A. D., & Adair, T. (2019). Is the long-term decline in cardiovascular-disease mortality in high-income countries over? Evidence from national vital statistics. *International Journal of Epidemiology*, *48*(6), 1815–1823. https://doi.org/10.1093/ije/dyz143

Marshall, L., Finch, D., Cairncross, L., & Bibby, J. (2019). *Mortality and life expectancy trends in the UK: stalling progress*. London, England: The Health Foundation.

Martin, S., Longo, F., Lomas, J., & Claxton, K. (2021). Causal impact of social care, public health and healthcare expenditure on mortality in England: Cross-sectional evidence for 2013/2014. *BMJ Open*, *11*, e046417. https://doi.org/10.1136/bmjopen-2020-046417

Masters, R. K., Tilstra, A. M., & Simon, D. H. (2018). Explaining recent mortality trends among younger and middle-aged White Americans. *International Journal of Epidemiology*, *47*(1), 81–88. https://doi.org/10.1093/ije/dyx127

McCartney, G., McMaster, R., Popham, F., Dundas, R., & Walsh, D. (2022). Is austerity a cause of slower improvements in mortality in high-income countries? A panel analysis. *Social Science & Medicine*, *313*, 115397. https://doi.org/10.1016/j.socscimed.2022.115397

McCartney, G., Walsh, D., Fenton, L., & Devine, R. (2022). *Resetting the course for population health. Evidence and recommendations to address stalled mortality improvements in Scotland and the rest of the UK*. Glasgow, Scotland: Glasgow Centre for Population Health / University of Glasgow. https://www.gcph.co.uk/publications/1036_resetting_the_course_for_population_health

Mehta, N. K., Abrams, L. R., & Myrskylä, M. (2020). US life expectancy stalls due to cardiovascular disease, not drug deaths. *Proceedings of the National Academy of Sciences*, *117*(13), 6998–7000. https://doi.org/10.1073/pnas.1920391117

Minton, J., Fletcher, E., Ramsay, J., Little, K., & McCartney, G. (2020). How bad are life expectancy trends across the UK, and what would it take to get back to previous trends? *Journal of Epidemiology and Community Health*, *74*, 741. https://doi.org/10.1136/jech-2020-213870

Minton, J., Hiam, L., McKee, M., & Dorling, D. (2023). Slowing down or returning to normal? Life expectancy improvements in Britain compared to five large European countries before the COVID-19 pandemic. *British Medical Bulletin*, *145*(1), 6–16. https://doi.org/10.1093/bmb/ldac036

Moody, A. (2020). *Health Survey for England 2019. Overweight and obesity in adults and children*. England: NHS Digital. https://digital.nhs.uk/data-and-information/publications/statistical/health-survey-for-england/2019

Murphy, M. (2021). Recent mortality in Britain: A review of trends and explanations. *Age and Ageing*, *50*(3), 676–683. https://doi.org/10.1093/ageing/afab016

Murphy, M., & Grundy, E. (2022). Slowdown in mortality improvement in the past decade: A US/UK comparison. *The Journals of Gerontology: Series B*, *77*(Supplement_2), S138–S147. https://doi.org/10.1093/geronb/gbab220

Murphy, M., Luy, M., & Torrisi, O. (2019). *Mortality change in the United Kingdom and Europe: An analytical review of the evidence* [Working Paper 11-19]. London, England: LSE Department of Social Policy.

Nichols, M., Townsend, N., Scarborough, P., & Rayner, M. (2013). Trends in age-specific coronary heart disease mortality in the European Union over three decades: 1980–

2009. *European Heart Journal*, *34*(39), 3017–3027. https://doi.org/10.1093/eurheartj/eht159

Office for National Statistics. (2023). *Deaths related to drug poisoning in England and Wales: 2022 registrations*. https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/bulletins/deathsrelatedtodrugpoisoninginenglandandwales/2022registrations

Opazo Breton, M., & Gray, L. A. (2023). An age-period-cohort approach to studying long-term trends in obesity and overweight in England (1992–2019). *Obesity*, *31*(3), 823–831. https://doi.org/10.1002/oby.23657

Papanicolas, I., Mossialos, E., Gundersen, A., Woskie, L., & Jha, A. K. (2019). Performance of UK National Health Service compared with other high income countries: Observational study. *BMJ*, *367*, l6326. https://doi.org/10.1136/bmj.l6326

Pascariu, M. D., Rizzi, S., Schoeley, J., & Danko, M. J. (2024). *ungroup: Penalized composite link model for efficient estimation of smooth distributions from coarsely binned data* (Version 1.4.4) [Computer software]. https://CRAN.R-project.org/package=ungroup

Polizzi, A., & Dowd, J. B. (2024). Working-age mortality is still an important driver of stagnating life expectancy in the United States. *Proceedings of the National Academy of Sciences*, *121*(4), e2318276121. https://doi.org/10.1073/pnas.2318276121

Polizzi, A., Zhang, L., Timonin, S., Gupta, A., Dowd, J. B., Leon, D. A., & Aburto, J. M. (2025). Indirect effects of the COVID-19 pandemic: A cause-of-death analysis of life expectancy changes in 24 countries, 2015 to 2022. *PNAS Nexus*, *4*(1), pgae508. https://doi.org/10.1093/pnasnexus/pgae508

Preston, S. H., Heuveline, P., & Guillot, M. (2001). *Demography: Measuring and modeling population processes*. Malden, MA: Blackwell Publishers.

Preston, S. H., Vierboom, Y. C., & Stokes, A. (2018). The role of obesity in exceptionally slow US mortality improvement. *Proceedings of the National Academy of Sciences*, *115*(5), 957–961. https://doi.org/10.1073/pnas.1716802115

Public Health England. (2018). *A review of recent trends in mortality in England*. London, England: Public Health England. https://www.gov.uk/government/publications/recent-trends-in-mortality-in-england-review-and-data-packs

R Core Team. (2024). *R: a language and environment for statistical computing* (Version 4.4.2) [Computer software]. Vienna, Austria: R Foundation for Statistical Computing. https://www.R-project.org

Rajmil, L., & Fernández de Sanmamed, M.-J. (2019). Austerity policies and mortality rates in European countries, 2011–2015. *American Journal of Public Health*, *109*(5), 768–770. https://doi.org/10.2105/AJPH.2019.304997

Raleigh, V. (2019). Trends in life expectancy in EU and other OECD countries: Why are improvements slowing? *OECD Health Working Papers*, *108*. https://doi.org/10.1787/223159ab-en

Raleigh, V. (2024). *What is happening to life expectancy in England?* London, England: The King's Fund. https://www.kingsfund.org.uk/insight-and-analysis/long-reads/whats-happening-life-expectancy-england

Reeves, A., Basu, S., McKee, M., Marmot, M., & Stuckler, D. (2013). Austere or not? UK coalition government budgets and health inequalities. *Journal of the Royal*

Society of Medicine, *106*(11), 432–436. https://doi.org/10.1177/0141076813501101

Riffe, T. (2023). *HMDHFDplus: Read Human Mortality Database and Human Fertility Database data from the web* (Version 2.0.3) [Computer software]. https://CRAN.R-project.org/package=HMDHFDplus

Rizzi, S., Gampe, J., & Eilers, P. H. C. (2015). Efficient estimation of smooth distributions from coarsely grouped data. *American Journal of Epidemiology*, *182*(2), 138–147. https://doi.org/10.1093/aje/kwv020

Seaman, R., Walsh, D., Beatty, C., McCartney, G., & Dundas, R. (2024). Social security cuts and life expectancy: A longitudinal analysis of local authorities in England, Scotland and Wales. *Journal of Epidemiology and Community Health*, *78*, 82–87. https://doi.org/10.1136/jech-2023-220328

Shah, R., Wilkins, E., Nichols, M., Kelly, P., El-Sadi, F., Wright, F. L., & Townsend, N. (2019). Epidemiology report: Trends in sex-specific cerebrovascular disease mortality in Europe based on WHO mortality data. *European Heart Journal*, *40*(9), 755–764. https://doi.org/10.1093/eurheartj/ehy378

Shelton, J., Zotow, E., Smith, L., Johnson, S. A., Thomson, C. S., Ahmad, A., Murdock, L., Nagarwalla, D., & Forman, D. (2024). 25 year trends in cancer incidence and mortality among adults aged 35-69 years in the UK, 1993-2018: Retrospective secondary analysis. *BMJ*, *384*, e076962. https://doi.org/10.1136/bmj-2023-076962

Stierman, B., Afful, J., Carroll, M. D., Chen, T.-C., Davy, O., Fink, S., & et al. (2021). National Health and Nutrition Examination Survey 2017–March 2020 pre-pandemic data files: Development of files and prevalence estimates for selected health outcomes. *National Health Statistics Reports*, *158*. https://doi.org/10.15620/cdc:106273

Stokes, A., & Preston, S. H. (2016). Revealing the burden of obesity using weight histories. *Proceedings of the National Academy of Sciences*, *113*(3), 572–577. https://doi.org/10.1073/pnas.1515472113

Stuckler, D., Reeves, A., Loopstra, R., Karanikolos, M., & McKee, M. (2017). Austerity and health: The impact in the UK and Europe. *European Journal of Public Health*, *27*(suppl_4), 18–21. https://doi.org/10.1093/eurpub/ckx167

van den Brand, T. (2024). *ggh4x: Hacks for "ggplot2"* (Version 0.3.0) [Computer software]. https://CRAN.R-project.org/package=ggh4x

Vaughan, D., & Dancho, M. (2022). *furrr: Apply mapping functions in parallel using futures* (Version 0.3.1) [Computer software]. https://CRAN.R-project.org/package=furrr

Vogt, T., van Raalte, A., Grigoriev, P., & Myrskylä, M. (2017). The German east-west mortality difference: Two crossovers driven by smoking. *Demography*, *54*(3), 1051–1071. https://doi.org/10.1007/s13524-017-0577-z

Walsh, D., Dundas, R., McCartney, G., Gibson, M., & Seaman, R. (2022). Bearing the burden of austerity: How do changing mortality rates in the UK compare between men and women? *Journal of Epidemiology and Community Health*, *76*, 1027–1033. https://doi.org/10.1136/jech-2022-219645

Walsh, D., & McCartney, G. (2025). *Social murder? Austerity and life expectancy in the UK*. Bristol, England: Policy Press.

Walsh, D., Tod, E., McCartney, G., & Levin, K. A. (2022). How much of the stalled mortality trends in Scotland and England can be attributed to obesity? *BMJ Open*, *12*, e067310. https://doi.org/10.1136/bmjopen-2022-067310

Watkins, J., Wulaningsih, W., Zhou, C. D., Marshall, D. C., Sylianteng, G. D. C., Rosa, P. G. D., Miguel, V. A., Raine, R., Lawrence P King, & Maruthappu, M. (2017).

Effects of health and social care spending constraints on mortality in England: A time trend analysis. *BMJ Open*, *7*, e017722. https://doi.org/10.1136/bmjopen-2017-017722

WHO MD. (2024). *World Health Organization Mortality Database* [Dataset]. Available at www.who.int (Version 21 February 2024).

Wickham, H. (2023). *tidyverse: Easily install and load the "tidyverse"* (Version 2.0.0) [Computer software]. https://CRAN.R-project.org/package=tidyverse

Wilkins, D. (2023). *gggenes: Draw gene arrow maps in "ggplot2"* (Version 0.5.1) [Computer software]. https://CRAN.R-project.org/package=gggenes

Wilson, L., Bhatnagar, P., & Townsend, N. (2017). Comparing trends in mortality from cardiovascular disease and cancer in the United Kingdom, 1983–2013: Joinpoint regression analysis. *Population Health Metrics*, *15*, 23. https://doi.org/10.1186/s12963-017-0141-5

Woolf, S. H. (2023). Falling behind: The growing gap in life expectancy between the United States and other countries, 1933–2021. *American Journal of Public Health*, *113*(9), 970–980. https://doi.org/10.2105/AJPH.2023.307310

World Health Organization Regional Office for Europe. (2022). *WHO European Regional Obesity Report 2022*. Copenhagen, Denmark: WHO Regional Office for Europe. https://iris.who.int/handle/10665/353747

Chapter 3

Indirect effects of the COVID-19 pandemic: a cause-of-death analysis of life expectancy changes in 24 countries, 2015 to 2022[1]

Chapter word count: 7,155

3.1. Abstract

Worldwide, mortality was strongly affected by the COVID-19 pandemic, both directly through COVID-19 deaths and indirectly through changes in other causes of death. Here, we examine the impact of the pandemic on COVID-19 and non-COVID-19 mortality in 24 countries: Australia, Austria, Brazil, Bulgaria, Canada, Chile, Croatia, Czechia, Denmark, England and Wales, Hungary, Japan, Latvia, Lithuania, the Netherlands, Northern Ireland, Poland, Russia, Scotland, South Korea, Spain, Sweden, Switzerland, and the United States of America (USA). Using demographic decomposition methods, we compare age- and cause-specific contributions to changes in female and male life expectancy at birth in 2019–2020, 2020–2021, and 2021–2022 with those before the COVID-19 pandemic (2015–2019). We observe large life expectancy losses due to COVID-19 in most countries, usually followed by partial recoveries. Life expectancy losses due to cardiovascular disease (CVD)

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[1] This chapter is joint work with Luyin Zhang, Sergey Timonin, Aashish Gupta, Jennifer Beam Dowd, David A. Leon, and José Manuel Aburto. A version of this chapter has been published as: Polizzi, A., Zhang, L., Timonin, S., Gupta, A., Dowd, J. B., Leon, D. A., & Aburto, J. M. (2025). Indirect effects of the COVID-19 pandemic: A cause-of-death analysis of life expectancy changes in 24 countries, 2015 to 2022. *PNAS Nexus*, *4*(1), pgae508. https://doi.org/10.1093/pnasnexus/pgae508.

mortality were widespread during the pandemic, including in countries with substantial (Russia, Central and Eastern Europe, and the Baltic countries) and more modest (USA) improvements in CVD mortality before the pandemic. Many Anglo-Saxon countries, including Canada, Scotland, and the USA, continued their pre-pandemic trajectories of rising drug-related mortality. Most countries saw small changes in suicide mortality during the pandemic, while alcohol mortality increased and cancer mortality continued to decline. Patterns for other causes were more variable. By 2022, life expectancy had still not returned to pre-pandemic levels in several countries. Our results suggest important indirect effects of the pandemic on non-COVID-19 mortality through the consequences of COVID-19 infection, non-pharmaceutical interventions, and underreporting of COVID-19-related deaths.

3.2. Introduction

Life expectancy trajectories have become more diverse in recent years. Japan continues to lead global life expectancy trends with steady linear increases (Vaupel et al., 2021), while South Korea saw a remarkable 16-year improvement from 1970 to 2005 (Yang et al., 2010). Most European countries have also experienced steady, and parallel, increases in life expectancy at birth, with Central and Eastern Europe and the Baltics catching up since the mid-1990s after periods of stagnation and decline (Aburto & van Raalte, 2018; Leon, 2011). However, since 2010, many high-income countries, including Western European countries, Australia, and Canada, have seen a slowdown in mortality improvements (Raleigh, 2019). In England and Wales, life expectancy has stagnated since 2011, due to high working-age mortality and the lagged effects of smoking behaviors (Leon et al., 2019). In the United States of America (USA), life expectancy even declined before the COVID-19 pandemic, due to a slowdown in improvements in cardiovascular mortality and increases in alcohol-related deaths, fatal drug overdoses, and suicides—often collectively referred to as "deaths of despair" (Case & Deaton, 2015; Mehta et al., 2020). Similarly, life expectancy improvements in many Latin American countries such as Brazil have been slowed down by high levels of violence (Canudas-Romo & Aburto, 2019).

The COVID-19 pandemic further diversified life expectancy trajectories, with many countries experiencing substantial losses in life expectancy at birth in 2020, albeit with large heterogeneity (Aburto et al., 2021; Aburto, Schöley, et al., 2022; Aburto, Tilstra, et al., 2022; Islam, Jdanov, et al., 2021; Mazzuco & Campostrini, 2022). In 2021, the pandemic's impact on life expectancy varied further (Heuveline, 2022), with most of Western Europe seeing improvements compared to 2020, while Central and Eastern Europe, the Baltic states, and the USA experienced additional life expectancy declines (Masters et al., 2022; Schöley et al., 2022). Moreover, the age profile of mortality impacts in 2021 was often younger, with working-age groups in many countries contributing more to life expectancy losses than in 2020. Latin American countries, including Brazil and Chile, saw significant excess mortality in 2020 (Lima et al., 2021), with existing studies highlighting large variation in life expectancy declines at the sub-national level (Castro et al., 2021; García-Guerrero & Beltrán-Sánchez, 2021; Mena & Aburto, 2022; Zazueta-Borboa et al., 2024). Notably, East Asian countries and Australia saw almost no drops in life expectancy in 2020 or 2021 (Adair et al., 2023; Mo et al., 2023). Finally, in 2022 and 2023, many countries experienced (further) recoveries in life expectancy, usually driven by improvements in mortality at older ages (Huang et al., 2024). Nevertheless, life expectancy had rarely returned to pre-2020 levels (Huang et al., 2024), illustrating the long-lasting disruption of life expectancy trends caused by the COVID-19 pandemic. Some countries, such as Australia (Adair et al., 2023), even experienced (further) life expectancy losses in 2022 and/or 2023 (Huang et al., 2024).

Life expectancy is an important measure of the pandemic mortality burden because it is comparable over time and across countries. However, most studies rely on all-cause mortality, and few quantify how COVID-19 vs. other causes of death contributed to observed life expectancy changes during the pandemic years (Aburto, Tilstra, et al., 2022; Adair et al., 2023; Fernandes et al., 2023; Zazueta-Borboa et al., 2024). Examining the contributions of other causes of death (e.g., cardiovascular diseases, cancers, suicide) to life expectancy changes can illuminate the indirect pathways through which the pandemic affected mortality and population health. A comparison across countries can help highlight differences in pandemic experiences that might inform future policy and pandemic preparedness.

For example, the USA recorded more than 350,000 deaths from COVID-19 in 2020 (https://wonder.cdc.gov). Excess mortality in the same year was estimated even higher, over 500,000, contributing to a large drop in life expectancy at birth of around 25.5 months (Karlinsky & Kobak, 2021; Schöley et al., 2022; Woolf et al., 2021). While there is evidence that deaths attributed to COVID-19 may be undercounted or misclassified (Luck et al., 2023; Paglino et al., 2024), it is likely that the pandemic did affect mortality from other causes of death, both positively and negatively. For example, lockdowns may have led to lower mortality from accidents and other external causes of death (Calderon-Anyosa & Kaufman, 2021), whereas the overload of healthcare systems in many countries could have led to increased mortality from diseases that require treatments or prompt interventions (e.g. cancer, heart attacks). Similarly, fear of infection and avoidance of hospital care may have increased mortality from certain conditions, including acute cardiovascular events. This is consistent with the large increase in deaths at home seen in some countries (O’Donnell et al., 2021). Notably, the impact of these changes in cause-of-death profiles is likely to be different across countries due to differences in the overall quality of healthcare systems, socioeconomic resources and inequalities, pre-pandemic trends in mortality, and the pharmaceutical and non-pharmaceutical interventions employed during the pandemic.

In this article, we compare changes in female and male life expectancy at birth in 2019–2020, 2020–2021, and 2021–2022 with those before the COVID-19 pandemic (2015–2019) in 24 countries. Importantly, we go beyond the analysis of all-cause mortality by estimating the contributions of COVID-19 and 11 non-COVID-19 causes of death to changes in life expectancy, including mortality from cardiovascular disease, cancer, acute respiratory disease, chronic obstructive pulmonary disease, infectious diseases, as well as alcohol, drug, suicide, and accident mortality. Our analysis draws attention to the broad disruptions in mortality caused by SARS-CoV-2, highlights variation in how different countries adapted to the initial pandemic shocks, and allows us to hypothesize how this may affect their life expectancy trajectories in the future.

3.3. Results

3.3.1. Life expectancy differences and trends

Among the 24 countries included in our study (see Materials and methods), life expectancy ranged from a low of 65.6 years for Russian males in 2021 to a high of 87.9 years for Japanese females in 2020 (Tables 3-1 and 3-2). From 2015 to 2019, Russia had the largest gains in female and male life expectancy, at 1.5 and 2.4 years, respectively. The smallest gains were observed in the USA, improving only 0.3 and 0.2 years among females and males, respectively.

In 2020, life expectancy declined in most countries, except for females and males in Australia, Denmark, Japan, and South Korea. The largest decline was seen for males in the USA (-2.1 years). In 2021, most countries experienced further declines in life expectancy, with the largest losses, of more than two years, occurring in Bulgaria (females) and Latvia (males). Spanish females experienced the largest gains in life expectancy in 2021, at 0.8 years. Although often substantial, life expectancy gains in 2021 rarely compensated for the losses experienced in 2020, so that life expectancy in 2021 was still lower than observed before the pandemic, except for females and males in Australia, Denmark, Japan, and South Korea, as well as females in Sweden and Switzerland. Finally, in 2022, most countries with available cause-of-death information experienced gains in life expectancy, except for females and males in Australia and Canada, as well as females in Sweden, where life expectancy declined (further). 2022 gains in life expectancy were greatest among males in Hungary, at 1.9 years, while losses were greatest among females and males in Australia, as well as females in Canada, at -0.7 years. By 2022, only Sweden had returned to pre-pandemic life expectancy levels.

Overall, the life expectancy trends based on our dataset agree well with the trends published in the United Nations World Population Prospects (UNWPP) 2024 revision (United Nations, Department of Economic and Social Affairs, Population Division, 2024). The last four columns in Tables 3-1 and 3-2 highlight differences in time trends between our dataset and the UNWPP where they occur (see also Figure S4 in the Supplementary Information[2]). One asterisk indicates an increase in life expectancy according to our dataset, while UNWPP reports a decrease in life expectancy. Conversely, two asterisks indicate a decrease in life expectancy according to our dataset, while UNWPP reports an increase in life expectancy. For example, in Denmark, life expectancy in 2021 increased by 0.6 years (females) and 0.7 years (males) according to our estimates, whereas UNWPP reports a life expectancy decline for that year.

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[2] Due to space constraints in this dissertation, all Supplementary Information to this chapter can be found online in the published version of this chapter, at: https://doi.org/10.1093/pnasnexus/pgae508.

Table 3-1. Female life expectancy at birth and changes in female life expectancy at birth by country, 2015–2022.

Sex	Country	Life expectancy at birth					Changes in life expectancy			
		2015	2019	2020	2021	2022	2015–2019	2019–2020	2020–2021	2021–2022
Female	Australia	84.5	85.1	85.8	85.5	84.8	+0.6	+0.7	-0.3	-0.7
	Austria	83.5	84.1	83.7	83.8	–	+0.6	-0.4**	+0.1	–
	Brazil	78.3	78.9	77.9	76.0	–	+0.6	-1.0	-2.0	–
	Bulgaria	78.0	78.6	77.3	75.0	–	+0.6	-1.3	-2.4	–
	Canada	84.4	84.8	84.2	84.4	83.8	+0.4	-0.6	+0.3	-0.7
	Chile	83.0	83.9	83.0	82.1	–	+0.9	-0.9	-0.8	–
	Croatia	80.6	81.5	80.8	79.9	–	+1.0	-0.7	-0.9	–
	Czechia	81.4	82.0	81.2	80.4	–	+0.6	-0.8	-0.8	–
	Denmark	82.7	83.4	83.5	84.0	–	+0.7	+0.1	+0.6*	–
	England and Wales	82.9	83.7	82.5	82.9	83.3	+0.8	-1.1	+0.4	+0.4
	Hungary	78.8	79.6	78.9	77.7	79.3	+0.8	-0.6	-1.3	+1.6
	Japan	87.1	87.6	87.9	87.7	–	+0.5	+0.3	-0.2	–
	Latvia	79.4	80.1	80.0	78.1	–	+0.6	-0.1	-1.9	–
	Lithuania	79.5	80.9	79.9	78.7	79.9	+1.4	-1.0	-1.2	+1.2
	Netherlands	83.1	83.5	83.0	83.0	83.1	+0.5	-0.5	-0.1	+0.1
	Northern Ireland	82.2	82.8	81.9	82.0	–	+0.6	-0.8	+0.1	–
	Poland	81.2	81.5	80.4	79.4	–	+0.3	-1.1	-1.0	–
	Russia	76.6	78.0	76.2	74.4	–	+1.5	-1.8	-1.9	–
	Scotland	81.0	81.2	80.6	80.5	–	+0.3	-0.6	-0.2	–
	South Korea	85.6	87.0	87.2	87.2	–	+1.4	+0.2	+0.0	–
	Spain	85.2	86.0	84.9	85.7	–	+0.8	-1.1	+0.8	–
	Sweden	83.9	84.6	84.1	84.7	84.6	+0.7	-0.4	+0.6	-0.1
	Switzerland	84.8	85.5	85.0	85.6	–	+0.7	-0.5	+0.6	–
	USA	80.9	81.3	79.7	79.3	80.2	+0.3	-1.5	-0.4	+0.9

* Life expectancy increase in authors' dataset, but decrease in UNWPP.

** Life expectancy decrease in authors' dataset, but increase in UNWPP.

Table 3-2. Male life expectancy at birth and changes in male life expectancy at birth by country, 2015–2022.

Sex	**Country**	**Life expectancy at birth**					**Changes in life expectancy**			
		2015	**2019**	**2020**	**2021**	**2022**	**2015–2019**	**2019–2020**	**2020–2021**	**2021–2022**
Male	Australia	80.5	80.9	81.7	81.6	80.8	+0.4	+0.8	-0.1**	-0.7
	Austria	78.6	79.5	78.9	78.8	–	+0.9	-0.6	-0.1	–
	Brazil	71.7	72.8	71.2	69.4	–	+1.0	-1.6	-1.8	–
	Bulgaria	71.1	71.5	69.8	67.9	–	+0.3	-1.6	-1.9	–
	Canada	80.2	80.5	79.6	79.6	79.2	+0.3	-0.9	-0.1**	-0.3
	Chile	78.2	79.5	78.0	77.1	–	+1.2	-1.5	-0.8	–
	Croatia	74.1	75.0	74.3	73.4	–	+0.9	-0.7	-0.9	–
	Czechia	75.5	76.2	75.1	74.0	–	+0.7	-1.1	-1.1	–
	Denmark	78.8	79.5	79.6	80.3	–	+0.7	+0.1	+0.7*	–
	England and Wales	79.4	80.0	78.6	78.9	79.5	+0.7	-1.4	+0.3	+0.6
	Hungary	72.1	73.0	72.2	70.7	72.6	+0.8	-0.7	-1.5	+1.9
	Japan	81.0	81.7	81.9	81.8	–	+0.7	+0.2	-0.1	–
	Latvia	69.9	71.1	70.8	68.5	–	+1.2	-0.3	-2.3	–
	Lithuania	69.1	71.4	69.9	69.3	70.9	+2.3	-1.5	-0.6	+1.6
	Netherlands	79.7	80.4	79.6	79.6	80.0	+0.7	-0.8	+0.0	+0.4
	Northern Ireland	78.1	79.0	78.1	78.1	–	+0.8	-0.9	+0.0	–
	Poland	73.3	73.9	72.3	71.5	–	+0.6	-1.5	-0.8	–
	Russia	65.9	68.3	66.6	65.6	–	+2.4	-1.7	-0.9	–
	Scotland	76.9	77.2	76.1	76.3	–	+0.3	-1.1	+0.2	–
	South Korea	79.1	80.5	80.7	80.7	–	+1.4	+0.2*	+0.0	–
	Spain	79.7	80.6	79.4	80.1	–	+0.9	-1.2	+0.7	–
	Sweden	80.2	81.2	80.4	81.1	81.2	+0.9	-0.8	+0.7	+0.1
	Switzerland	80.6	81.9	80.9	81.6	–	+1.2	-0.9	+0.7	–
	USA	76.5	76.7	74.6	74.0	75.2	+0.2	-2.1	-0.7	+1.3

* Life expectancy increase in authors' dataset, but decrease in UNWPP.

** Life expectancy decrease in authors' dataset, but increase in UNWPP.

3.3.2. Cause-of-death contributions.

Figure 3-1 shows cause-of-death-specific contributions to changes in female life expectancy in months over the periods 2015–2019, 2019–2020, 2020–2021, and 2021–2022 for each of the 24 countries. For the period 2015–2019, Figure 3-1 shows average annual contributions over the four-year observation window. Contributions for each country–period–cause combination are represented by square tiles, with darker tiles indicating larger negative or positive contributions and lighter tiles representing smaller negative or positive contributions. Negative values indicate that a given cause of death contributed to losses in life expectancy over a given period, whereas positive values indicate life expectancy gains. Gray tiles for a given period indicate a lack of available cause-of-death information. The countries in Figure 3-1 are ordered according to the contribution from deaths coded as COVID-19 to life expectancy changes over the period 2019–2020, the first year of the pandemic. The black dots in Figure 3-1 serve as visual guide. The Materials and methods section describes our coding and decomposition procedures in more detail. Additionally, Figure S7 breaks down the cause-specific contributions by ten-year age groups (0–9, 10–19, ..., 70–79, 80+).

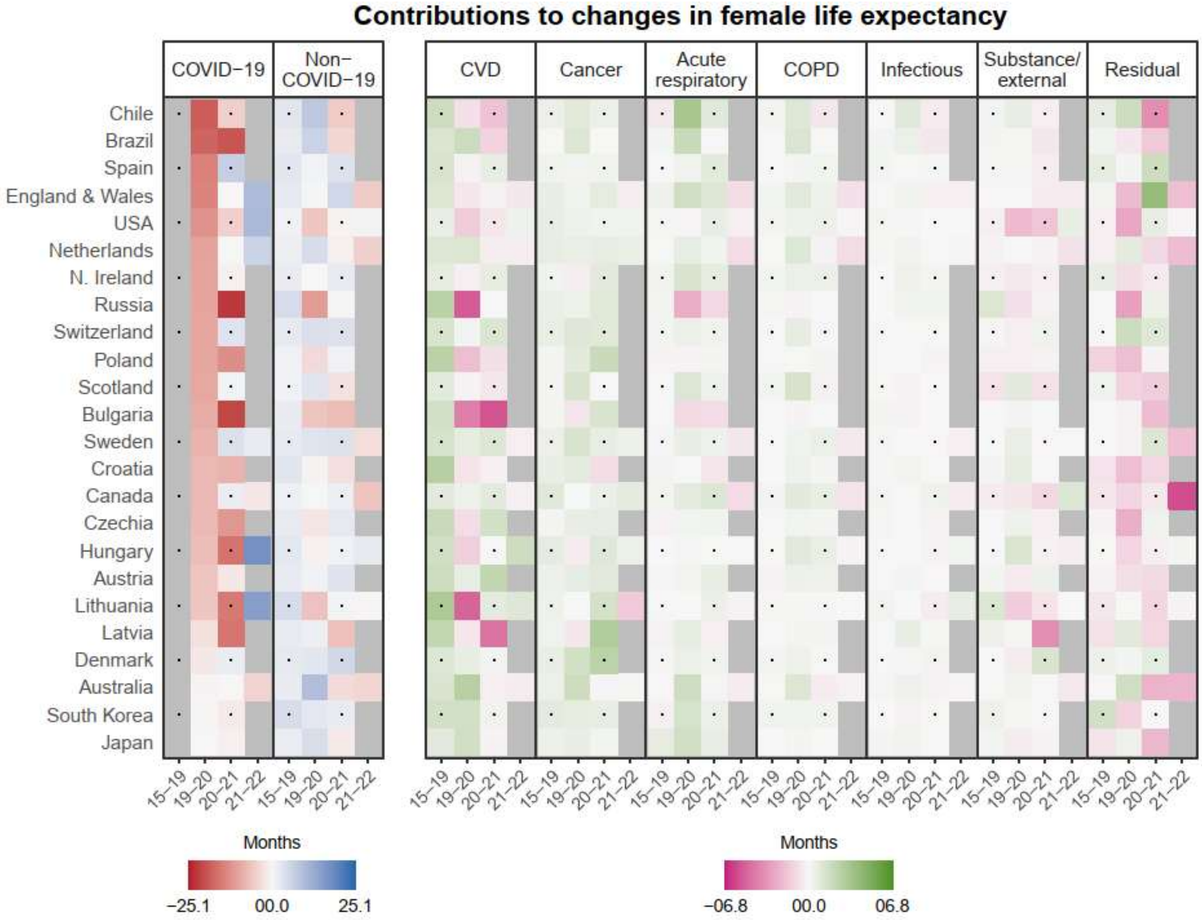

Figure 3-1. Cause-of-death-specific contributions to changes in female life expectancy at birth by country and period. *Note:* Contributions in months. Tiles for period 2015–2019 show average annual contributions. Cause-of-death data for period 2021–2022 only available for: Australia, Canada, England and Wales, Hungary, Lithuania, the Netherlands, Sweden, and the USA.

The first two panels in Figure 3-1 respectively show the contributions from COVID-19 and all non-COVID-19 mortality to changes in female life expectancy, on a scale ranging from negative contributions (red) over no contributions (white) to positive contributions (blue). In 2019–2020, COVID-19 contributed to sizeable losses in female life expectancy in almost all countries (leftmost panel in Figure 3-1). The largest losses from COVID-19 were seen in Spain (-14.4 months), Brazil (-17.8), and Chile (-18.7), while Australia (-0.5 months), South Korea (-0.4), and Japan (-0.2) experienced the smallest losses. In 2020–2021, COVID-19 contributed to additional losses in female life expectancy, particularly in Brazil, Russia, and among Central and Eastern European and Baltic countries. Although COVID-19 mortality was mostly concentrated in older age groups, many of the latter countries also had substantial negative contributions at middle adult ages (see Figure S7). Finally, most of the countries with available cause-of-death data in 2021–2022 experienced improvements in COVID-19 mortality, except for Australia and Canada, where COVID-19 mortality worsened (further).

Moving to mortality from all non-COVID-19 causes (second panel in Figure 3-1), all countries experienced gains in female life expectancy over the period 2015–2019. These contributions ranged from an average of 0.8 months per year in Scotland to 4.4 months per year in Russia. In contrast, we observed large heterogeneity in life expectancy contributions for the periods 2019–2020, 2020–2021, and 2021–2022, with sizeable life expectancy losses due to non-COVID-19 mortality in Russia (-11.2 months), Lithuania (-6.3 months), the USA (-5.9 months), and all Central and Eastern European countries (-0.6 months in Croatia to -6.1 months in Bulgaria) in 2020. In 2021, losses in female life expectancy due to non-COVID-19 mortality were geographically more dispersed. Many of these losses persisted even in 2022, with only Hungary and the USA experiencing recovery.

The remaining panels in Figure 3-1 break the contributions from non-COVID-19 mortality down into more detailed causes of death. We differentiate between mortality from (1) cardiovascular diseases (CVD), (2) cancer, (3) acute respiratory diseases, (4) chronic obstructive pulmonary disease (COPD), (5) certain infectious diseases, and (6) substance and external mortality, with all remaining causes of death grouped into a residual category. Contributions from these seven causes of death are shown on a scale ranging from negative contributions (pink) over no contributions (white) to positive contributions (green). Figure

S5 further disaggregates the category “CVD” into “Acute CVD” and “Other CVD,” and further disaggregates the category “Substance/external” into “Alcohol,” “Drug,” “Suicide,” and “Other external.”

Improvements in CVD mortality constituted one of the largest sources of gains in female life expectancy over the period 2015–2019. On average, CVD mortality contributed to life expectancy gains of 0.5 (USA) to 3.0 (Lithuania) months per year. Improvements were seen in mortality from both acute and non-acute CVD (see Figure S5) and were concentrated above age 60 (see Figure S7). In the first two years of the pandemic, earlier improvements in CVD mortality were reversed in several countries, with the largest losses seen in Russia in 2019–2020 (-5.3 months) and Bulgaria in 2020–2021 (-5.5 months). These losses were disproportionately driven by rising mortality from non-acute CVD. In Russia as well as many Central and Eastern European and Baltic countries, the age profile of CVD- and COVID-19-related life expectancy losses strongly overlapped. Among many countries with available cause-of-death data, life expectancy losses from CVD mortality persisted even in 2021–2022, such as in England and Wales (-0.5 months).

Next, reductions in cancer mortality contributed substantially to gains in female life expectancy in most countries, including during pandemic years. The bulk of these improvements in cancer mortality happened above age 50 (see Figure S7). During the pandemic years, individual countries experienced increases in cancer mortality, most notably Lithuania in 2021–2022, where rising cancer mortality led to life expectancy losses of 1.6 months among females.

The following three panels show contributions from acute respiratory diseases, COPD, and infectious diseases to female life expectancy changes. These contributions were generally small and mixed. Particularly noteworthy were the large gains from acute respiratory diseases in Chile (3.2 months) in 2019–2020 as well as the large losses in Russia in 2019–2020 and 2020–2021 (-2.6 and -1.1 months, respectively). In Bulgaria and Russia, the negative contributions from COVID-19 and acute respiratory mortality had similar age profiles (see Figure S7).

Contributions from substance and external mortality to female life expectancy changes were generally small. In 2019–2020, negative contributions were particularly pronounced for the USA (-2.1 months) and Lithuania (-1.4 months). While increasing drug-related mortality in middle adulthood was mostly responsible for the negative contributions in the USA, alcohol mortality was driving the patterns in Lithuania (Figure S5). In 2020–2021, negative contributions from substance and external mortality also stood out in Latvia (-3.7 months), which were driven by alcohol and accident mortality. While generally small, alcohol-related losses in female life expectancy were visible across a broad range of countries during the pandemic, whereas drug-related losses were mostly visible in Canada, Northern Ireland, Scotland, and the USA. Suicide mortality declined in many countries during the pandemic years, with comparatively large increases in Japan (-0.7 months) and Northern Ireland (-0.7 months) in 2019–2020.

Finally, while more difficult to interpret, we note that a large number of countries experienced losses in female life expectancy due to mortality increases in the residual category (up to -5.7 months in Canada in 2021–2022). Nonetheless, some relatively large improvements were also visible, such as for England and Wales in 2020–2021 (4.0 months).

Figure 3-2 shows the decomposition results for changes in male life expectancy. To facilitate comparison, the decomposition results for females and males are shown on the same scale. Like for females, the countries on the vertical axis are ordered according to the contributions from COVID-19 mortality in 2019–2020. Although the order of countries in Figures 3-1 and 3-2 is different, the countries with the smallest (Australia, Japan, South Korea) and largest (Brazil, Chile, Spain) contributions from deaths coded as COVID-19 in 2019–2020 were the same for females and males. In 2020–2021, a few countries (Denmark, England and Wales, Scotland, Spain, Sweden, and Switzerland) experienced gains in male life expectancy due to reductions in COVID-19 mortality, while most countries experienced further losses. Brazil, Russia, the Baltics, and several Central and Eastern European countries experienced the largest COVID-19-related declines during this period. In contrast, in 2021–2022, we observed life expectancy gains due to COVID-19 in most countries with available cause-of-death data, except for Australia and Canada.

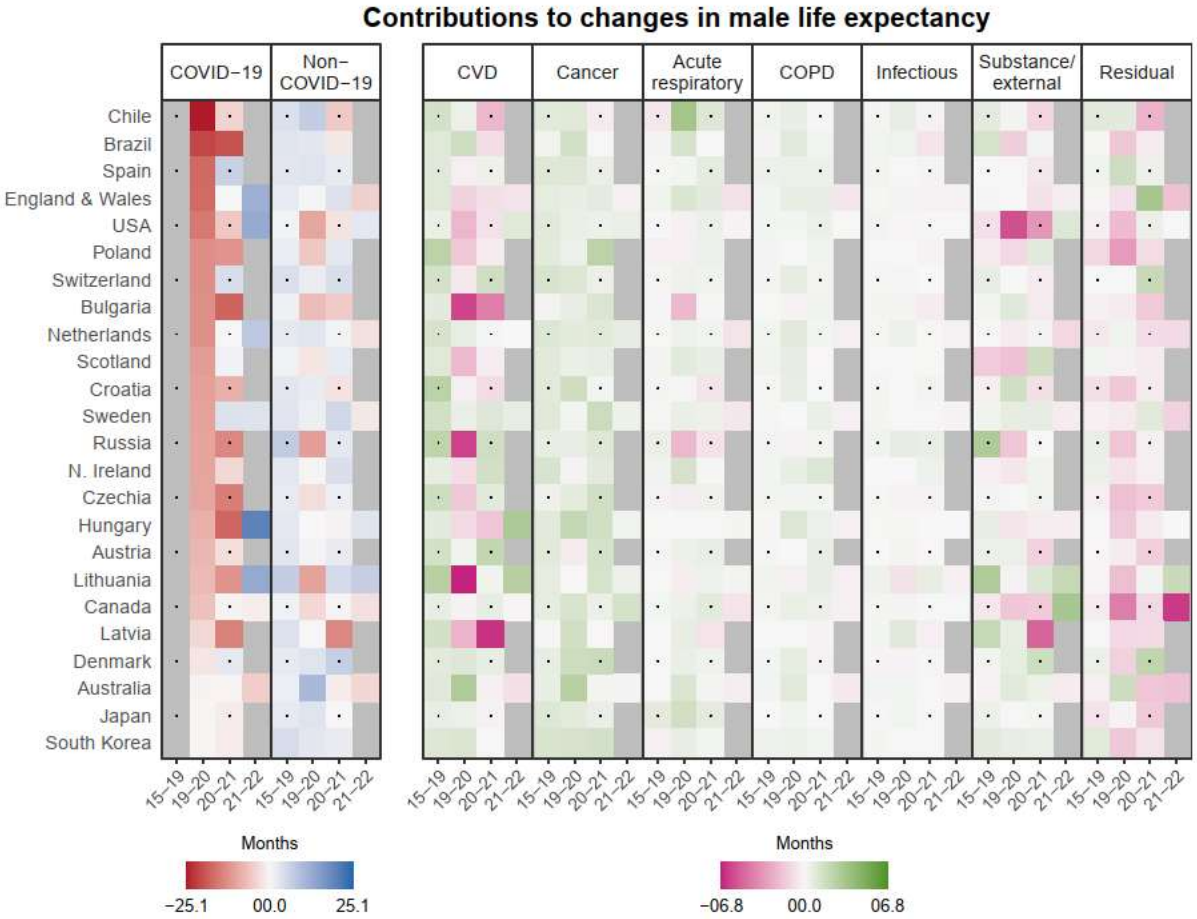

Figure 3-2. Cause-of-death-specific contributions to changes in male life expectancy at birth by country and period. *Note:* Contributions in months. Tiles for period 2015–2019 show average annual contributions. Cause-of-death data for period 2021–2022 only available for: Australia, Canada, England and Wales, Hungary, Lithuania, the Netherlands, Sweden, and the USA.

In 2019–2020, Russia, Lithuania, and many Central and Eastern European and Anglo-Saxon countries (Canada, Northern Ireland, Scotland, and the USA) saw male life expectancy losses due to rising non-COVID-19 mortality. Similar losses were seen on a geographically wider scale in 2020–2021 and continued in 2021–2022, except for Hungary, Lithuania, and the USA. CVD mortality, particularly non-acute CVD, appeared to be the main driver of changes in non-COVID-19 mortality during the pandemic years (see Figure S6).

Before and during the pandemic, we observed widespread positive contributions to changes in male life expectancy from reductions in cancer mortality, with few exceptions. Contributions from acute respiratory diseases, COPD, and infectious diseases were small and mixed, with some exceptionally large positive or negative contributions from acute respiratory diseases in Bulgaria, Chile, and Russia during the pandemic.

Contributions from substance and external mortality were generally larger among males vs. females. Before the pandemic, life expectancy losses due to substances and external causes were particularly visible for Canada, Scotland, and the USA. These negative contributions were predominantly driven by rising drug-related mortality, which continued to worsen during the pandemic, except for Scotland in 2020–2021 and Canada and the USA in 2021–2022 (see Figure S6). In the USA, mortality from other external causes, including accidents, also worsened noticeably during the pandemic. Several other countries experienced losses in male life expectancy due to rising substance and external mortality during the pandemic years. Our more detailed decomposition results in Figure S6 suggest that these negative contributions were to a large extent driven by alcohol and/or drug mortality, which increased in many countries during the pandemic, most notably in Latvia in 2020–2021. Like for females, suicide and accident mortality often declined during the pandemic years, with many of the positive contributions appearing larger for males, especially for accident mortality.

Finally, similar to the decomposition results for females, we observed widespread losses in male life expectancy due to rising mortality in the residual category, with some exceptions, such as England and Wales in 2020–2021.

3.4. Discussion

The first waves of the COVID-19 pandemic in 2020 induced sizable life expectancy losses in many countries around the world, with very few exceptions (Aburto, Schöley, et al., 2022; Heuveline, 2022; Mazzuco & Campostrini, 2022; Schöley et al., 2022). In many countries, life expectancy continued to deteriorate in 2021 and had still not returned to pre-pandemic levels by 2022 (Huang et al., 2024). In this study, we comprehensively analyzed life expectancy changes due to 12 major causes of death in 24 countries during the period 2015–2021, and in eight countries through 2022. Comparing changes before the COVID-19 pandemic with those in 2020–2022 puts into perspective the magnitude and diversity of the sharp mortality changes observed since the first SARS-CoV-2 outbreaks. While most countries in our study experienced life expectancy declines at some point during the pandemic, life expectancy trajectories showed considerable variability after 2019. In particular, our results highlight how different causes of death were driving life expectancy trends over this period.

We find that prior to the pandemic, declines in cardiovascular and cancer mortality were the main drivers of increases in life expectancy. Russia as well as many Central and Eastern European and Baltic countries experienced particularly large gains due to improvements in CVD mortality, consistent with their late onset of the cardiovascular mortality transition (Aburto & van Raalte, 2018; Grigoriev et al., 2014). These improvements were concentrated at middle and older ages. In contrast, changes in CVD mortality were smaller in Canada, England and Wales, Northern Ireland, Scotland, and the USA. Stagnation in CVD mortality improvements in these countries has been linked to changes in behavioral risk factors, such as rising levels of obesity and alcohol consumption (Acosta et al., 2022). Limited gains from further reductions in smoking-related mortality have also been discussed as a potential cause for stagnating CVD mortality in Anglo-Saxon countries (Lopez & Adair, 2019).

Our results also show that drug-related mortality contributed to life expectancy losses in most English-speaking countries prior to the pandemic. This is consistent with previous evidence showing worsening mortality due to fatal drug overdoses in these countries, especially among males (Angus et al., 2023). While synthetic opioids have played a dominant role for drug mortality trends in Canada and the USA, the United Kingdom countries have also seen a fast rise in mortality involving benzodiazepines and cocaine (Office for National Statistics, 2023).

Consistent with previous studies, we find that most countries suffered substantial drops in life expectancy due to COVID-19 mortality in 2019–2020. These losses were sizable in England and Wales, Spain, and the USA. However, life expectancy losses skewed much younger in the USA, potentially due to more risk factors for severe COVID-19 at younger ages or social factors that increased exposure for working-age populations (Aburto, Tilstra, et al., 2022; Pongiglione et al., 2022). Brazil and Chile also saw large life expectancy declines from COVID-19 in 2019–2020. Previous studies have documented considerable subnational variation in COVID-19 mortality in these two countries (Castro et al., 2021; Mena & Aburto, 2022). In addition, other Latin American countries have experienced similar or larger COVID-19-related losses in life expectancy (García-Guerrero & Beltrán-Sánchez, 2021). In line with previous studies, we find that COVID-19-related life expectancy losses in 2019–2020 were smallest in Australia, Japan, and South Korea (Adair et al., 2023; Mo et al., 2023).

In 2021, many Central and Eastern European and Baltic countries saw larger losses due to COVID-19 than in the first year of the pandemic. Like the USA, these countries generally exhibited a younger mortality profile of COVID-19 deaths than many Western European countries (Schöley et al., 2022). Finally, among the eight countries with available cause-of-death information for 2021–2022, females and males in Australia and Canada experienced (further) losses in life expectancy due to rising COVID-19 mortality. Evidence from Australia suggests that COVID-19-related life expectancy losses in 2022 may be due to the comparatively late relaxation of non-pharmaceutical interventions and restrictions, despite high vaccination coverage (Adair et al., 2023).

Our cause-of-death-specific decomposition results support the hypothesis that the pandemic affected a wide range of causes of death unrelated to SARS-CoV-2. This may have occurred through the indirect impacts of non-pharmaceutical interventions, such as lockdowns, the increased strain on health care systems, pre-existing social inequalities, as well as the misclassification of COVID-19 deaths. In particular, in 15 out of 24 countries (females) and 16 out of 24 countries (males), rising non-COVID-19 mortality contributed to life expectancy losses in 2020 and/or 2021, albeit with large variation in magnitude. In 2022, (further) life expectancy losses from non-COVID-19 mortality were seen in six (female) and five (male) out of eight countries with available cause-of-death data.

Rising CVD mortality was a major driver of increasing non-COVID-19 mortality during the pandemic, especially in 2019–2020 and 2020–2021. In 2020 and 2021 combined, we observed the greatest life expectancy losses from CVD among both females and males in Bulgaria, around ten months. Only females in Canada and Switzerland, males in the Netherlands, and females and males in Austria, Denmark, South Korea, and Sweden did not experience losses from CVD in 2020 and 2021. However, females in Canada and Sweden did experience subsequent losses in 2022. Miscoding of COVID-19 deaths as CVD may account for a large proportion of the changes observed (Luck et al., 2023; Paglino et al., 2024). In addition, evidence from multiple countries shows a substantial decrease in admission rates for acute cardiovascular disease during the pandemic, which may have led to an increase in untreated strokes and heart attacks (Ball et al., 2020; Hoyer et al., 2020; Kiss et al., 2021), explaining some of the observed life expectancy losses, including from non-acute CVD. More research to aid our understanding of the impacts of the pandemic on cardiovascular mortality in the medium and long term is needed. Recent evidence suggests that survivors of COVID-19 are at a higher risk of incident cardiovascular disease (Xie et al., 2022), which may be reflected in higher CVD mortality in future years.

In contrast to the negative pandemic trends in CVD mortality, cancer mortality usually continued to contribute to life expectancy gains, more so among males. Cumulatively in 2020 and 2021, only females in Croatia saw stagnating improvements in cancer mortality. The generally positive contributions for cancer mortality during the pandemic may be suggestive of limited disruptions to cancer care. Alternatively, our observed patterns may be the result of mortality displacement (Islam, Shkolnikov, et al., 2021), with cancer patients dying of COVID-19, thereby lowering cancer-related mortality. In fact, improvements in cancer mortality in most countries during the pandemic years exceeded average annual improvements seen in the pre-pandemic period. Still, it is possible that the positive contributions for cancer mortality documented in our study were smaller than would have been seen in the absence of the pandemic, which would be suggestive of disruptions in cancer care. Related to this point, we observed worsening cancer mortality in several countries during the pandemic period, possibly due to delayed diagnoses or treatment (American Association for Cancer Research, 2022). We suggest that changes in cancer mortality after 2019 be further explored using counterfactual estimation approaches, such as cause-of-death-specific estimation of excess mortality (Degtiareva et al., 2024), to determine whether cancer mortality was higher or lower than expected in the absence of the COVID-19 pandemic. In addition, use of individual-level diagnostic and treatment data and a closer examination of specific slow- or fast-growing cancer types will be helpful to determine the degree to which cancer care was disrupted. It may also be possible that pandemic disruptions in cancer care will only be visible in the near or more distant future, underlining the importance of prospective data to monitor changes in cancer incidence and mortality in the coming years.

We find that COPD and acute respiratory mortality often improved during the pandemic, particularly at older ages. On the one hand, this might suggest that older age groups were particularly protected from COVID-19 and lived longer than they would have in the absence of non-pharmaceutical interventions. On the other hand, this pattern might also be suggestive of potential mortality displacement. Many older individuals that would have died from respiratory conditions may have died earlier than in the absence of the pandemic. Further research using more fine-grained mortality data is required to disentangle these two pathways.

Alcohol- and drug-related deaths, suicides, and accidents contributed substantially to life expectancy losses in several countries. Females and males in Latvia and the USA, as well as males in Canada, experienced losses of more than three months in 2020 and 2021 combined. Substance- and accident-related mortality accounted for most of these losses. Latvia has historically had high levels of alcohol- and accident-related mortality, often contributing to stagnating or declining life expectancy (Aburto & van Raalte, 2018). Improvements in recent decades have led to rapid increases in life expectancy prior to 2020, which were, however, reversed during the pandemic. As discussed above, Canada, Scotland, and the USA have had high and rising levels of drug-related mortality before the pandemic. However, these countries experienced small improvements in mortality from lethal drug overdoses in some pandemic years, consistent with recent evidence of a levelling off of drug mortality (Angus et al., 2023; Spencer et al., 2024). So far, the reasons for these trend changes in lethal drug overdoses remain underexplored and may likely reflect country- and substance-specific factors (Angus et al., 2023).

The widespread rise in alcohol-related mortality shown in our study should be of concern, as longer-term impacts of high alcohol consumption may be anticipated in addition to the observed pandemic increases in alcohol deaths. Despite early concerns, we find no evidence that suicide mortality strongly and systematically increased during the pandemic, with many countries even showing improvements. However, females in Japan and Northern Ireland saw comparatively large losses from suicide mortality in 2019–2020. In Northern Ireland, suicide mortality appears to have followed the upward trajectory already seen before 2020 (NISRA Vital Statistics, 2023), while in Japan, suicide mortality declined at the beginning of the pandemic only to increase in later waves (Koda et al., 2022; Tanaka & Okamoto, 2021). Pandemic changes in accident mortality were more mixed, with many countries seeing small life expectancy gains from fewer accidents, especially among males. This is likely explained by lockdown measures and work-from-home schemes, including their effects on car traffic (Calderon-Anyosa & Kaufman, 2021).

Finally, the residual category accounted for a large share of changes due to non-COVID-19 mortality, and most of its contributions were negative. Although we classified deaths according to broad cause-of-death categories that feature prominently in the current discourse on pandemic mortality dynamics, our findings underline that the pandemic has noticeably affected other causes of death that are less regularly studied. For example, a recent study from Australia showed rising mortality due to Parkinson's disease, disorders of gallbladder, biliary tract and pancreas, diseases of the musculoskeletal system and connective tissue, and other disorders of the urinary system in 2021 (Adair et al., 2023). The Australian case suggests that the indirect effects of the COVID-19 outbreak may have created unmet needs across a wide range of causes of death. The recent rise in the complexity of cause-of-death profiles in high-income countries means that it may become increasingly difficult to predict which causes of death will be most influential for life expectancy changes (Bergeron-Boucher et al., 2020). Future studies and policies should increase efforts to account for this growing diversity of causes of death.

Our study has several limitations. First, our analysis is restricted to 24 countries. Understanding the experience of more countries, including low- and middle-income countries, in this comparative perspective would be valuable. Second, while our estimated life expectancy trends tend to agree well with those of more established sources such as the UNWPP, there are a few cases where the directions of life expectancy changes differ. One example is Denmark, where life expectancy increased in 2020–2021 according to our estimates, but decreased according to UNWPP estimates. Further examination of the mortality age schedules from both sources suggests that this deviation may be due to an underestimation of young adult mortality in our dataset. We note that we have used the most recent available data on population and deaths by cause to estimate mortality dynamics during the COVID-19 pandemic as accurately as possible, and we have highlighted deviations between data sources where they occurred. Finally, the process of cause-of-death coding varies across countries, and pandemic-associated impacts, such as misclassification between underlying and contributory causes of deaths, delays in registration, and the location of deaths (at home vs. hospital or nursing home), could affect estimates (Stokes et al., 2021). Importantly, differences in testing capacities and willingness to assign COVID-19 as an underlying cause of death mean that an increase in CVD and respiratory mortality in some countries may reflect undercounted COVID-19 deaths (Luck et al., 2023; Paglino et al., 2024). For example, we observed a strong overlap in the age patterns of COVID-19, CVD, and acute respiratory mortality in Bulgaria and Russia, pointing towards potential large under-detection of COVID-19 deaths in vital statistics, particularly during the first year of the pandemic (Dyer, 2020; Timonin et al., 2022). Detailed analysis of the temporal and geographic patterns of non-COVID-19 excess mortality in the USA suggests that a high proportion were likely undercounted COVID-19 deaths (Paglino et al., 2024). Moreover, it is estimated that causes of death other than COVID-19 represented 19.6% of the total mortality burden associated with COVID-19 during the first year of the pandemic in the USA, with circulatory diseases making up the highest percentage of these (Luck et al., 2023). While difficult to test directly, we suspect that undercounting also accounts for much of the increased CVD mortality in Central and Eastern European and Baltic countries as well as Russia, which had even higher ratios of excess deaths to official COVID-19 deaths than the USA (Karlinsky & Kobak, 2021; Wang et al., 2022). Furthermore, the fact that these countries saw large gains in life expectancy due to CVD before the pandemic as well as noticeable CVD-related losses during the pandemic may be related to the poorer public health and medical infrastructure in these countries, which may have contributed to both a later ‘cardiovascular revolution’ and

COVID-19 underreporting. Our findings highlight the need for high-quality data on causes of death, which are often lacking in many countries, and the need to develop methods to mitigate existing data limitations, such as miscoding of causes of death and a lack of data on multiple causes of death.

To summarize, we find that the indirect effects of the COVID-19 pandemic on mortality varied across countries, even those with a comparable burden of COVID-19 mortality. This variation may suggest that some explanations for changes in non-COVID-19 mortality, such as mortality displacement, do not provide a comprehensive explanation for the cross-country variation observed in our study. Rather, our results highlight variability in the impact of the pandemic on overall population health through the (non-)implementation of pharmaceutical and non-pharmaceutical interventions, as well as pre-existing vulnerabilities in the population. The variable impact of the COVID-19 pandemic across countries has therefore contributed to a further diversification of life expectancy trajectories, a trend already observed prior to the outbreak of SARS-CoV-2. Importantly, the continued life expectancy losses due to rising non-COVID-19 mortality, even in 2022, represent a major puzzle and an important point of intervention for public health efforts and research in the post-pandemic period.

3.5. Materials and methods

We used data for the 2015–2022 period for 24 countries: Australia, Austria, Brazil, Bulgaria, Canada, Chile, Croatia, Czechia, Denmark, England and Wales (treated as one country), Hungary, Japan, Latvia, Lithuania, the Netherlands, Northern Ireland, Poland, Russia, Scotland, South Korea, Spain, Sweden, Switzerland, and the United States of

America (USA). We describe our country selection in more detail in the Supplementary Information.

Annual death counts by sex, age group (0, 1–4, 5–9, 10–14, ..., 85+/90+/95+/100+), and cause of death were taken from: (1) for England and Wales in 2021 and 2022, the United Kingdom Office for National Statistics (ONS), (2) for Russia, the depersonalized death records provided by the Russian Federal State Statistics Service, (3) for the USA in 2022, the Underlying Cause of Death Database compiled by the Centers for Disease Control and Prevention, (4) for all remaining country–year combinations, the World Health Organization Mortality Database. Cause-of-death information was available for all 24 countries for the period 2015–2021, and available for eight countries for the year 2022: Australia, Canada, England and Wales, Hungary, Lithuania, the Netherlands, Sweden, and the USA. Recognizing the variation in death certification practices between countries, we categorized deaths by assigning ICD-10 codes to create 12 cause-of-death groups of public health and clinical relevance, in line with previous analyses (see Table S1): (1) Acute cardiovascular diseases (CVD) (acute ischemic heart disease and strokes), (2) other CVD, (3) acute respiratory diseases, (4) chronic obstructive pulmonary disease (COPD), (5) certain infectious diseases, (6) suicide, (7) drug-related deaths, (8) alcohol-related deaths, (9) cancers, (10) other external causes of death, (11) COVID-19, and (12) remaining causes of death. For each country, annual cause-of-death counts were harmonized into consistent age groups. We used 85+ as open-ended age group for Canada and England and Wales; 90+ as open-ended age group for Northern Ireland and Scotland; 100+ as open-ended age group for Russia; and 95+ as open-ended age group for all remaining countries.

We used annual sex- and age-group-specific population exposures for the period 2015–2022 provided in the United Nations World Population Prospects (UNWPP) 2024 revision. Population exposures in UNWPP are provided by single years of age (0, 1, ..., 99, 100+). We aggregated the population exposures for each country to match the age groups used in the cause-of-death data. Since UNWPP does not provide separate data for England and Wales, Northern Ireland, and Scotland, we used population exposures for these three countries as provided by ONS. For Russia, we used population exposures from the Russian Fertility and Mortality Database.

We estimated annual sex-, age-group-, and cause-specific mortality rates by dividing the available cause-specific death counts by the corresponding population exposures for each country. Life expectancy at birth for each available country–sex–calendar-year combination was derived from piecewise-exponential life tables constructed from these cause-specific mortality rates following standard procedures (Preston et al., 2001). In the Supplementary Information (Figures S1–S4), we compare all-cause mortality rates and life expectancies at birth based on our dataset with external sources and find generally high agreement.

To disentangle changes in life expectancy over time into age-group- and cause-specific contributions, we applied the linear integral decomposition method (Horiuchi et al., 2008). Decomposition was performed for adjacent years (i.e., 2015–2016, 2016–2017, …, 2019–2020, 2020–2021, and, where available, 2021–2022). We compare contributions over 2019–2020, 2020–2021, and, where available, 2021–2022 with average annual contributions before the pandemic (2015–2019). In the main manuscript, we focus on total cause-of-death-specific contributions across all ages. For this purpose, we combine the categories “acute CVD” and “other CVD” into “CVD,” and combine the categories “alcohol,” “drug,” “suicide,” and “other external” into “substance and external.” We present the full decomposition results in the Supplementary Information (Figures S5–S6). Moreover, we further explore variations in cause-of-death contributions by ten-year age groups (0–9, 10–19, ..., 70–79, 80+) in the Supplementary Information (Figures S7–S8).

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3.8. Author contributions

Conceptualization: A.P. and J.M.A.; data preparation: A.P. and L.Z.; data analysis: A.P. and J.M.A.; initial draft: A.P. and J.M.A.; interpretation and final draft: A.P., L.Z, S.T., A.G., J.B.D., D.A.L., J.M.A.

3.9. Data availability

This study uses data from the World Health Organization Mortality Database (WHO MDB), downloaded on 13 May 2024; the United Nations World Population Prospects (UNWPP), downloaded on 14 July 2024; the Russian Fertility and Mortality Database (RusFMD), downloaded on 07 July 2024; the Russian Federal State Statistics Service (Rosstat), downloaded on 07 July 2024; the United Kingdom ONS, downloaded on 23 May 2024; and the USA Centers for Disease Control and Prevention (CDC), downloaded on 14 May 2024. Data from WHO MDB are publicly available, for non-commercial purposes, from: *https://www.who.int/data/data-collection-tools/who-mortality-database*. Data from UNWPP are publicly available, under a Creative Commons license CC BY 3.0 IGO, from: *https://population.un.org/wpp*. Data from RusFMD are publicly available, for scholarly, educational, and research purposes, from: *http://demogr.nes.ru*. Data from Rosstat are available from: *https://rosstat.gov.ru.* Data from ONS are available from: *https://www.ons.gov.uk.* Data from CDC are publicly available, for the purpose of health statistical reporting and analysis, from: *https://wonder.cdc.gov*. To facilitate replication, we provide source code through our Open Science Framework (OSF) repositories: *https://doi.org/10.17605/OSF.IO/86PMY* and *https://doi.org/10.17605/OSF.IO/89NZK*.

3.10. Supplementary Information

Due to space constraints in this dissertation, all Supplementary Information to this chapter can be found online in the published version of this chapter, at: *https://doi.org/10.1093/pnasnexus/pgae508*.

References

Aburto, J. M., Kashyap, R., Schöley, J., Angus, C., Ermisch, J., Mills, M. C., & Dowd, J. B. (2021). Estimating the burden of the COVID-19 pandemic on mortality, life expectancy and lifespan inequality in England and Wales: A population-level analysis. *Journal of Epidemiology and Community Health*, *75*(8), 735–740. https://doi.org/10.1136/jech-2020-215505

Aburto, J. M., Schöley, J., Kashnitsky, I., Zhang, L., Rahal, C., Missov, T. I., Mills, M. C., Dowd, J. B., & Kashyap, R. (2022). Quantifying impacts of the COVID-19 pandemic through life-expectancy losses: A population-level study of 29 countries. *International Journal of Epidemiology*, *51*(1), 63–74. https://doi.org/10.1093/ije/dyab207

Aburto, J. M., Tilstra, A. M., Floridi, G., & Dowd, J. B. (2022). Significant impacts of the COVID-19 pandemic on race/ethnic differences in US mortality. *Proceedings of the National Academy of Sciences*, *119*(35), e2205813119. https://doi.org/10.1073/pnas.2205813119

Aburto, J. M., & van Raalte, A. (2018). Lifespan dispersion in times of life expectancy fluctuation: The case of Central and Eastern Europe. *Demography*, *55*(6), 2071–2096. https://doi.org/10.1007/s13524-018-0729-9

Acosta, E., Mehta, N., Myrskylä, M., & Ebeling, M. (2022). Cardiovascular mortality gap between the United States and other high life expectancy countries in 2000–2016.

The Journals of Gerontology: Series B, *77*(Supplement_2), S148–S157. https://doi.org/10.1093/geronb/gbac032

Adair, T., Houle, B., & Canudas-Romo, V. (2023). Effect of the COVID-19 pandemic on life expectancy in Australia, 2020-22. *International Journal of Epidemiology*, *52*(6), 1735–1744. https://doi.org/10.1093/ije/dyad121

American Association for Cancer Research. (2022). *AACR report on the impact of COVID-19 on cancer research and patient care*. https://www.AACR.org/COVIDReport

Angus, C., Buckley, C., Tilstra, A. M., & Dowd, J. B. (2023). Increases in ‘deaths of despair’ during the COVID-19 pandemic in the United States and the United Kingdom. *Public Health*, *218*, 92–96. https://doi.org/10.1016/j.puhe.2023.02.019

Ball, S., Banerjee, A., Berry, C., Boyle, J. R., Bray, B., Bradlow, W., Chaudhry, A., Crawley, R., Danesh, J., Denniston, A., Falter, F., Figueroa, J. D., Hall, C., Hemingway, H., Jefferson, E., Johnson, T., King, G., Lee, K. K., McKean, P., … Wyatt, M. (2020). Monitoring indirect impact of COVID-19 pandemic on services for cardiovascular diseases in the UK. *Heart*, *106*(24), 1890–1897. https://doi.org/10.1136/heartjnl-2020-317870

Bergeron-Boucher, M.-P., Aburto, J. M., & van Raalte, A. (2020). Diversification in causes of death in low-mortality countries: Emerging patterns and implications. *BMJ Global Health*, *5*(7), e002414. https://doi.org/10.1136/bmjgh-2020-002414

Calderon-Anyosa, R. J. C., & Kaufman, J. S. (2021). Impact of COVID-19 lockdown policy on homicide, suicide, and motor vehicle deaths in Peru. *Preventive Medicine*, *143*, 106331. https://doi.org/10.1016/j.ypmed.2020.106331

Canudas-Romo, V., & Aburto, J. M. (2019). Youth lost to homicides: Disparities in survival in Latin America and the Caribbean. *BMJ Global Health*, *4*(2), e001275. https://doi.org/10.1136/bmjgh-2018-001275

Case, A., & Deaton, A. (2015). Rising morbidity and mortality in midlife among white non-Hispanic Americans in the 21st century. *Proceedings of the National Academy of Sciences*, *112*(49), 15078–15083. https://doi.org/10.1073/pnas.1518393112

Castro, M. C., Gurzenda, S., Turra, C. M., Kim, S., Andrasfay, T., & Goldman, N. (2021). Reduction in life expectancy in Brazil after COVID-19. *Nature Medicine*, *27*, 1629–1635. https://doi.org/10.1038/s41591-021-01437-z

Degtiareva, E., Tilstra, A. M., Schöley, J., Kashyap, R., & Dowd, J. B. (2024). Cause-specific excess mortality in the US during the COVID-19 pandemic. *medRxiv*. https://doi.org/10.1101/2024.03.05.24303783

Dyer, O. (2020). Covid-19: Russia admits to understating deaths by more than two thirds. *BMJ*, *371*, m4975. https://doi.org/10.1136/bmj.m4975

Fernandes, F., Turra, C. M., França, G. V. A., & Castro, M. C. (2023). Mortality by cause of death in Brazil: Effects of the COVID-19 pandemic and contribution to changes in life expectancy at birth. *medRxiv*. https://doi.org/10.1101/2023.02.13.23285842

García-Guerrero, V. M., & Beltrán-Sánchez, H. (2021). Heterogeneity in excess mortality and its impact on loss of life expectancy due to COVID-19: Evidence from Mexico. *Canadian Studies in Population*, *48*(2), 165–200. https://doi.org/10.1007/s42650-021-00051-1

Grigoriev, P., Meslé, F., Shkolnikov, V. M., Andreev, E., Fihel, A., Pechholdova, M., & Vallin, J. (2014). The recent mortality decline in Russia: Beginning of the cardiovascular revolution? *Population and Development Review*, *40*(1), 107–129. https://doi.org/10.1111/j.1728-4457.2014.00652.x

Heuveline, P. (2022). Global and national declines in life expectancy: An end-of-2021 assessment. *Population and Development Review*, *48*(1), 31–50. https://doi.org/10.1111/padr.12477

Horiuchi, S., Wilmoth, J. R., & Pletcher, S. D. (2008). A decomposition method based on a model of continuous change. *Demography*, *45*(4), 785–801. https://doi.org/10.1353/dem.0.0033

Hoyer, C., Ebert, A., Huttner, H. B., Puetz, V., Kallmünzer, B., Barlinn, K., Haverkamp, C., Harloff, A., Brich, J., Platten, M., & Szabo, K. (2020). Acute stroke in times of the COVID-19 pandemic. *Stroke*, *51*(7), 2224–2227. https://doi.org/10.1161/STROKEAHA.120.030395

Huang, G., Guo, F., Liu, L., Taksa, L., Cheng, Z., Tani, M., Zimmermann, K. F., Franklin, M., & Silva, S. S. M. (2024). Changing impact of COVID-19 on life expectancy 2019–2023 and its decomposition: Findings from 27 countries. *SSM - Population Health*, *25*, 101568. https://doi.org/10.1016/j.ssmph.2023.101568

Islam, N., Jdanov, D. A., Shkolnikov, V. M., Khunti, K., Kawachi, I., White, M., Lewington, S., & Lacey, B. (2021). Effects of covid-19 pandemic on life expectancy and premature mortality in 2020: Time series analysis in 37 countries. *BMJ*, *375*, e066768. https://doi.org/10.1136/bmj-2021-066768

Islam, N., Shkolnikov, V. M., Acosta, R. J., Klimkin, I., Kawachi, I., Irizarry, R. A., Alicandro, G., Khunti, K., Yates, T., Jdanov, D. A., White, M., Lewington, S., & Lacey, B. (2021). Excess deaths associated with covid-19 pandemic in 2020: Age and sex disaggregated time series analysis in 29 high income countries. *BMJ*, *373*, n1137. https://doi.org/10.1136/bmj.n1137

Karlinsky, A., & Kobak, D. (2021). Tracking excess mortality across countries during the COVID-19 pandemic with the World Mortality Dataset. *eLife*, *10*, e69336. https://doi.org/10.7554/eLife.69336

Kiss, P., Carcel, C., Hockham, C., & Peters, S. A. E. (2021). The impact of the COVID-19 pandemic on the care and management of patients with acute cardiovascular disease: A systematic review. *European Heart Journal - Quality of Care and Clinical Outcomes*, *7*(1), 18–27. https://doi.org/10.1093/ehjqcco/qcaa084

Koda, M., Harada, N., Eguchi, A., Nomura, S., & Ishida, Y. (2022). Reasons for suicide during the COVID-19 pandemic in japan. *JAMA Network Open*, *5*(1), e2145870. https://doi.org/10.1001/jamanetworkopen.2021.45870

Leon, D. A. (2011). Trends in European life expectancy: A salutary view. *International Journal of Epidemiology*, *40*(2), 271–277. https://doi.org/10.1093/ije/dyr061

Leon, D. A., Jdanov, D. A., & Shkolnikov, V. M. (2019). Trends in life expectancy and age-specific mortality in England and Wales, 1970–2016, in comparison with a set of 22 high-income countries: An analysis of vital statistics data. *The Lancet Public Health*, *4*(11), e575–e582. https://doi.org/10.1016/S2468-2667(19)30177-X

Lima, E. E. C., Vilela, E. A., Peralta, A., Rocha, M., Queiroz, B. L., Gonzaga, M. R., Piscoya-Díaz, M., Martinez-Folgar, K., García-Guerrero, V. M., & Freire, F. H. M. A. (2021). Investigating regional excess mortality during 2020 COVID-19 pandemic in selected Latin American countries. *Genus*, *77*(1), 30. https://doi.org/10.1186/s41118-021-00139-1

Lopez, A. D., & Adair, T. (2019). Is the long-term decline in cardiovascular-disease mortality in high-income countries over? Evidence from national vital statistics.

International Journal of Epidemiology, *48*(6), 1815–1823. https://doi.org/10.1093/ije/dyz143

Luck, A. N., Stokes, A. C., Hempstead, K., Paglino, E., & Preston, S. H. (2023). Associations between mortality from COVID-19 and other causes: A state-level analysis. *PLOS ONE*, *18*(3), e0281683. https://doi.org/10.1371/journal.pone.0281683

Masters, R. K., Aron, L. Y., & Woolf, S. H. (2022). *Changes in life expectancy between 2019 and 2021: United States and 19 peer countries*. medRxiv. https://doi.org/10.1101/2022.04.05.22273393

Mazzuco, S., & Campostrini, S. (2022). Life expectancy drop in 2020. Estimates based on Human Mortality Database. *PLOS ONE*, *17*(1), e0262846. https://doi.org/10.1371/journal.pone.0262846

Mehta, N. K., Abrams, L. R., & Myrskylä, M. (2020). US life expectancy stalls due to cardiovascular disease, not drug deaths. *Proceedings of the National Academy of Sciences*, *117*(13), 6998–7000. https://doi.org/10.1073/pnas.1920391117

Mena, G., & Aburto, J. M. (2022). Unequal impact of the COVID-19 pandemic in 2020 on life expectancy across urban areas in Chile: A cross-sectional demographic study. *BMJ Open*, *12*(8), e059201. https://doi.org/10.1136/bmjopen-2021-059201

Mo, Y., Feng, Q., & Gu, D. (2023). Impacts of the COVID-19 pandemic on life expectancy at birth in Asia. *BMC Public Health*, *23*(1), 1508. https://doi.org/10.1186/s12889-023-16426-9

NISRA Vital Statistics. (2023). *Suicide statistics in Northern Ireland, 2002-2022.*

O’Donnell, S. B., Bone, A. E., Finucane, A. M., McAleese, J., Higginson, I. J., Barclay, S., Sleeman, K. E., & Murtagh, F. E. M. (2021). Changes in mortality patterns and place of death during the COVID-19 pandemic: A descriptive analysis of mortality data across four nations. *Palliative Medicine*, *35*(10), 1975–1984. https://doi.org/10.1177/02692163211040981

Office for National Statistics. (2023). *Deaths related to drug poisoning in England and Wales: 2022 registrations*. https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/bulletins/deathsrelatedtodrugpoisoninginenglandandwales/2022registrations

Paglino, E., Lundberg, D. J., Wrigley-Field, E., Zhou, Z., Wasserman, J. A., Raquib, R., Chen, Y.-H., Hempstead, K., Preston, S. H., Elo, I. T., Glymour, M. M., & Stokes, A. C. (2024). Excess natural-cause mortality in US counties and its association with reported COVID-19 deaths. *Proceedings of the National Academy of Sciences*, *121*(6), e2313661121. https://doi.org/10.1073/pnas.2313661121

Pongiglione, B., Ploubidis, G. B., & Dowd, J. B. (2022). Older adults in the United States have worse cardiometabolic health compared to England. *The Journals of Gerontology: Series B*, *77*(Supplement_2), S167–S176. https://doi.org/10.1093/geronb/gbac023

Preston, S. H., Heuveline, P., & Guillot, M. (2001). *Demography: Measuring and modeling population processes*. Malden, MA: Blackwell Publishers.

Raleigh, V. S. (2019). Trends in life expectancy in EU and other OECD countries: Why are improvements slowing? *OECD Health Working Papers*, *108*. https://doi.org/10.1787/223159ab-en

Schöley, J., Aburto, J. M., Kashnitsky, I., Kniffka, M. S., Zhang, L., Jaadla, H., Dowd, J. B., & Kashyap, R. (2022). Life expectancy changes since COVID-19. *Nature Human Behaviour*, *6*, 1649–1659. https://doi.org/10.1038/s41562-022-01450-3

Spencer, M. R., Garnett, M. F., & Miniño, A. M. (2024). *Drug overdose deaths in the United States, 2002-2022* (NCHS Data Brief 491). https://doi.org/10.15620/cdc:135849

Stokes, A. C., Lundberg, D. J., Bor, J., Elo, I. T., Hempstead, K., & Preston, S. H. (2021). Association of health care factors with excess deaths not assigned to COVID-19 in the US. *JAMA Network Open*, *4*(9), e2125287. https://doi.org/10.1001/jamanetworkopen.2021.25287

Tanaka, T., & Okamoto, S. (2021). Increase in suicide following an initial decline during the COVID-19 pandemic in Japan. *Nature Human Behaviour*, *5*(2), 229–238. https://doi.org/10.1038/s41562-020-01042-z

Timonin, S., Klimkin, I., Shkolnikov, V. M., Andreev, E., McKee, M., & Leon, D. A. (2022). Excess mortality in Russia and its regions compared to high income countries: An analysis of monthly series of 2020. *SSM - Population Health*, *17*, 101006. https://doi.org/10.1016/j.ssmph.2021.101006

United Nations, Department of Economic and Social Affairs, Population Division. (2024). *World Population Prospects 2024*. Https://Population.Un.Org/Wpp/.

Vaupel, J. W., Villavicencio, F., & Bergeron-Boucher, M.-P. (2021). Demographic perspectives on the rise of longevity. *Proceedings of the National Academy of Sciences*, *118*(9), e2019536118. https://doi.org/10.1073/pnas.2019536118

Wang, H., Paulson, K. R., Pease, S. A., Watson, S., Comfort, H., Zheng, P., Aravkin, A. Y., Bisignano, C., Barber, R. M., Alam, T., Fuller, J. E., May, E. A., Jones, D. P., Frisch, M. E., Abbafati, C., Adolph, C., Allorant, A., Amlag, J. O., Bang-Jensen, B., … Murray, C. J. L. (2022). Estimating excess mortality due to the COVID-19 pandemic: A systematic analysis of COVID-19-related mortality, 2020–21. *The Lancet*, *399*(10334), 1513–1536. https://doi.org/10.1016/S0140-6736(21)02796-3

Woolf, S. H., Chapman, D. A., Sabo, R. T., & Zimmerman, E. B. (2021). Excess deaths from COVID-19 and other causes in the US, March 1, 2020, to January 2, 2021. *JAMA*, *325*(17), 1786–1789. https://doi.org/10.1001/jama.2021.5199

Xie, Y., Xu, E., Bowe, B., & Al-Aly, Z. (2022). Long-term cardiovascular outcomes of COVID-19. *Nature Medicine*, *28*(3), 583–590. https://doi.org/10.1038/s41591-022-01689-3

Yang, S., Khang, Y.-H., Harper, S., Davey Smith, G., Leon, D. A., & Lynch, J. (2010). Understanding the rapid increase in life expectancy in South Korea. *American Journal of Public Health*, *100*(5), 896–903. https://doi.org/10.2105/AJPH.2009.160341

Zazueta-Borboa, J.-D., Vázquez-Castillo, P., Gargiulo, M., & Aburto, J. M. (2024). Mexico’s surge of violence and COVID-19 drive life expectancy losses 2015–2021. *medRxiv*. https://doi.org/10.1101/2024.05.07.24306982

Addendum to Chapter 3

Life expectancy stagnation and divergence in the USA and the UK before and during the COVID-19 pandemic

Chapter word count: 3,031

3-add.1. Life expectancy stagnation during the COVID-19 pandemic

Before this dissertation, it was not known how different causes of death contributed to life expectancy changes during the COVID-19 pandemic, and how these contributions differed across countries. The analysis in Chapter 3 therefore established the fact base from which I am able to further investigate questions about life expectancy *stagnation* and life expectancy *divergence* during the COVID-19 pandemic. In this Addendum to Chapter 3, I look more closely at the causes of death that led to (a) life expectancy stagnation in the USA and the UK during the COVID-19 pandemic, compared to the pre-pandemic period; and (b) life expectancy divergence of the USA and the UK from better-performing countries before and during the COVID-19 pandemic.

To clarify, despite following a comparative within-country approach, Chapter 3 itself neither took a *stagnation* nor a *divergence* perspective. Rather, it described changes in life expectancy before (2015–2019) and during (2019–2022) the COVID-19 pandemic and used decomposition methods to disaggregate these changes into cause-of-death-specific contributions. The *stagnation* perspective, however, is usually based in counterfactual analysis, comparing the actual mortality trajectory in a population to the trajectory that would have been observed if mortality dynamics at an earlier period had persisted (e.g., Ramsay et al., 2020). For example, according to Table 3-1, female life expectancy at birth in England and Wales improved by 0.8 years over the period 2015–2019, for an average of 0.2 years per annum. For the period of the COVID-19 pandemic, we can now formulate a counterfactual scenario, in which female life expectancy at birth in England and Wales had continued to increase by 0.2 years per annum through 2022, for a total of 0.6 years over 2019–2022. In this counterfactual scenario, female life expectancy at birth in England and Wales would have been 84.3 years in 2022—an increase by 0.6 years from the 2019 value of 83.7 years. Instead, life expectancy in 2022 was 83.3 years. Thus, while the COVID-19 pandemic resulted in a loss of life expectancy of 0.4 years—from 83.7 years in 2019 to 83.3 years in 2022—we could argue that it set back the country's life expectancy by one whole year, from 84.3 years—if the 2015–2019 gains had continued through 2022—to the 83.3 years observed in 2022. Averaged across the three years of the pandemic, this corresponds to a total stagnation of around -4 months per annum. This example, based on all-cause mortality, illustrates the difference between the descriptive decomposition approach taken in Chapter 3 and a counterfactual *stagnation* perspective.

Figure 3-add-1 extends the all-cause mortality example above by a cause-of-death perspective. For both England and Wales (left column) and the USA (right column), it shows the average annual contributions to female (top row) and male (bottom row) life expectancy changes during 2015–2019 (circles) and 2019–2022 (triangles) for each cause of death in months (see Figure 3-add-S1 in the Supplementary Information for total cause-specific contributions to changes in life expectancy across 2015–2019 and 2019–2022).

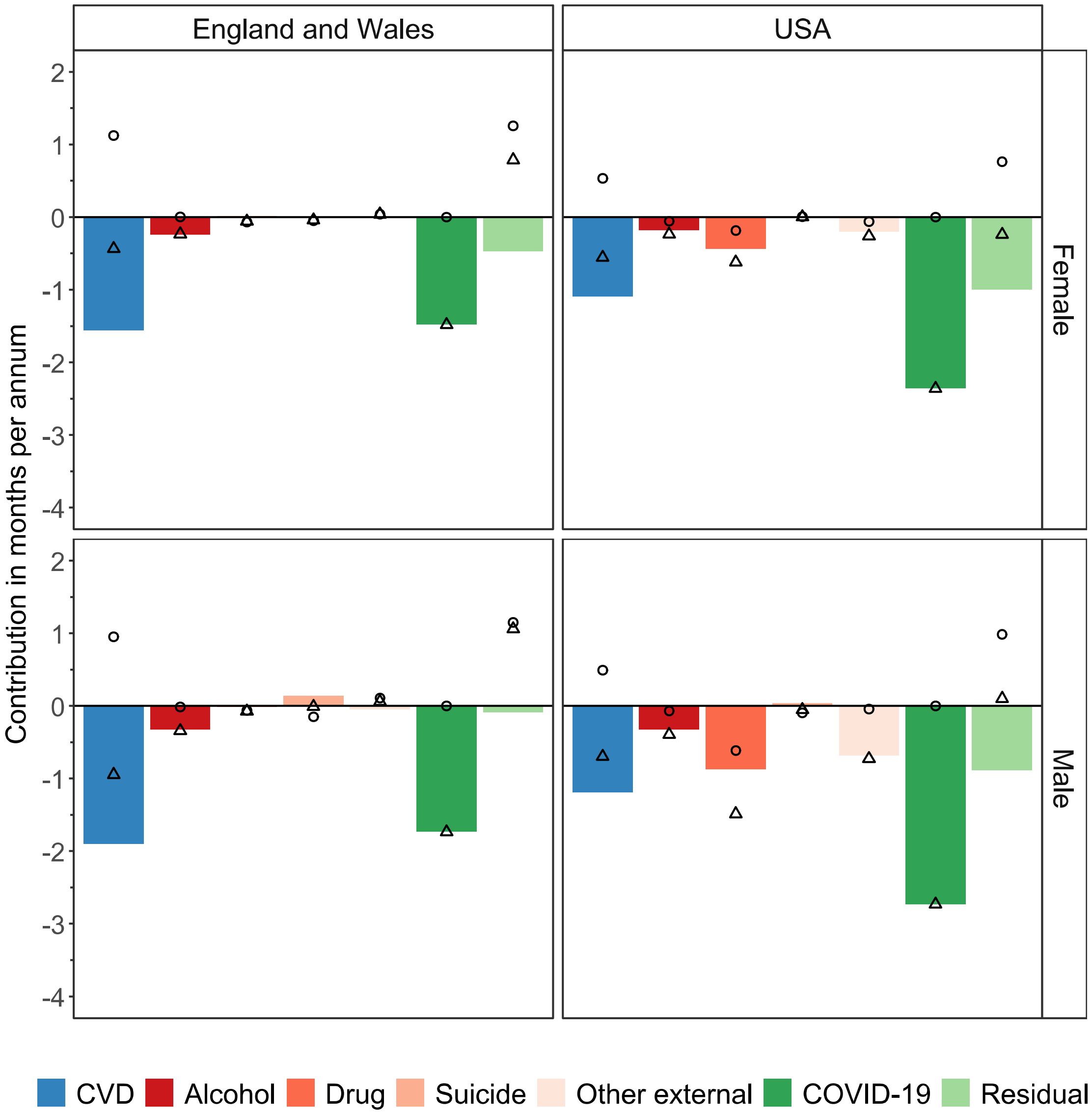

Figure 3-add-1. Contribution of seven causes of death to life expectancy stagnation in England and Wales and the USA in 2019–2022. *Note:* bars represent difference between triangles (average annual contribution to life expectancy change in 2019–2022) and circles (average annual contribution to life expectancy change in 2015–2019) in months. Negative bars = cause of death contributed to life expectancy stagnation. Positive bars = cause of death offset life expectancy stagnation. Sum of bars equals total annual life expectancy stagnation in 2019–2022. *Source:* see Chapter 3.

The circles in Figure 3-add-1 correspond to the tiles for 2015–2019 in Figures 3-1 and 3-2 in Chapter 3, while the triangles correspond to the average of the tiles for 2019–2020, 2020–2021, and 2021–2022. For the analysis in this Addendum, I focus on England and Wales only, instead of all UK countries, since cause-of-death data through 2022 were not available for Northern Ireland and Scotland. Moreover, I combined the causes “acute cardiovascular disease" and "other cardiovascular disease" into one category "cardiovascular disease," and I combined the causes "cancer," "acute respiratory," "COPD," "infectious," and "residual" into one category "residual." I did not aggregate external and substance-related causes of death. This allows me to investigate their individual and combined contributions to life expectancy stagnation and divergence, in line with the main research question of this dissertation.

According to Figure 3-add-1, changes in CVD mortality during 2015–2019 added an average of around one month per annum to female life expectancy in England and Wales (circle). However, across 2019–2022, changes in CVD mortality resulted in an average life expectancy loss of around half a month per annum (triangle). Thus, for each pandemic year, deviation from the pre-pandemic CVD mortality trend contributed -1.5 months to the total stagnation of around -4 months per annum, as represented by the blue bar (see also Table 3-add-S1 in the Supplementary Information). This even slightly exceeded the contribution from COVID-19 to the total life expectancy stagnation. This is because we would not have expected any (positive or negative) contributions from COVID-19 to life expectancy changes based on pre-pandemic trends, because this cause of death did not exist. Thus, even though COVID-19 was responsible for the largest share of the life expectancy loss in 2019–2022 (see Figure 3-add-S1), the *stagnation* perspective would conclude that changes in CVD mortality were more consequential for the deviation of England and Wales females from their pre-pandemic life expectancy trajectory. This illustrates the difference between the descriptive decomposition approach applied in Chapter 3 and the counterfactual *stagnation* approach applied in this Addendum and elsewhere (Ramsay et al., 2020).

The residual category also contributed to the stagnation in female life expectancy in England and Wales during 2019–2022—around -0.5 months per annum—due to smaller mortality improvements than would have been expected based on pre-pandemic trends. Alcohol-related mortality increased during the pandemic, whereas we would have expected no mortality change based on pre-pandemic trends, contributing about a quarter of a month per annum to life expectancy stagnation. The remaining external and substance-related categories contributed little to life expectancy stagnation during 2019–2022, as mortality from these causes was relatively stable during the pre-pandemic and pandemic periods.

A similar pattern of life expectancy stagnation during the COVID-19 pandemic was visible for males in England and Wales, except for an offsetting effect from suicide mortality. Averaged over 2019–2022, male suicide mortality remained stable, while we would have expected an increase—and a negative contribution to changes in life expectancy—based on pre-pandemic trends.

In the USA, the patterns of life expectancy stagnation were also broadly similar for males and females. As in England and Wales, CVD mortality increased on average during the pandemic, whereas we would have expected an improvement based on pre-pandemic trends. Thus, CVD mortality also contributed to life expectancy stagnation in the USA. However, in contrast to England and Wales, the contribution of CVD mortality did not exceed that of COVID-19 because of the much higher recorded COVID-19 mortality in the USA, as well as the smaller pre-pandemic CVD mortality improvements. As in England and Wales, male mortality from residual causes improved less during the pandemic than would have been expected based on pre-pandemic trends, contributing to life expectancy stagnation. For USA females, mortality from residual causes actually increased slightly on average during the pandemic. Turning to mortality from external and substance-related causes, all causes of death increased more during the pandemic than would have been expected based on pre-pandemic trends, except for suicide mortality, which did not change much across the pre-pandemic and pandemic periods. Thus, alcohol- and drug-related mortality as well as mortality from other external causes of death—such as accidents—all contributed to life expectancy stagnation among USA females and males during the COVID-19 pandemic. For males, the combined contributions of external and substance-related causes to life expectancy stagnation even exceeded those of CVD mortality.

3-add.2. Life expectancy divergence before and during the COVID-19 pandemic

As I argued above, the *stagnation* perspective is usually based in counterfactual analysis, where the actual mortality trajectory in a population is compared to the trajectory that would have been observed if mortality dynamics at an earlier period had persisted. In contrast, the study by Polizzi and Dowd (2024) reviewed in the Introduction, and the analysis in Chapter 2 have illustrated that the *divergence* perspective can be rooted in either counterfactual analysis—where mortality dynamics of a different population are assumed to apply—or in decomposition analysis—where country-specific contributions to life expectancy changes over time are compared. In what follows, I examine changes in life expectancy shortfalls of England and Wales and the USA before and during the COVID-19 pandemic using a decomposition approach. Based on the findings produced in Chapter 3, I examine which causes of death contributed most to widening life expectancy gaps between England and Wales and the USA, on the one hand, and Sweden, on the other hand. I use Sweden as a benchmark, since it was the only country with available data through 2022 whose life expectancy had fully returned to pre-pandemic levels by 2022.

In 2015, male life expectancy in England and Wales was 79.4 years (see Table 3-2), whereas male life expectancy in Sweden was 80.2 years, resulting in a gap of -0.8 years. By 2019, male life expectancy had increased to 80.0 years and 81.2 years in England and Wales and Sweden, respectively, resulting in a gap of -1.2 years. Thus, the added shortfall during 2015–2019 was (-1.2) – (-0.8) = -0.4 years—or -0.28 years (-3.3 months) without rounding errors. By 2022, the gap had widened to -1.7 years, for an added shortfall of (-1.7) – (-1.2) = -0.5 years compared to 2019—or -0.59 years (-7.1 months) without rounding errors. To obtain the cause-specific contributions to the pre-pandemic and pandemic life expectancy divergence, we can similarly compare the country- and cause-specific contributions to life expectancy changes over time. Between 2015–2019 CVD mortality contributed 3.8 months to the change in male life expectancy in England and Wales, but 6.2 months in Sweden. Thus, CVD mortality contributed 3.8 – 6.2 = -2.4 months to the added shortfall of -3.3 months during the pre-pandemic period, or around 70%. Over 2019–2022, England and Wales males lost 2.8 months of life expectancy due to changes in CVD mortality, compared to gains of 2 months in Sweden, resulting in a contribution of (-2.8) – 2 = -4.8 months (or around 70%) to the life expectancy divergence during the pandemic. This method of obtaining cause-specific contributions to life expectancy divergences represents a simplified version of the contour decomposition approach used in Chapter 2 and focuses on the trend component only. A similar method has previously been applied by Ho (2019) to estimate the contribution of drug-related mortality to USA life expectancy divergence during the period 2003–2013.

Figure 3-add-2 shows the percent contributions of different causes of death to life expectancy divergences of England and Wales and the USA from Sweden during the pre-pandemic (2015–2019) and the pandemic (2019–2022) periods. Like before, I distinguish

between (a) CVD mortality; (b) mortality from alcohol, drugs, suicide, and other external causes; (c) COVID-19 mortality; and (d) mortality from all other causes combined ("Residual").

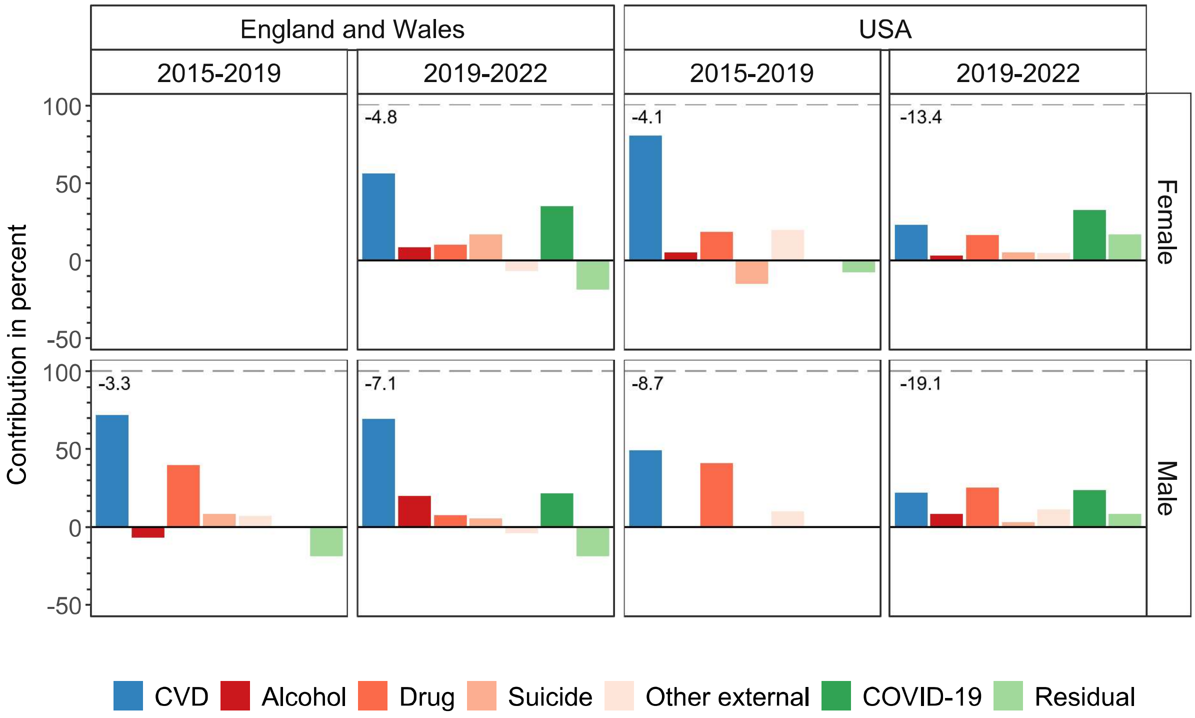

Figure 3-add-2. Contribution of seven causes of death to increasing life expectancy disadvantage of England and Wales vs. Sweden and the USA vs. Sweden in 2015–2019 and 2019–2022. *Note:* numbers in upper-left corner show rise in life expectancy disadvantage in months. Bars represent percent contributions to increasing life expectancy disadvantage. Positive bars = cause of death contributed to increasing life expectancy disadvantage. Negative bars = cause of death offset increasing life expectancy disadvantage. Sum of bars equals 100%. *Source:* see Chapter 3.

The values in the upper-left corner of each panel in Figure 3-add-2 represent the total life expectancy divergence during the corresponding period in months. A negative value indicates that the life expectancy shortfall compared to Sweden increased further. This was seen for all life expectancy shortfalls, with the exception of the female life expectancy gap between England and Wales and Sweden during the pre-pandemic period, which narrowed by 0.1 years (or one month) (see Table 3-1). Therefore, I do not show results for England and Wales females in Figure 3-add-2. In the remaining seven panels, positive values for a given cause of death indicate that it contributed to the life expectancy divergence from Sweden, while negative values indicate that the cause of death counteracted life expectancy divergence. The bars in each panel sum to 100%, represented by the dashed grey line in each panel.

In the pre-pandemic period, CVD mortality improved less among England and Wales males than among their Swedish counterparts, as already discussed above. As mentioned before, this divergence in CVD mortality trends contributed around 70% of the total life expectancy divergence of -3.3 months in that period (see also Table 3-add-S2 in the Supplementary Information). On the other hand, drug-related mortality increased in England and Wales but declined in Sweden, making this cause of death responsible for around 40% of the total pre-pandemic life expectancy divergence. In contrast, mortality from residual causes improved more in England and Wales than in Sweden, offsetting the widening life expectancy gap before the pandemic, as represented by the negative contribution for this cause of death. Mortality from alcohol, suicide, and other external causes only contributed little to the pre-pandemic life expectancy divergence between males in England and Wales and Sweden.

Patterns for male life expectancy divergence during the pandemic were roughly similar, with three exceptions: (a) increases in alcohol mortality in England and Wales contributed to the country's life expectancy divergence; (b) contributions from drug-related mortality to the life expectancy divergence were smaller than before the pandemic; (c) COVID-19 mortality was higher in England and Wales than in Sweden, making COVID-19 a contributor to the life expectancy divergence of England and Wales from Sweden. Patterns for England and Wales females during the pandemic were similar, except that suicide mortality played a larger role for divergence than alcohol-related mortality. Taken together, CVD mortality played the most important role for life expectancy divergence between males in England and Wales and males in Sweden before and during the COVID-19 pandemic; as well as for life expectancy divergence between females in England and Wales and females in Sweden during the COVID-19 pandemic.

Moving to the results for the USA, USA females saw smaller CVD mortality improvements before the COVID-19 pandemic than their Swedish counterparts, making CVD the most important cause of death for life expectancy divergence. Rising mortality from drugs and other external causes in the USA also contributed to the country's life expectance divergence, albeit at a lower percentage than CVD mortality. In contrast, suicide mortality increased among Swedish females ahead of the pandemic, creating some offsetting effects on life expectancy divergence. Among males, CVD mortality "only" contributed about 50% to the pre-pandemic life expectancy divergence between the USA and Sweden, followed by drug-related mortality at around 40% and mortality from other external causes at around 10%.

During the pandemic, all causes of death contributed to the life expectancy divergence of USA males and females from their Swedish counterparts. In both cases, the roughly equal contributions of CVD and drug-related mortality stand out. Among females, these contributions were only slightly exceeded by those from COVID-19 mortality, while among males, CVD, drug-related, and COVID-19 mortality made roughly equal contributions to the life expectancy divergence of the USA. However, when combined, external and substance-related mortality were the most important contributor to the life expectancy divergence of USA males from their Swedish counterparts, at close to 50%.

3-add.3. Discussion

In Chapter 3, COVID-19 generally emerged as the main driver of life expectancy change over the period 2019–2022. The *stagnation* analysis for England and Wales in this Addendum showed that COVID-19 was also relevant in explaining the deviation of England and Wales from its pre-pandemic life expectancy trajectory. However, CVD mortality was relatively more important in explaining life expectancy stagnation, because we would have expected further life expectancy gains from this cause based on pre-pandemic trends, but the country experienced life expectancy losses from CVD mortality during the pandemic. Among USA females and males, COVID-19 remained the most important cause of death for life expectancy stagnation. Among males, the combined contribution of all external and substance-related mortality exceeded the contribution from CVD mortality to life expectancy stagnation.

In England and Wales before and during the pandemic and the USA before the pandemic, CVD mortality was the largest contributor to the *divergence* in life expectancy from Sweden. In the USA during the pandemic, however, the contributions of CVD, drug-related mortality, and COVID-19 were more similar. Among men, external and substance-related mortality together were the most important contributor to the divergence of USA life expectancy from that of Sweden, exceeding even the contributions of COVID-19 mortality.

Thus, consistent with the Introduction and Chapter 2 of this dissertation, the analysis in this Addendum has once again demonstrated the value of considering analyses of life expectancy *stagnation* and *divergence* together. Even in the presence of such strong causes of death as COVID-19, deteriorations in other causes of death can emerge as more important drivers of stagnation—because we would have expected further improvements—and divergence—because high COVID-19 mortality affected almost all countries. In addition, by 2022, COVID-19 mortality recovered in many countries, weakening its importance for life expectancy stagnation and divergence in the long term. Despite these recoveries, the remaining large contributions of COVID-19 mortality to life expectancy stagnation and divergence by the third pandemic year are striking. Although the data used in this analysis are subject to potential misclassification of COVID-19 mortality as CVD deaths, and although the dynamics in the causes of death considered in this analysis may have common underlying drivers, such as the introduction of non-pharmaceutical interventions to prevent the spread of SARS-CoV-2, this Addendum highlights the importance of a cause-specific analysis of life expectancy stagnation *and* divergence to avoid a narrow focus on SARS-CoV-2 mortality as an explanation for all life expectancy dynamics during the COVID-19 pandemic.

3-add.4. Supplementary Information

3-add.4.1. Figures

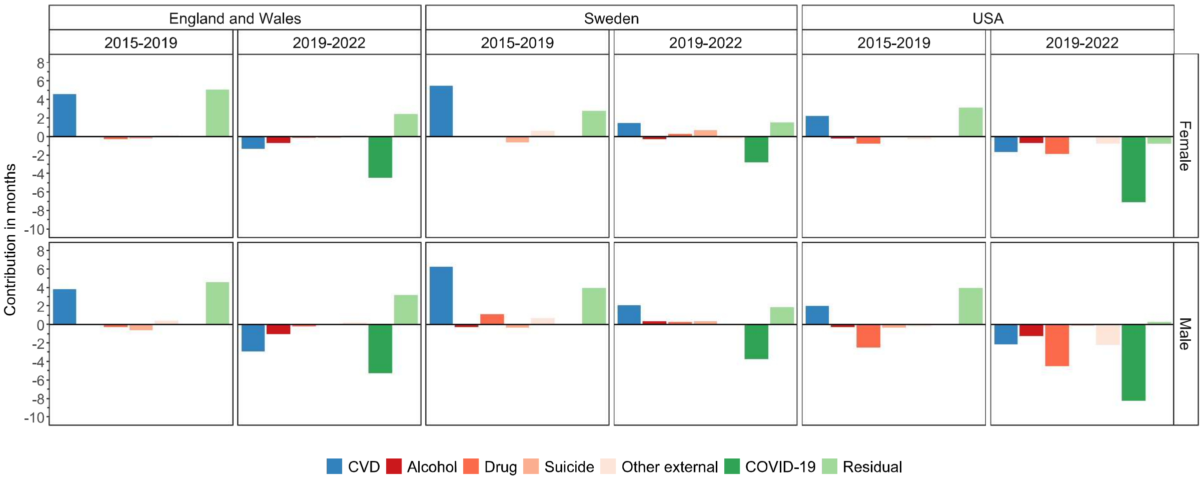

Figure 3-add-S1. Contribution of seven causes of death to life expectancy change in 2015–2019 and 2019–2022 in England and Wales, Sweden, and the USA. *Source:* see Chapter 3.

3-add.4.2. Tables

Table 3-add-S1. Contribution of seven causes of death to life expectancy stagnation in England and Wales and the USA in 2019–2022.

Country	Sex	CVD	Alcohol	Drug	Suicide	Other external	COVID-19	Residual
England and Wales	Female	−1.6	−0.2	0.0	0.0	0.0	−1.5	−0.5
	Male	−1.9	−0.3	0.0	0.1	0.0	−1.7	−0.1
USA	Female	−1.1	−0.2	−0.4	0.0	−0.2	−2.4	−1.0
	Male	−1.2	−0.3	−0.9	0.0	−0.7	−2.7	−0.9

Note: values represent difference between average annual contribution to life expectancy change in 2019–2022 and average annual contribution to life expectancy change in 2015–2019 in months. Negative values = cause of death contributed to life expectancy stagnation. Positive values = cause of deaths offset life expectancy stagnation. Sum across causes of death equals total annual life expectancy stagnation in 2019–2022. *Source:* see Chapter 3.

Table 3-add-S2. Contribution of seven causes of death to increasing life expectancy disadvantage of England and Wales vs. Sweden and the USA vs. Sweden in 2015–2019 and 2019–2022.

Country	Sex	Period	CVD	Alcohol	Drug	Suicide	Other external	COVID-19	Residual
England and Wales	Female	2019-2022	55.7	8.3	9.8	16.6	−6.6	34.8	−18.6
	Male	2015-2019	71.7	−6.8	39.4	7.9	6.7	–	−18.9
		2019-2022	69.1	19.7	7.2	5.3	−3.7	21.2	−18.7
USA	Female	2015-2019	80.0	4.9	18.0	−14.7	19.3	–	−7.6
		2019-2022	22.8	3.0	16.2	5.0	4.4	32.3	16.4
	Male	2015-2019	49.1	−0.1	40.7	0.5	9.6	–	0.2
		2019-2022	21.7	8.1	24.9	2.7	11.0	23.5	8.1

Note: percent contributions to increasing life expectancy disadvantage. Positive values = cause of death contributed to increasing life expectancy disadvantage. Negative values = cause of death offset increasing life expectancy disadvantage. Sum across causes of death equals 100%. *Source:* see Chapter 3.

References

Ho, J. Y. (2019). The contemporary American drug overdose epidemic in international perspective. *Population and Development Review*, *45*, 7–40. https://doi.org/10.1111/padr.12228

Polizzi, A., & Dowd, J. B. (2024). Working-age mortality is still an important driver of stagnating life expectancy in the United States. *Proceedings of the National Academy of Sciences*, *121*(4), e2318276121. https://doi.org/10.1073/pnas.2318276121

Ramsay, J., Minton, J., Fischbacher, C., Fenton, L., Kaye-Bardgett, M., Wyper, G. M. A., Richardson, E., & McCartney, G. (2020). How have changes in death by cause and age group contributed to the recent stalling of life expectancy gains in Scotland? Comparative decomposition analysis of mortality data, 2000–2002 to 2015–2017. *BMJ Open*, *10*(10), e036529. https://doi.org/10.1136/bmjopen-2019-036529

Chapter 4

The impact of early death on birth counts in the United States, 1950–2019[1]

Chapter word count: 6,066

4.1. Abstract

Jacob Bor and colleagues quantified the number of "missing Americans"—the deaths that would have been averted if the United States of America (USA) had experienced the mortality conditions of other wealthy nations (Bor et al., 2023). In 2019 alone, their estimates indicate that more than 100,000 individuals in reproductive ages (15–49) would have survived. The concept of the "missing Americans" is a valuable one, but here we argue that it is incomplete because it does not include children that would have been born to those who died an early death. We examine three indicators to assess the strength of the mortality–fertility nexus at the population level, showing that mortality more negatively affects birth counts in the USA than in other wealthy nations. Using the mortality conditions in other wealthy nations as a reference, we estimate that between 2010 and 2019 alone, approximately 200,000 children were not born in the USA due to the premature death of their potential mothers. Our findings highlight that improving morbidity and mortality among people of reproductive age—without compromising their reproductive autonomy—is critical in the USA.

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[1] This chapter is joint work with Andrea M. Tilstra. A version of this chapter has been published as: Polizzi, A., & Tilstra, A. M. (2024). The impact of early death on birth counts in the United States, 1950 to 2019. *PNAS Nexus*, *3*(6), pgae058. https://doi.org/10.1093/pnasnexus/pgae058.

4.2. Introduction

Jacob Bor and colleagues provided an estimate of the number of deaths that would have been averted if the USA had experienced the mortality conditions of other wealthy nations (Bor et al., 2023). In 2019 alone, their estimates point to a total of 600,000 Americans that ‘went missing,’ or individuals that died an early death.

The concept of the “missing Americans” is a valuable tool to illustrate the USA mortality disadvantage because it quantifies the comparatively high levels of mortality in the USA using an intuitive metric. It also complements the often difficult-to-communicate summary indicators of all-cause mortality—such as life expectancy at birth or age-standardized mortality rates—that demographers use when sharing their findings with a broader audience. Finally, “missing Americans” points to the avoidable consequences of early mortality for society more broadly. As Bor et al. argue, preventable mortality and underlying health issues may impact individuals’ ability to contribute to the economic, political, as well as social spheres and may negatively affect the socioeconomic and emotional well-being of family members and members of the social network of sick or deceased individuals (Bor et al., 2023).

The enumeration of missing populations has a long tradition in demography, as evidenced by the abundance of literature on “missing girls,” “missing women,” or “missing females” (Sen, 1990).[2] “Missingness” here is not defined as the lack of knowledge of the whereabouts of a person due to their disappearance by their own will or by the force of

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[2] In line with the two-sex structure of the data and methodological approaches reviewed and used in this article, we use the terms ‘girl,’ ‘woman,’ and ‘female’ interchangeably to refer to individuals capable of pregnancy. We recognize that our data and methods (a) do not capture all individuals self-identifying with one or more of these terms at some or all time points; (b) capture some individuals not self-identifying with one or more of these terms at some or all time points; (c) capture some individuals not capable of pregnancy, even when self-identifying with one or more of these terms at some or all time points (Moseson et al., 2020, 2021).

another person. Rather, it refers to the fact that a given society would include more individuals if demographic conditions were or had been different. For example, Bongaarts and Guilmoto estimated that 126 million more girls and women would have been alive worldwide in 2010 if age-specific sex ratios were not biased towards males (Bongaarts & Guilmoto, 2015). Skewed population sex ratios are typically explained by patriarchal structures that encourage sex-selective abortion, infanticide, and childcare practices, as well as differential access to resources, resulting in biased sex ratios at birth and elevated female mortality (Pennington et al., 2023). Thus, the literature on missing females calls attention to the fact that social inequality frequently manifests itself in fertility and mortality outcomes, and the concept of the "missing Americans" follows this tradition.

Despite drawing attention to some important sequelae of early mortality at the individual and societal levels, "missing Americans," as currently defined by Bor and colleagues, does not account for the forgone fertility due to mortality before the end of the reproductive period. Of the 600,000 total excess deaths observed in 2019, more than 100,000 were in reproductive ages (15–49). Many of these individuals would have had children if they had not died prematurely, leading to 'missing births.'[3] We argue that expanding the concept of "missing Americans" to account for the nexus between mortality and fertility provides a more comprehensive assessment of the negative consequences of the USA mortality environment for society.

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[3] In the literature on missing females, the concepts "missing female births" and "females missing at birth" are used to refer to never-born female children due to sex-selective abortion (Bongaarts & Guilmoto, 2015). Thus, "missing females" is a broad concept that comprises the postnatal pathway of female excess mortality and the prenatal pathway of sex-selective abortion. We borrow the term 'missing births' in this article to only highlight the indirect consequences of high (male and female) excess mortality in the USA for birth counts.

Thinking about the fertility implications of early mortality is not a new approach in demographic research. Nearly 30 years ago, demographers asked questions like “How many Americans are alive because of twentieth-century improvements in mortality?” (White & Preston, 1996) or “How many Americans might have been alive in the twentieth century?” (Muszyńska & Rau, 2009) and used a counterfactual population projection approach to estimate the number of Americans that “literally owe their lives to health progress” (White & Preston, 1996) or that “could be alive […] had mortality in the United States […] been the lowest possible at the time” (Muszyńska & Rau, 2009). Estimates from these studies already included lives saved directly in the first generation and those saved indirectly in subsequent generations.

Besides projection methods, formal demographic summary indicators of the mortality–fertility nexus, such as the net reproduction rate, have existed for decades (Lewes, 1984). These easy-to-calculate indicators are regularly reported for all countries by the United Nations Department of Economic and Social Affairs (UNDESA) (United Nations, Department of Economic and Social Affairs, Population Division, 2022). In high-income contexts, there is a tendency to think that mortality before the end of the reproductive period is sufficiently low to assess mortality and fertility conditions separately using period life expectancy at birth and the total fertility rate. However, considering the rising mortality gap between the USA and its peer countries that has resulted in excess premature mortality among people of reproductive ages, we argue for the continued and extended use of mortality–fertility indicators for high-income countries, especially in a comparative setting.

In this article, we review three existing summary indicators that can be used to communicate the magnitude of the mortality–fertility nexus in the USA, both within the community of demographic researchers and to a broader audience: (a) the probability of survival from birth to age 50; (b) reproductive-age life expectancy; and (c) the reproduction–survival ratio. Moreover, we advocate for the continued utility of counterfactual population projections to study the nexus between mortality and fertility at the population level. We review the principles behind counterfactual population projections, illustrating how this method can be used to study the population impact of short-term demographic shocks or longer-term demographic disadvantages. Our empirical application shows that the contemporary USA performs worse on the three mortality–fertility indicators than its peer nations, indicating that mortality more negatively affects birth counts in the USA. Using the mortality conditions in other wealthy nations as a reference, our counterfactual population projections suggest that between 2010 and 2019 alone, approximately 200,000 children were not born in the USA due to the premature death of their potential mothers.

Beyond measurement, we emphasize that improving the morbidity and mortality of reproductive-aged people is critical in the USA. Pronatalist and nationalist ideologies often aim to restrict women's reproductive autonomy to increase future population size, usually at the expense of the health of pregnant and birthing people currently alive (Gietel-Basten et al., 2022). Building on existing frameworks (Starrs et al., 2018), the indicators and methods examined in this article provide tools to quantify the extent to which USA individuals are constrained in their freedom to start and raise a family on their own terms. The constraint considered here is the risk of death before the end of the reproductive period. We argue that the unconditional focus on the physical integrity and reproductive autonomy of those alive today can also reap benefits tomorrow by enabling individuals to participate actively in society, embedded in kinship and social networks that are not disrupted by premature mortality.

4.3. Quantifying the mortality–fertility nexus

4.3.1. Probability of survival to age 50 (ℓ_{50})

The period life table is a demographic tool that allows for the calculation of different summary indicators of survival under the assumption that the mortality conditions observed in a given year and population were held constant for the individuals born in that year (Preston et al., 2001).[4] For example, USA life expectancy at birth (e_0) in the year 2010 is *not* a forecast of the actual length of life of a person born in the USA in that year. Rather, it indicates the average number of years a newborn could expect to live under the mortality conditions found in the USA in 2010. Thus, the life table can succinctly summarize mortality conditions observed across a wide age range. Unlike other summary indicators of mortality, such as the crude death rate, indicators derived from the life table are not affected by the age structure of the population for which they are calculated, allowing for a straightforward comparison of these indicators across time and across populations.

Assuming a birth cohort (life table radix) of size 1, the ℓ_x column of the life table indicates the probability of survival from birth to age x under the life table assumptions described above. For example, ℓ_{50} is the probability of surviving from birth past the end of the reproductive period, i.e. to age 50.[5]

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[4] While all approaches discussed in this article can be applied with arbitrary year cutoffs, e.g. July to June, we always refer to the calendar year (January to December).

[5] The reproductive period varies between individuals of the same sex and between individuals of different sexes. For females, menopause limits the reproductive period, though this is changing with the widening availability of assisted reproductive technology. Defining the length of the reproductive period is also dependent on data availability, as data providers vary in the lower and upper age limits for which they report births. Still, among both females and males, most births occur during ages 15 to 49, which is the most common definition of the reproductive period in demographic research (Preston et al., 2001).

4.3.2. Reproductive-age life expectancy (RALE)

Temporary life expectancy, ${}_{n}e_{x}$, is a life table indicator of the average number of years a person that survived to age x could expect to live before age $x+n$ under the current mortality conditions (Arriaga, 1984). This indicator can reach a maximum value of n years, in which case there would be no mortality between ages x and $x+n$. For example, reproductive-age life expectancy (RALE), or ${}_{35}e_{15}$, is the average number of years a 15-year-old could expect to live before the end of the reproductive period (i.e. before age 50), with a maximum value of 35 years (Canudas-Romo et al., 2014).

4.3.3. Reproduction–survival ratio (RSR)

The gross reproduction rate (GRR) is a summary indicator of fertility that follows a similar logic to the life table. It indicates the average number of children of the same sex that an individual of a given sex would bear throughout their lifetime if the fertility conditions observed in a given year and population were held constant (Preston et al., 2001). GRR assumes no mortality before the end of the reproductive period and is, thus, sometimes regarded as an indicator of "potential reproductivity" (Shryock et al., 1998) in the absence of mortality among potential parents. In contrast, the net reproduction rate (NRR) assumes that individuals were exposed to both the fertility *and* mortality conditions observed in a given year and population (Preston et al., 2001). The ratio of NRR to GRR, or the reproduction–survival ratio (RSR), indicates the share of potential fertility that "survives the effects of mortality" (Shryock et al., 1998) among potential parents. By standardizing for potential fertility in the denominator, RSR can be compared across time and across populations without being biased by differences in the levels of fertility.

Traditionally, GRR, NRR, and RSR focus on the birth of female children to females. Given our interest in the implications of early death for total birth counts, we modify these indicators to account for the birth of children of any sex to females (Keilman et al., 2014).

Table 4-1 provides an overview of the three mortality–fertility indicators, showing the most common interpretation of each indicator, the formula used to calculate each indicator, and how deaths at earlier vs. later ages affect each indicator.

Table 4-1. Demographic indicators of the mortality–fertility nexus.

Indicator	**Interpretation**[a]	**Formula**[b]	**Maximum value**	**Deaths accounted for**	**Impact of deaths at different ages**
ℓ_{50}	Probability of survival to age 50	$\prod_{0}^{49} {}_1p_x$	1	< Age 50	Equal impact
Reproductive-age life expectancy (RALE)	Average number of years lived between ages 15–49, conditional on survival to age 15	$\frac{\sum_{15}^{49} {}_1L_x}{\ell_{15}}$	35	Ages 15–49	Stronger impact of earlier deaths
Reproduction–survival ratio (RSR)	Share of potential fertility that survives effects of mortality among potential parents	$\frac{\sum_{15}^{49} {}_1L_x \times {}_1F_x}{\sum_{15}^{49} {}_1F_x}$	1	< Age 50	Stronger impact of earlier deaths; equal impact of deaths < age 15

[a] Under the assumption that current mortality and fertility conditions are held constant and life table radix $\ell_0 = 1$.

[b] ${}_1p_x$=probability of surviving from age *x* to age *x+1*; ${}_1L_x$=person-years lived between ages *x* and *x+1*; ${}_1F_x$=(two-sex) fertility rate between ages *x* and *x+1*.

4.3.4. Counterfactual population projection

ℓ_{50}, RALE, and the RSR are age-standardized summary indicators of mortality and/or fertility conditions in a given year and population. These indicators also assume stability of the underlying demographic conditions. While this means that mortality and fertility conditions can be straightforwardly compared across time and across populations, the real-world implications of different demographic circumstances heavily depend on the age-structure of the individuals experiencing these circumstances. Thus, following previous studies (Preston & Vierboom, 2021; Woolhandler et al., 2021), Bor et al. calculated the number of missing Americans by counterfactually subjecting the observed USA population in each year to the age-specific mortality rates found in a group of peer countries.

However, the consequences of early mortality for birth counts are not limited to the year of observation. For example, a 30-year-old that died in 1990 would have been able to have children until 2009, if the premature death had been avoided. Thus, quantifying the fertility implications of mortality before the end of the reproductive period requires a counterfactual approach with a longer-term perspective—one, in which the missing Americans are not only assumed to survive but also to have children later on. Research on the population implications of COVID-19 has popularized again an approach known as "counterfactual population projection" (Murphy, 2021) to study the long-term effects of demographic shocks (Charles-Edwards et al., 2021; González-Leonardo & Spijker, 2022; Tilstra et al., 2024). Here, the population before the shock is projected forward with the cohort component method (Preston et al., 2001) under two scenarios: (a) a baseline scenario, in which the starting population is exposed to the age-specific mortality, fertility, and migration rates actually observed during the shock; and (b) a counterfactual scenario, in which the starting population is exposed to counterfactual demographic conditions that would have likely prevailed in the absence of the shock. The difference in any indicator between the two scenarios, such as the number of live births, represents the population effect of the demographic shock. This approach can be applied for different time scales to quantify the short- and/or long-term implications of the demographic shock. In addition, we contend that counterfactual population projections are not limited to the study of instantaneous demographic shocks but can also be applied to study the effects of longer-term demographic disadvantages. For example, in the context of the missing Americans, it is possible to study short- and long-term differences in birth outcomes if the USA had experienced the more favorable mortality conditions of its peer countries (Muszyńska & Rau, 2009).

While the counterfactual projection of live births takes inspiration from the previously discussed demographic indicators, especially the RSR, it is an independent approach to quantify the implications of early death for birth counts. Compared with the demographic indicators, the strength of the counterfactual projection approach lies in its ability to account for changes in the mortality and fertility conditions across the lifetimes of multiple birth cohorts, even if these cohorts are only partially observed. The projection approach is also able to account for population size, population age structure, and the impact of migration, the latter being an important source of population growth and change (Billari, 2022).

4.4. Materials and methods

We compared the USA to a group of peer countries to illustrate the extent to which USA birth counts have been impacted by the unfavorable USA mortality environment highlighted in previous studies (National Academies of Sciences, Engineering, and

Medicine, 2021; National Research Council, 2013). In line with Bor et al., we varied our group of peer countries to comprise (a) the five largest Western European countries—France, Germany, Italy, Spain, and the United Kingdom; (b) the other Group of Seven (G7) countries—Canada, France, Germany, Italy, Japan, and the United Kingdom; and (c) 21 other wealthy nations—Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Iceland, Ireland, Italy, Japan, Luxembourg, The Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom. Our analysis was restricted to (early) death in the female population and, where applicable, accounted for the birth of children of any sex.

Using data from the 2022 United Nations World Population Prospects (UNWPP) for the period 1950–2100, we constructed annual life tables from estimated and forecasted information on female deaths and female exposures by single year of age and calculated age-specific fertility rates from estimated and forecasted information on births to females and female exposures by single year of age (United Nations, Department of Economic and Social Affairs, Population Division, 2022). We used the formulas reported in Table 4-1 and derived values of ℓ_{50}, RALE, and the RSR for the USA, each of the peer countries, and the population-weighted average of the peer countries for the period 1950–2019.

By comparing annual birth counts in a baseline (with USA mortality) and a counterfactual (with peer mortality) projection scenario, we determined the annual number of children that *were only* (‘additional births’) or *were not* (‘missing births’) born because the USA did not experience the mortality conditions of other wealthy nations beginning in 1950. To this end, we applied standard cohort component methodology (Preston et al., 2001) to estimated and forecasted USA population counts reported in UNWPP. Among the additional births, we distinguished between children born only because their mothers (second generation) or (great-)grandmothers (third and higher generations) survived under USA mortality conditions but would have died under peer mortality conditions. Similarly, among the missing births, we distinguished between children not born because their potential mothers (second generation) or (great-)grandmothers (third and higher generations) died under USA mortality conditions but would have survived under peer mortality conditions (Muszyńska & Rau, 2009). This approach is described in more detail in the Supplementary Information to this chapter. For the main analysis, we commenced and ceased our projections on January 1, 1950 and January 1, 2020, respectively. In supplementary analyses, we extended the projection period to January 1, 2050.

In the main manuscript, we report results for the comparison between the USA and the group of other wealthy nations. Results for the other comparison groups can be found in the Supplementary Information (Figures 4-S1 to 4-S8). Replication data and code for all figures are available through our Open Science Framework (OSF) repository: https://doi.org/10.17605/osf.io/z5djb.

4.5. The USA mortality–fertility nexus

Figure 4-1 shows trends over the period 1950–2019 in ℓ_{50} in the USA and the group of other wealthy nations. The inset in Figure 4-1 highlights the most recent period, 1980–2019. The thick solid (red) line shows the USA, while the thick dashed (dark blue) line shows the average among the peer countries. Each peer country is represented by a thin solid (light blue) line. Overall, levels of ℓ_{50} were high and close to the theoretical maximum of 1. This is especially noticeable at the end of the observation period (2019), where all countries reached values of ℓ_{50} above 95%.

In the 1950s, the USA had above-average probabilities of survival to age 50. By the mid-1960s, though, the USA stagnated while improvements continued for the peer countries, contributing to the emergence of a USA disadvantage in ℓ_{50}. The gap remained relatively stable during the 1970s, but began widening in the 1980s, driven by larger improvements for the peer countries. By the end of the 1990s, ℓ_{50} in the USA was lower than in all other wealthy nations. During the 2010s, deteriorations in the USA amid improvements in the peer countries led to further increases in the USA ℓ_{50} disadvantage. While the USA recovered slightly in the years before the COVID-19 pandemic, the gap remained substantial. If mortality conditions were held at 2019 levels, the probability of survival to age 50 would be 97.9% in the other wealthy nations but only 95.6% in the USA.

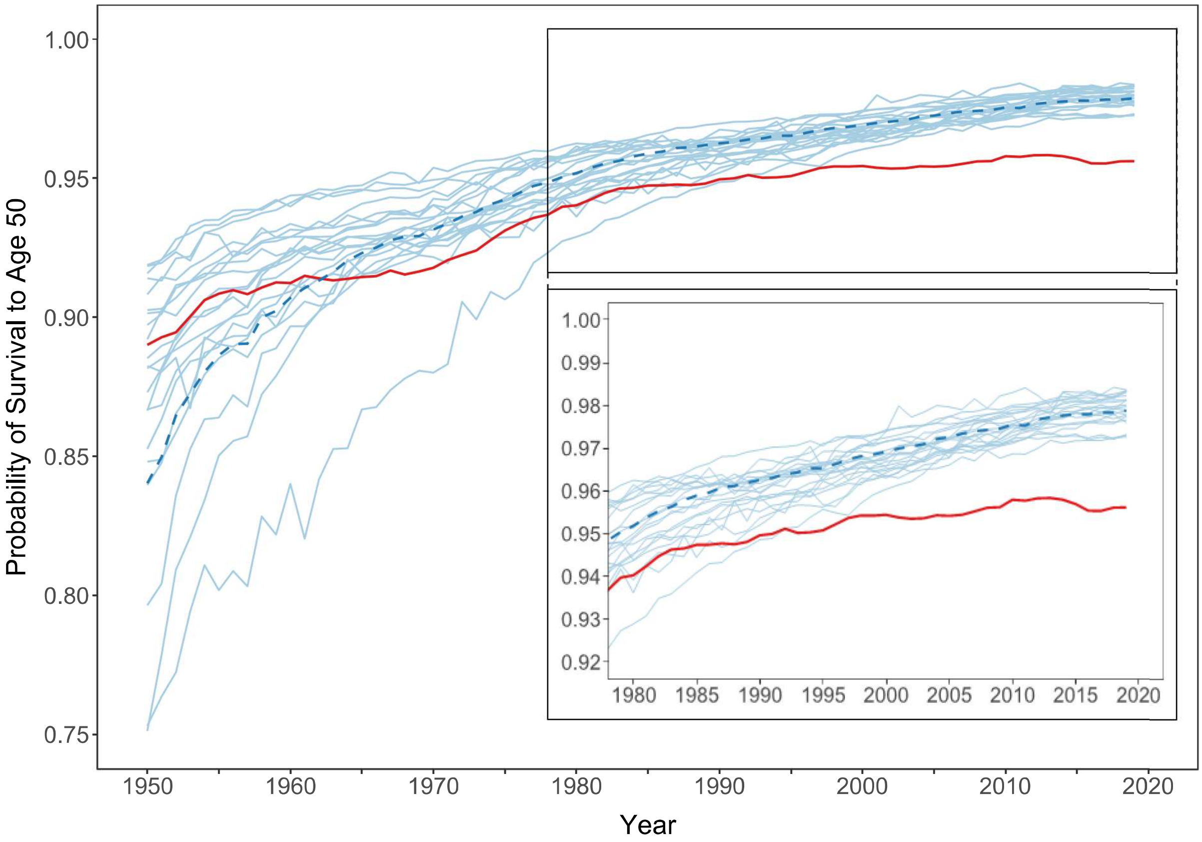

Figure 4-1. Female probability of survival to age 50 (ℓ_{50}) in the USA and 21 other wealthy nations, 1950–2019. *Notes*: Thick solid line=USA; thick dashed line=population-weighted average of the other wealthy nations; thin solid lines=country-specific trends for each of the other wealthy nations. Inset zooms in on period 1980–2019 for better readability. *Source*: Authors' calculations based on data from United Nations World Population Prospects 2022.

Figure 4-2 shows trends in RALE in the USA and the other wealthy nations between 1950 and 2019. Overall, trends followed a similar pattern as ℓ_{50}, suggesting that mortality before age 15 was not the underlying driver of the patterns seen in Figure 4-1. As with ℓ_{50}, values of RALE in the USA and the other wealthy nations have reached levels close to the theoretical maximum of 35 years, with RALE estimated to surpass 34.5 years in 1981 and 1971 in the USA and the peer average, respectively. In the early 2010s, RALE declined in the USA but recovered somewhat in the late 2010s. If mortality conditions observed in 2019 were held constant, 15-year-olds in the USA would, on average, live 2.9 fewer months before age 50 than their counterparts in other wealthy nations. While on the individual level, this difference may seem small, Bor and colleagues highlighted the large number of years of life lost in the USA at the population level. This loss, in turn, may have meaningful implications for population-level birth counts, as we illustrate below.

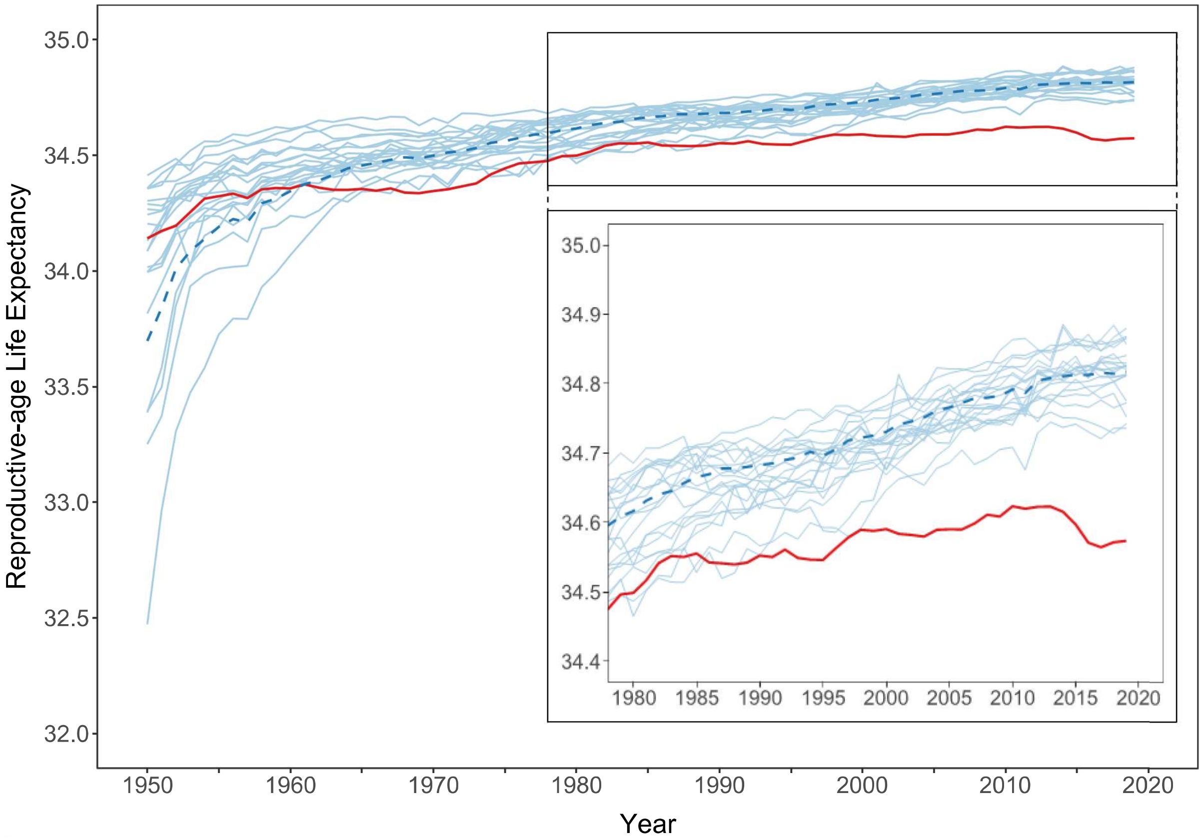

Figure 4-2. Female reproductive-age life expectancy (RALE) in the USA and 21 other wealthy nations, 1950–2019. *Notes*: Thick solid line=USA; thick dashed line=population-weighted average of the other wealthy nations; thin solid lines=country-specific trends for each of the other wealthy nations. Inset zooms in on period 1980–2019 for better readability. *Source*: Authors' calculations based on data from United Nations World Population Prospects 2022.

Echoing our findings for ℓ_{50} and RALE in Figures 4-1 and 4-2, Figure 4-3 shows a lower female RSR in the USA compared to the group of other wealthy nations starting in the 1960s. Assuming that (a) mortality and fertility conditions were held at 2019 levels; (b) deceased women would have had the same fertility as surviving women; (c) there was no international migration, the USA would realize 98.5% of its fertility potential, while this level would be somewhat higher, at 99.2%, in the peer countries.

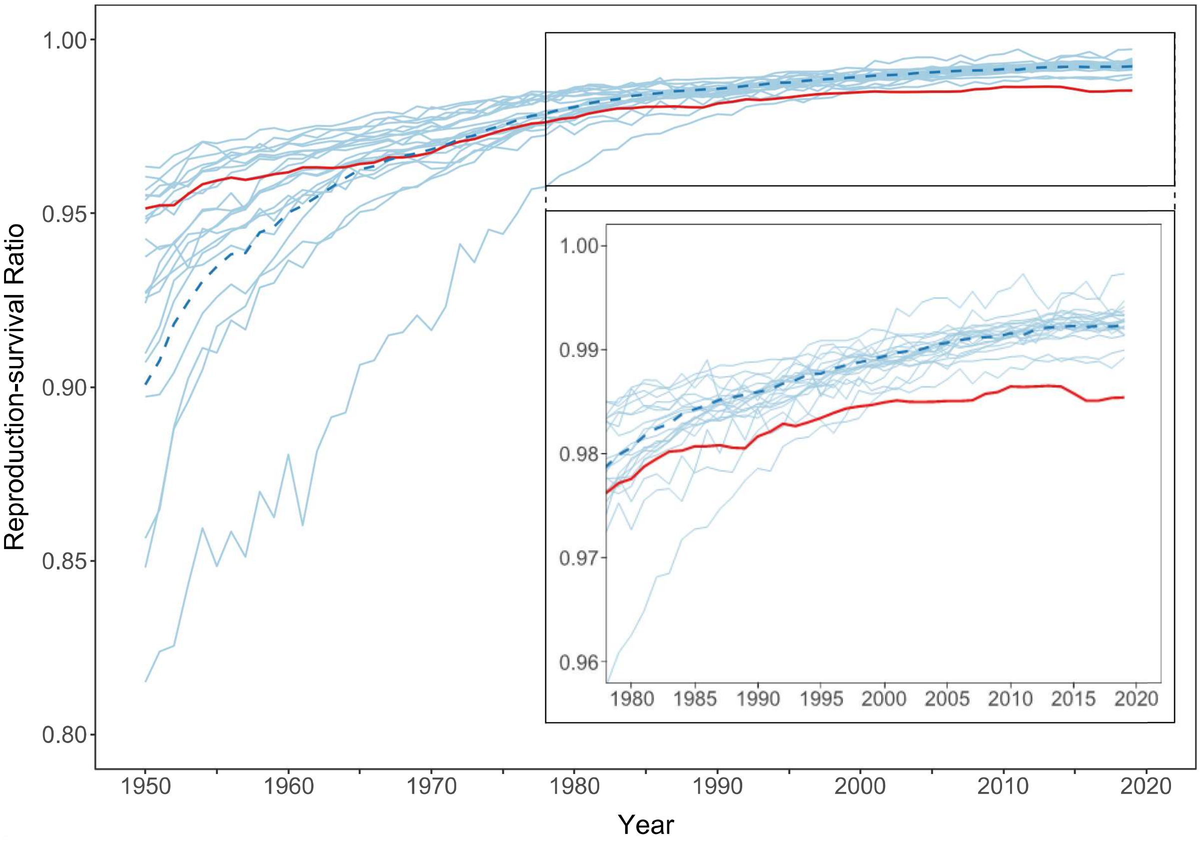

Figure 4-3. Female reproduction–survival ratio (RSR) in the USA and 21 other wealthy nations, 1950–2019. *Notes*: Thick solid line=USA; thick dashed line=population-weighted average of the other wealthy nations; thin solid lines=country-specific trends for each of the other wealthy nations. RSR accounts for the birth of children of any sex. Inset zooms in on period 1980–2019 for better readability. *Source*: Authors' calculations based on data from United Nations World Population Prospects 2022.

Finally, Figure 4-4 shows the annual number of additional and missing births across the period 1950–2019. Areas pointing up (and in blue) indicate USA live births that would not have occurred in a counterfactual scenario in which the mortality conditions of other wealthy nations applied beginning in 1950. Conversely, areas pointing down (and in red) indicate live births that would have only occurred under the mortality conditions of other wealthy nations. The dark and light shades disaggregate the additional and missing births further by generation (i.e. second generation vs. third and higher generations), as described in the Materials and methods. The dashed line represents the total annual difference in the number of live births under the baseline (with USA mortality) and counterfactual (with peer mortality) population projection scenarios and is equal to the sum of all (blue and red) areas.

Compared to the counterfactual scenario, the USA experienced more live births in each year of the period 1950–2019 (dashed line). Until the 1980s, this was predominantly because of children born only because their mothers' lives were saved under USA mortality conditions, i.e. additional births in the second generation (dark blue area pointing upward). Since then, the importance of children born only because their (great-)grandmothers' lives were saved under USA mortality conditions has increased, i.e. additional births in the third and higher generations (light blue area pointing upward). However, since the mid-1980s, the USA has also seen an increasing number of missing births in the second generation (dark red area pointing downward). Across the decade 2010–2019, around 200,000 children were not born in the USA because their potential mothers died prematurely under USA mortality conditions. Of these missing births, about 23,000 would have occurred in 2019 alone. Missing births in the third and higher generations, i.e. children not born because their potential (great-)grandmothers died prematurely under USA mortality conditions, played only a minor role during the period 1950–2019 (light red area pointing downward). Using partially observed and forecasted information on population, births, and deaths in the USA and other wealthy nations for the period after 2019, we project that in each year until 2049, the USA will see fewer births than in a counterfactual scenario in which the mortality conditions of other wealthy nations applied beginning in 1950 (see Figure 4-S9 in the Supplementary Information). Thus, although the USA reproductive-age mortality advantage in the 1950s and 1960s initially resulted in additional births, the persistent disadvantage in reproductive-age mortality that began to emerge in the 1960s is projected to have an offsetting effect on USA birth counts in the medium- and long-term.

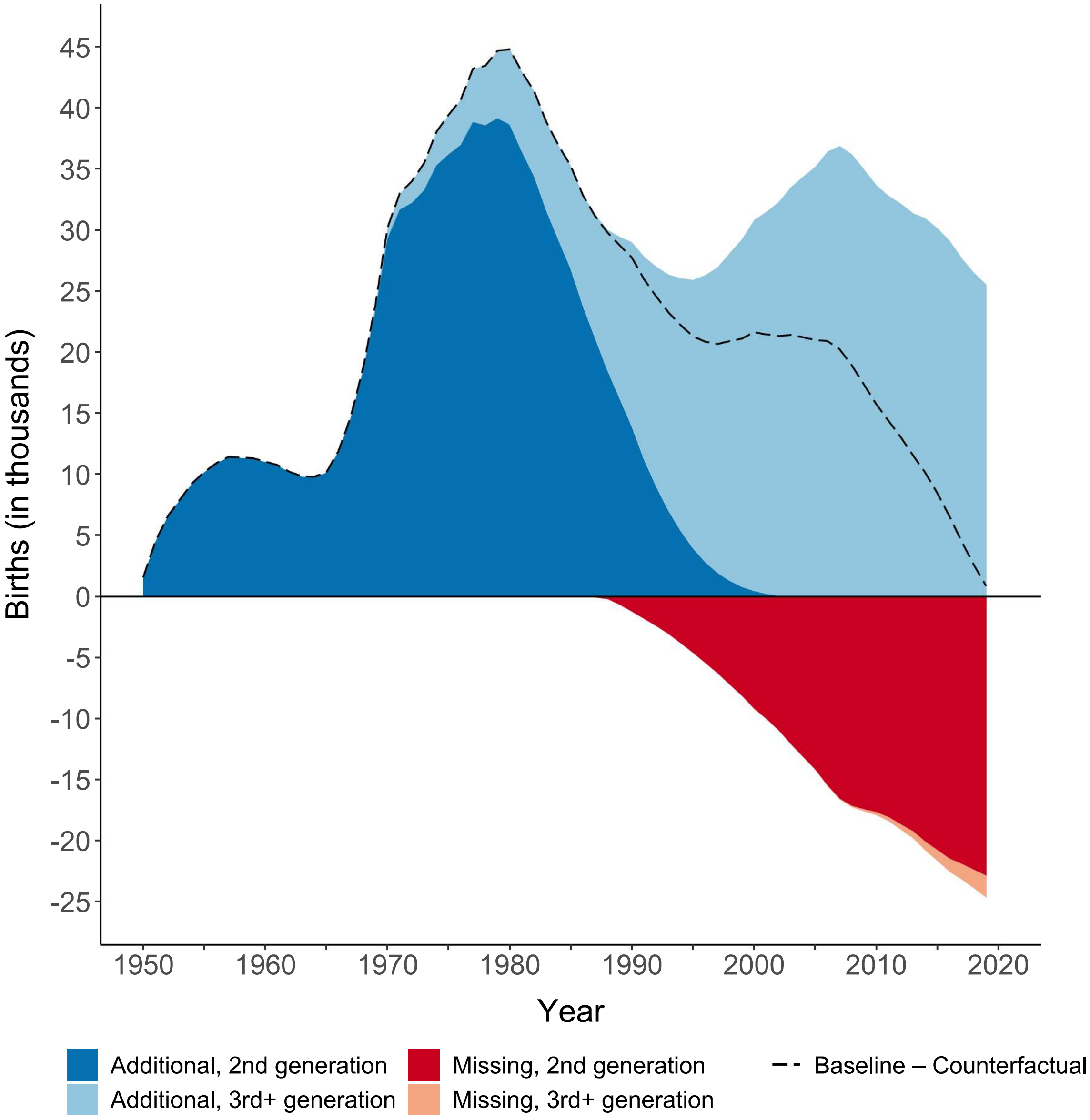

Figure 4-4. Additional births and missing births in the USA, 1950–2019. *Notes*: Areas=children that were only (pointing upward) or were not (pointing downward) born in the USA each year because the country did not experience the mortality conditions of 21 other wealthy nations beginning in 1950. *Source*: Authors' calculations based on data from United Nations World Population Prospects 2022.

4.6. Discussion

Jacob Bor and colleagues estimated the number of missing Americans—early deaths in the USA due to higher mortality than in other wealthy nations. In this article, we aim first to broaden the concept of "missing Americans" by estimating the number of missing births—the children that would have been born to those who died an early death. Using the mortality conditions in other wealthy nations as a reference, our counterfactual population projections suggest that between 2010 and 2019 alone, approximately 200,000 children were not born in the USA due to the premature death of their potential mothers. The early death of Americans thus has important implications for birth counts.

Our counterfactual projection approach—akin to those used by White and Preston (White & Preston, 1996) and Muszyńska and Rau (Muszyńska & Rau, 2009)—explicitly incorporates information on the population age structure and mimics the movement of actual birth cohorts through time. While estimates provided here mostly show consequences of the past, it is possible to provide projections of forgone fertility due to mortality in the near and more distant future (Tilstra et al., 2024). Using partially observed and forecasted information on population, births, and deaths in the USA and other wealthy nations, we project that the USA will continue to experience missing births in the next decades, while the number of additional births will continue to decline.

The effects of mortality on population-level birth counts can compound over time and across generations. Focusing on a 100-year period (1900–2000), Muszyńska and Rau provided estimates of never-born children due to the early death of potential parents, grandparents, and great-grandparents (Muszyńska & Rau, 2009). They estimated that more than 700,000 additional children could have been born in the year 2000 alone if the USA had had the highest life expectancy recorded in each year of the twentieth century. Counterfactual population projections have been criticized in the past for stretching the projection time window and incorporating the contributions from population momentum (i.e. the fact that never-born children would have had children) (Wang et al., 2018). While our approach does not fully avoid this issue, we focus on a time period in which the (great-)grandchildren of the missing Americans only make a minor contribution to the total number of missing births, as seen by the light red area pointing downward in Figure 4-4.

Our second contribution is to compare the USA to other wealthy nations on three easy-to-calculate summary indicators of the mortality–fertility nexus: (a) the probability of survival to age 50 (ℓ_{50}), (b) reproductive-age life expectancy (RALE), and (c) the reproduction–survival ratio (RSR). Although the three indicators differ in the way deaths and births at different ages are accounted for (see Table 4-1), we find that, regardless of the selected metric, the contemporary USA consistently performs worse than its peer nations. If mortality and fertility conditions observed in 2019 remained stable, 21 in 1000 newborn girls would die before age 50 in the other wealthy nations, while in the USA it would be more than twice as many at 44 in 1000 (ℓ_{50}). Under 2019 conditions, a girl alive at age 15 would, on average, live 2.9 fewer months before age 50 in the USA compared to the other wealthy nations (RALE). Finally, 15 of 1000 potential children would not be born under 2019 conditions in the USA because of premature mortality among potential mothers (RSR). In the other wealthy nations, it would only be about half as many: 8 out of 1000 children. Taken together, the three indicators reviewed here paint a comprehensive picture of the negative consequences of mortality before the end of the reproductive period for population-level birth counts in the USA. Whereas the counterfactual population projection approach is most effectively applied with some time lag, the three life table indicators are period-based and react instantaneously to changes in the mortality environment. Thus, these indicators can be used to track and communicate year-to-year progress on the USA mortality–fertility nexus. We recommend that the choice of the most suitable indicator is based on the metric of interest (probability, years of life, births) as well as the age range accounted for by the different indicators.

Our findings complement existing research that suggests the high burden of disease in the USA may prohibit individuals from starting and raising a family (Liu et al., 2023). Widening socioeconomic inequalities combined with a limited social safety net, the absence of universal healthcare coverage, and the lax regulation of health threats and threats to life—such as opioids, firearms, environmental pollutants, and unhealthy foods—have played an important role in the emergence of the missing Americans (Bor et al., 2023), including missing births. In 2019, the causes of death that afflicted women of reproductive age the most in the USA spanned accidents (including accidental drug poisonings), malignant neoplasms, diseases of the heart, suicide, and homicide (Gemmill et al., 2022; Margerison et al., 2022). Moreover, reproductive-aged women in the USA saw increases in a broad group of causes of death over the period 1999–2019, including accidents, suicide, chronic liver disease/cirrhosis, diabetes mellitus, septicemia, and nephritis/nephrotic syndrome/nephrosis (Gemmill et al., 2022). Mortality related to pregnancy/childbirth/the puerperium grew by more than 180% across the same period, further pointing to adverse consequences of restricted abortion access and/or access to high-quality maternal care (Gemmill et al., 2022; Stevenson, 2021). Therefore, following Bor and colleagues, we contend that preventing future missing Americans, including missing births, “will require efforts to address fundamental causes of poor population health in the USA that existed even before the [COVID-19] pandemic began” (Bor et al., 2023).

There are two limitations to the methods suggested in this article. First, we assume that the age-specific fertility rates observed among the surviving individuals in the USA would have applied to the deceased individuals as well, and that all unrealized live births estimated in this way should be counted as missing. However, this assumption does not account for heterogeneity in fertility outcomes, such as health-related fertility differences between surviving and dying individuals (Liu et al., 2023). Moreover, related to a broader limitation of macro-level fertility research, we are not able to capture the intentionality of births. Compared to other countries in Europe and Northern America, the USA has a high rate of unintended pregnancies (Bearak et al., 2022). This is especially true for groups that have been historically marginalized (Finer & Zolna, 2016) and that constitute a disproportionate share of the missing Americans. Whether unintended births should be included in a measure of missing births is up for debate. We encourage continued research and dialogue on the best ways to estimate missing births, and missing Americans more generally.

Second, against a history of misinterpretation of demographic period indicators (Sobotka & Lutz, 2011), sometimes deliberate, we caution that the three life table indicators included here (ℓ_{50}, RALE, and RSR) only describe the experience of actual birth cohorts if two assumptions hold: (a) that all demographic rates remain stable; and (b) that there is no migration. It is rare that these assumptions hold. While there have been various attempts to incorporate migration into demographic indicators of fertility and/or mortality, such as the total fertility rate (Parr, 2021) or the net reproduction rate (Preston & Wang, 2007), the assumption of stable demographic rates is almost always violated (Ní Bhrolcháin, 2011). The indicators suggested here should not be seen as forecasting instruments, but instead as helpful tools to summarize the mortality and fertility conditions in a given year, net of the underlying population age structure (Ní Bhrolcháin, 2011).

Despite these limitations, the strength of our approach lies in extending the concept of "missing Americans," as introduced by Bor and colleagues, and in emphasizing the relevance of the mortality–fertility nexus even in high-income countries where mortality before the end of the reproductive period is generally considered low. Going forward, the indicators and methods reviewed in this article could be valuable in monitoring progress toward removing barriers that prevent people from starting and raising a family on their own terms. This includes progress in addressing reproductive inequalities experienced by groups with historically higher rates of early mortality, such as those from lower socioeconomic backgrounds and some historically marginalized racial or ethnic groups in the USA, as these groups may face the greatest burden of missing births. Whether or not this means that preventing premature mortality will lead to larger birth cohorts—as those involved in depopulation discourses may hope or racist ideologues of "hyperfertility" (Mehra et al., 2020) may fear—should not determine if the physical integrity and reproductive autonomy of those currently alive will be guaranteed. An unconditional focus on the health of those alive today will allow individuals to participate actively in society, embedded in kinship and social networks that are not disrupted by avoidable morbidity or mortality.

4.7. Acknowledgements

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4.9. Author contributions

Conceptualization, data analysis, and data visualization: A.P.; interpretation and writing: A.P. and A.M.T.

4.10. Data availability

Data are publicly available, under a Creative Commons license CC BY 3.0 IGO, from the United Nations World Population Prospects (UNWPP) 2022: *https://population.un.org/wpp/*. For ease of replication, all R scripts and project data, including the data underlying all figures, are available at our Open Science Framework (OSF) repository: https://doi.org/10.17605/osf.io/z5djb.

4.11. Supplementary Information

4.11.1. Methods

In step I of our counterfactual projection of live births, we compare annual birth counts in a baseline (with USA mortality) and a counterfactual (with peer mortality) projection scenario to determine the total annual number of children that *were not* (missing births) or *were only* (additional births) born because the USA did not experience the mortality conditions of other wealthy nations beginning in 1950. In step II of our counterfactual projection of live births, we disaggregate the missing births into children not born because their potential mothers (second generation) or (great-)grandmothers (third and higher generations) died under USA mortality conditions but would have survived under peer mortality conditions. Similarly, we disaggregate the additional births into children born only because their mothers (second generation) or (great-)grandmothers (third and higher generations) survived under USA mortality conditions but would have died under peer mortality conditions.

To disaggregate missing and additional births by generation, we developed a stepwise counterfactual population projection approach. First, we survive the observed USA population in 1950 to the end of the projection period using baseline and counterfactual mortality rates. In both the baseline and the counterfactual scenario, we allow for in-migration and record the total number of children, but not (great-)grandchildren, born. We correct the annual birth counts obtained in this way for out-migration of potential parents. Second, the annual birth counts after correction for out-migration are separated into two components: (a) births that occurred in both the baseline and the counterfactual scenario; (b) births that occurred only in the baseline (additional births) or the counterfactual (missing births) scenario. Third, births that occurred in both the baseline and the counterfactual scenario are themselves survived forward under baseline and counterfactual mortality conditions. Again, the children of these children, but not their (great-)grandchildren, are recorded and separated into two components: (a) births that occurred in both the baseline and the counterfactual scenario; (b) births that occurred only in the baseline (additional births) or the counterfactual (missing births) scenario. Step three is repeated until the end of the projection period is reached. Fourth, the additional and missing births recorded for each year and projection step are summed into separate annual totals of additional and missing births. These are the additional and missing births in the second generation, i.e. children that were only born because their mothers survived under USA mortality conditions but would have died under peer mortality conditions, and children that were not born because their potential mothers died under USA mortality conditions but would have survived under peer mortality conditions. Finally, we survive the additional births in the second generation forward under baseline mortality conditions and survive the missing births in the second generation forward under counterfactual mortality conditions. This time, we record all descendants of these children. These are the additional and missing births in the third and higher generations, i.e. children that were only born because their (great-)grandmothers survived under USA mortality conditions but would have died under peer mortality conditions, and children that were not born because their potential (great-

)grandmothers died under USA mortality conditions but would have survived under peer mortality conditions. The sum of all additional and missing births in each year (irrespective of their generation) corresponds to the annual difference in live births between a standard baseline and counterfactual population projection scenario from step I.

4.11.2. Figures

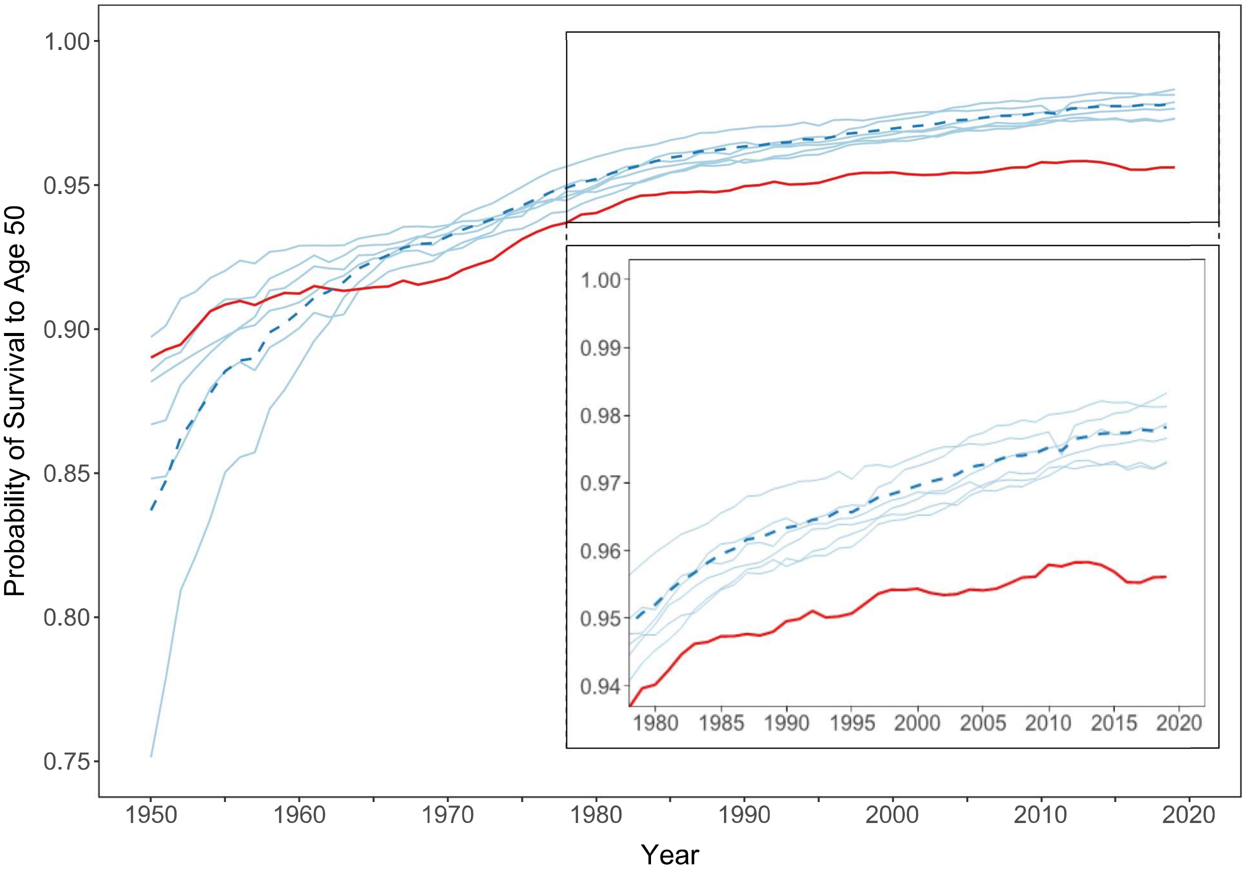

Figure 4-S1. Female probability of survival to age 50 (ℓ_{50}) in the USA and the other Group of Seven (G7) countries, 1950–2019. *Notes*: Thick solid line=USA; thick dashed line=population-weighted average of the other G7 countries; thin solid lines=country-specific trends for each of the other G7 countries. Inset zooms in on period 1980–2019 for better readability. *Source*: Authors' calculations based on data from United Nations World Population Prospects 2022.

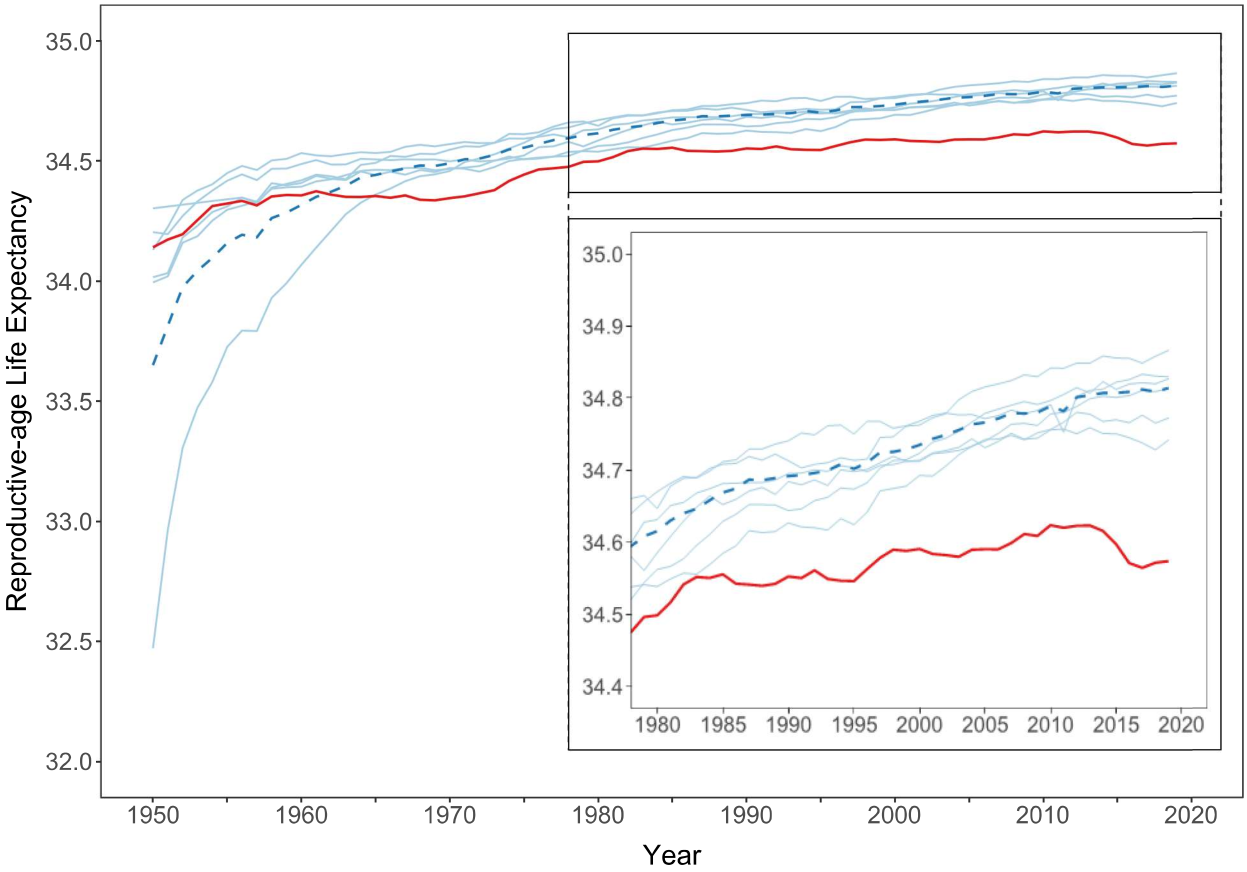

Figure 4-S2. Female reproductive-age life expectancy (RALE) in the USA and the other Group of Seven (G7) countries, 1950–2019. *Notes*: Thick solid line=USA; thick dashed line=population-weighted average of the other G7 countries; thin solid lines=country-specific trends for each of the other G7 countries. Inset zooms in on period 1980–2019 for better readability. *Source*: Authors' calculations based on data from United Nations World Population Prospects 2022.

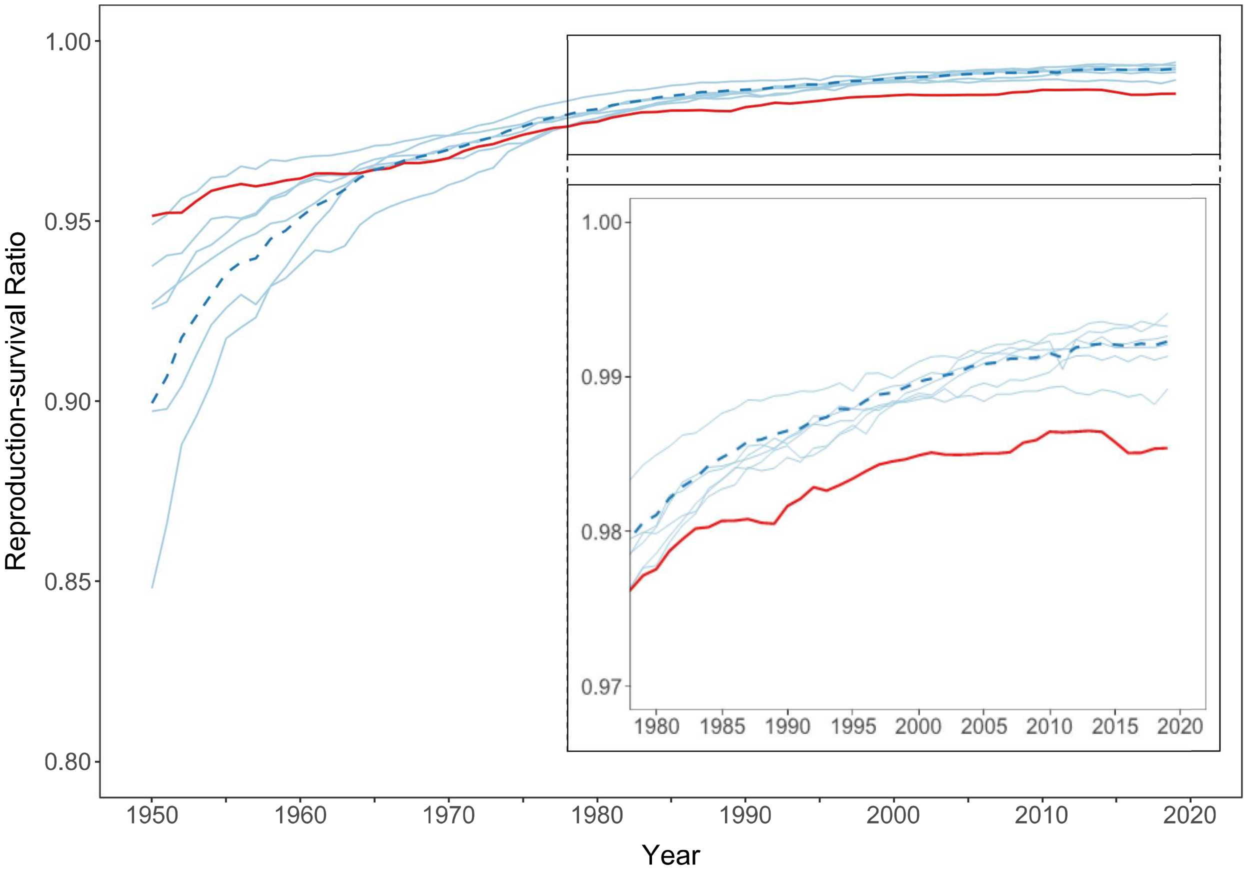

Figure 4-S3. Female reproduction–survival ratio (RSR) in the USA and the other Group of Seven (G7) countries, 1950–2019. *Notes*: Thick solid line=USA; thick dashed line=population-weighted average of the other G7 countries; thin solid lines=country-specific trends for each of the other G7 countries. Inset zooms in on period 1980–2019 for better readability. *Source*: Authors' calculations based on data from United Nations World Population Prospects 2022.

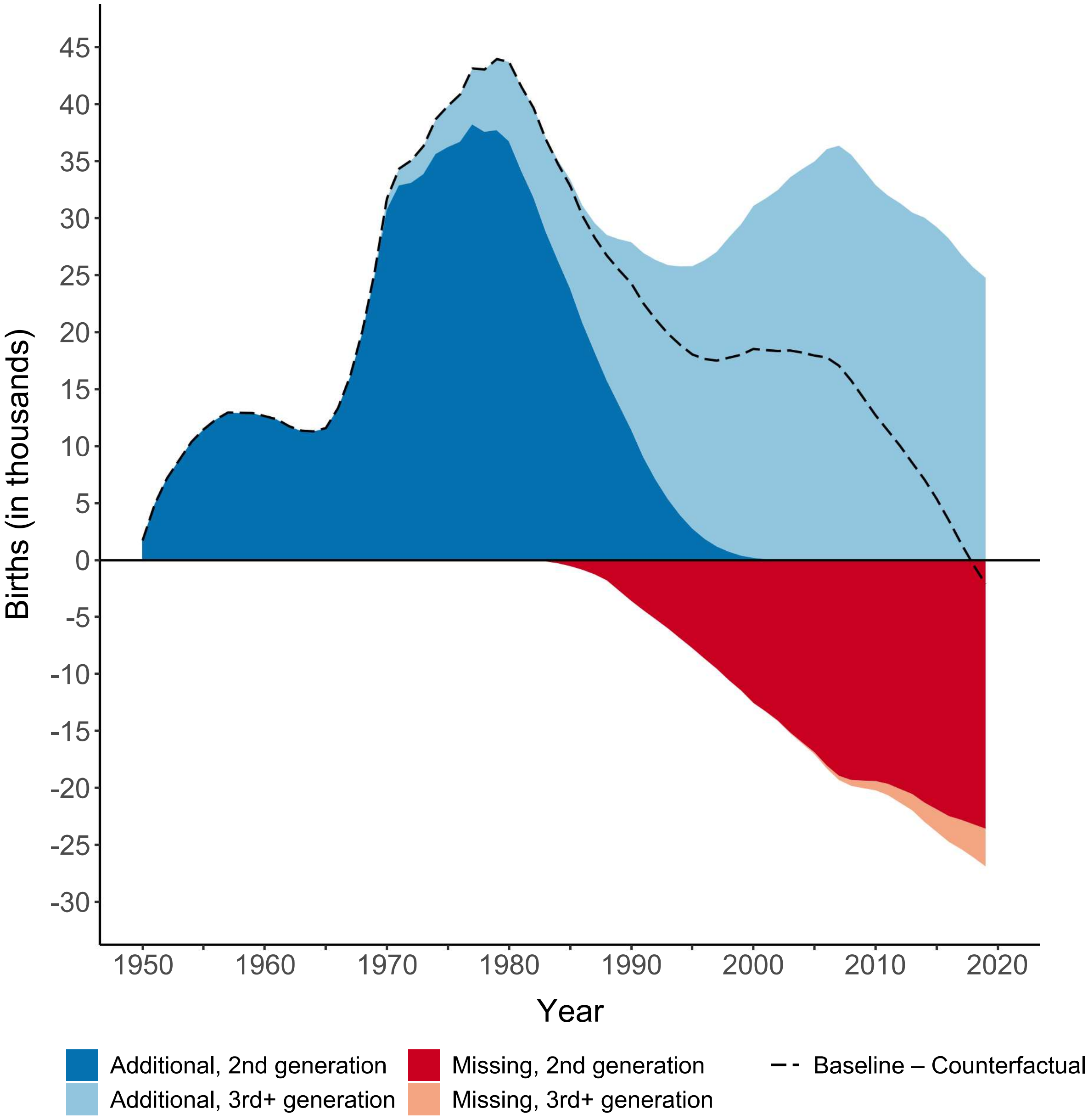

Figure 4-S4. Additional births and missing births in the USA, 1950–2019. *Notes*: Areas=children that were only (pointing upward) or were not (pointing downward) born in the USA each year because the country did not experience the mortality conditions of the other Group of Seven countries beginning in 1950. *Source*: Authors' calculations based on data from United Nations World Population Prospects 2022.

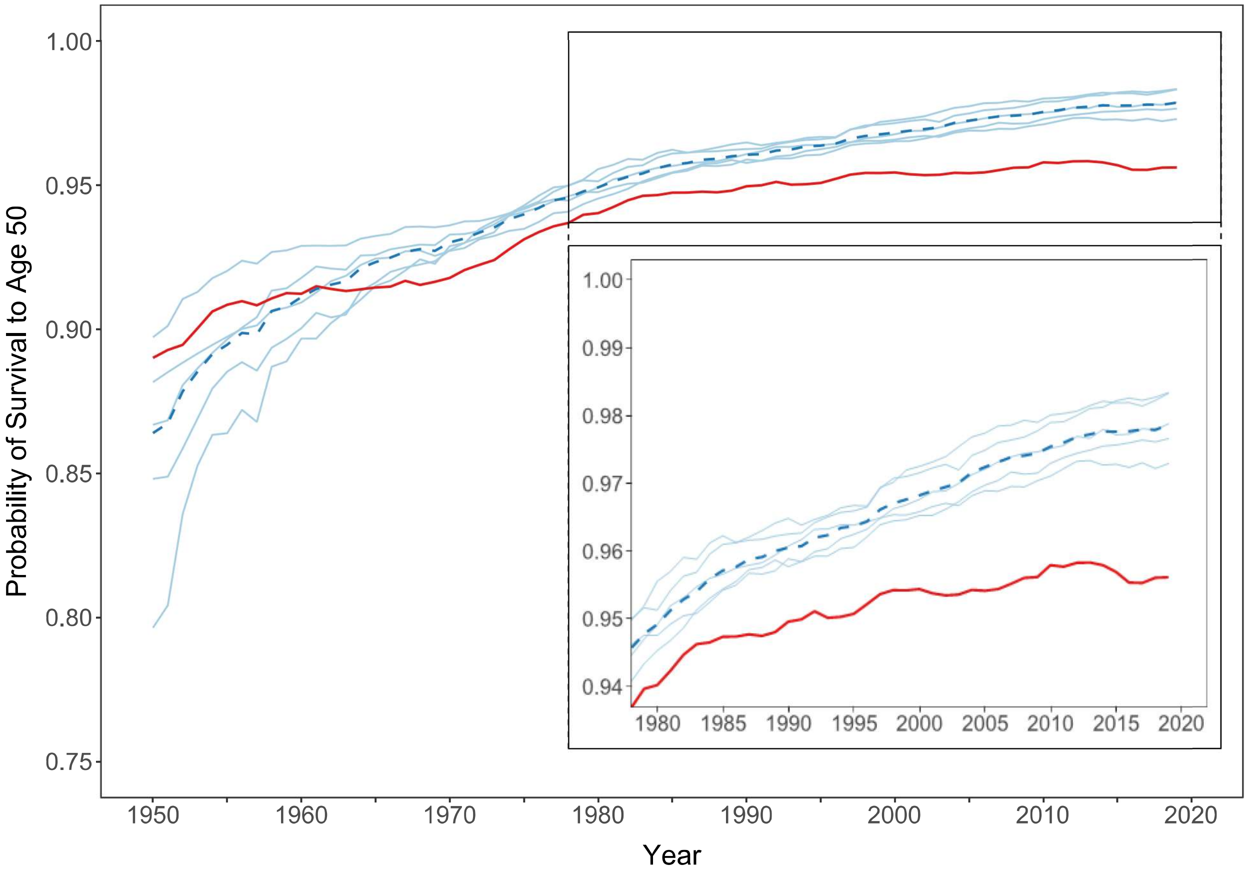

Figure 4-S5. Female probability of survival to age 50 (ℓ_{50}) in the USA and the five largest Western European countries, 1950–2019. *Notes*: Thick solid line=USA; thick dashed line=population-weighted average of the Western European countries; thin solid lines=country-specific trends for each of the Western European countries. Inset zooms in on period 1980–2019 for better readability. *Source*: Authors' calculations based on data from United Nations World Population Prospects 2022.

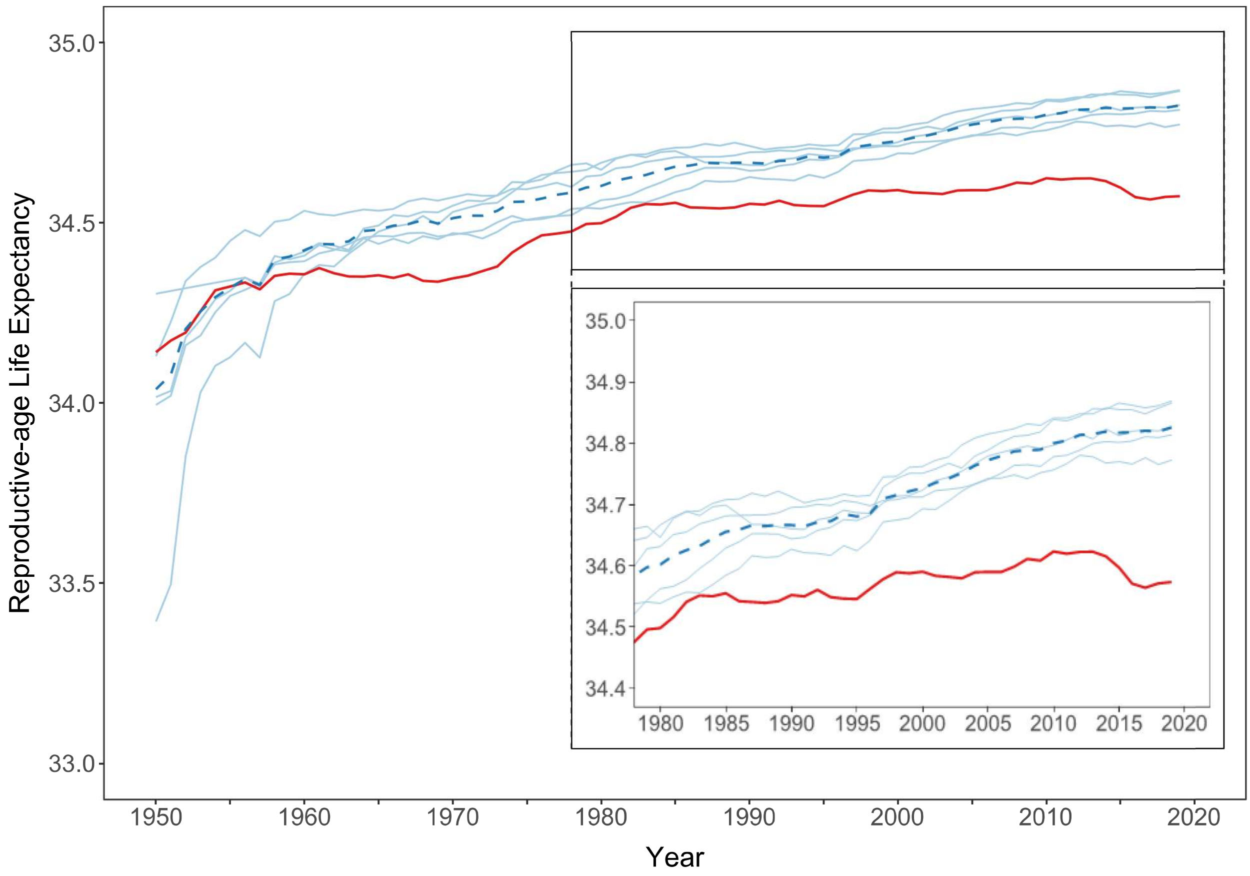

Figure 4-S6. Female reproductive-age life expectancy (RALE) in the USA and the five largest Western European countries, 1950–2019. *Notes*: Thick solid line=USA; thick dashed line=population-weighted average of the Western European countries; thin solid lines=country-specific trends for each of the Western European countries. Inset zooms in on period 1980–2019 for better readability. *Source*: Authors' calculations based on data from United Nations World Population Prospects 2022.

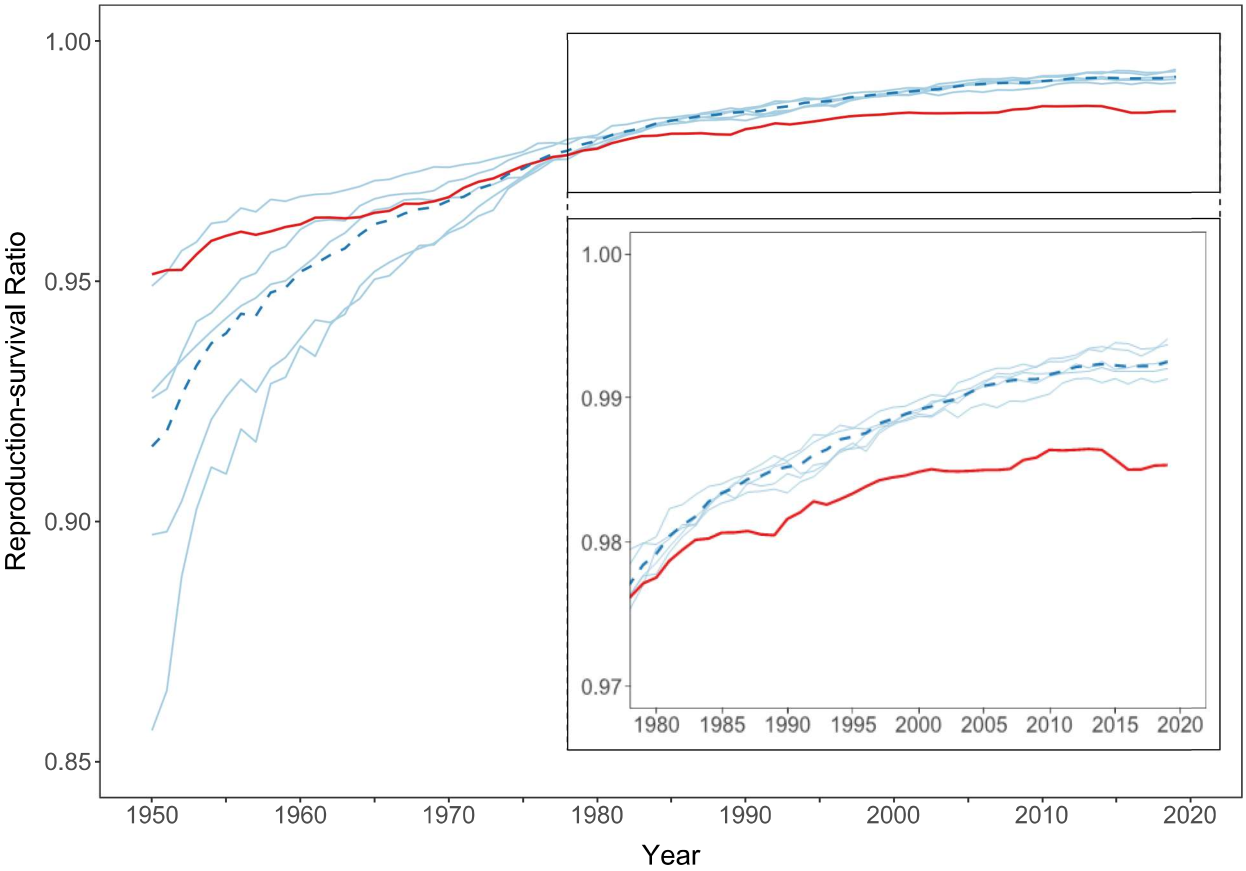

Figure 4-S7. Female reproduction–survival ratio (RSR) in the USA and the five largest Western European countries, 1950–2019. *Notes*: Thick solid line=USA; thick dashed line=population-weighted average of the Western European countries; thin solid lines=country-specific trends for each of the Western European countries. Inset zooms in on period 1980–2019 for better readability. *Source*: Authors' calculations based on data from United Nations World Population Prospects 2022.

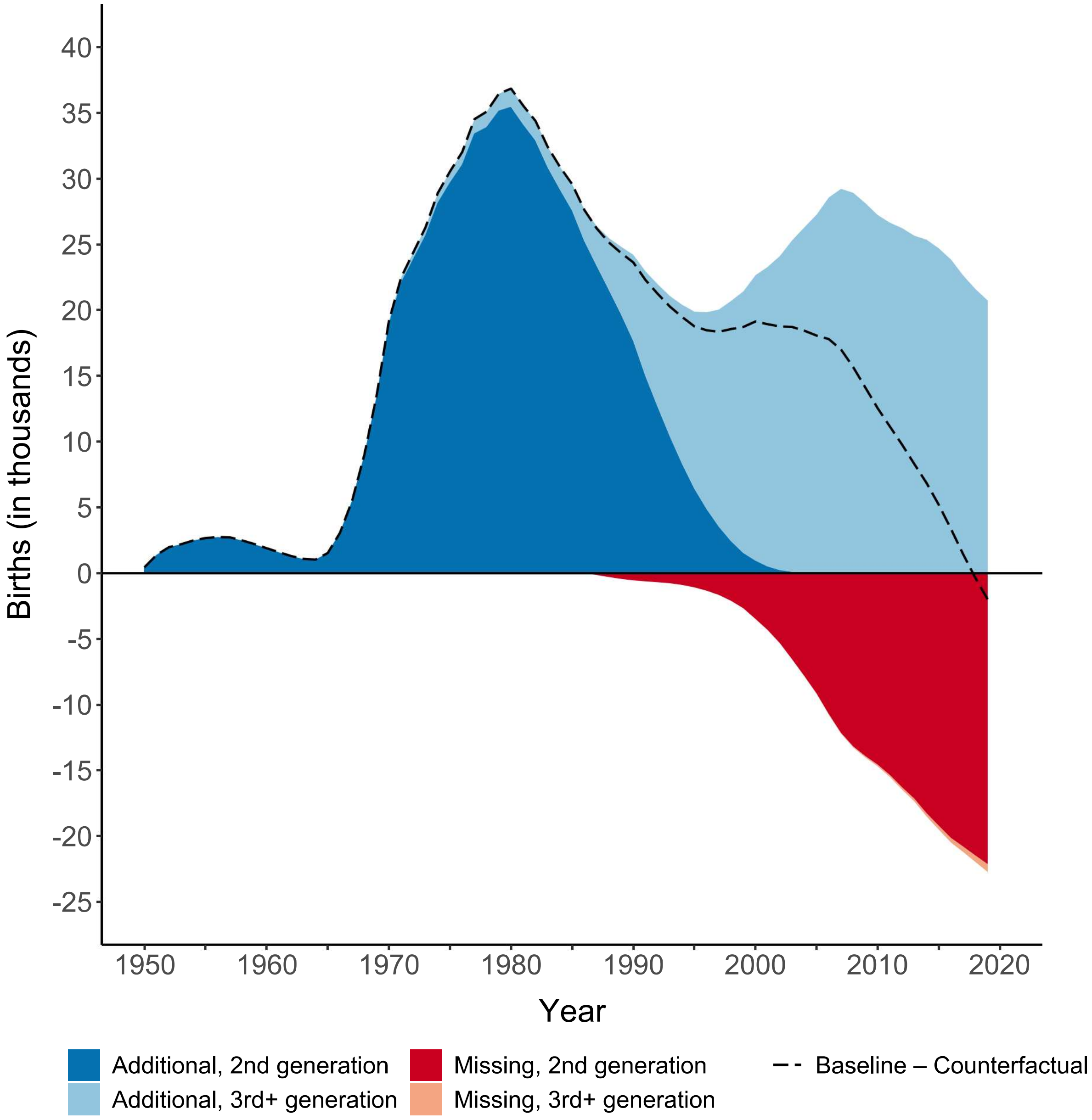

Figure 4-S8. Additional births and missing births in the USA, 1950–2019. *Notes*: Areas = children that were only (pointing upward) or were not (pointing downward) born in the USA each year because the country did not experience the mortality conditions of the five largest Western European countries beginning in 1950. *Source*: Authors' calculations based on data from United Nations World Population Prospects 2022.

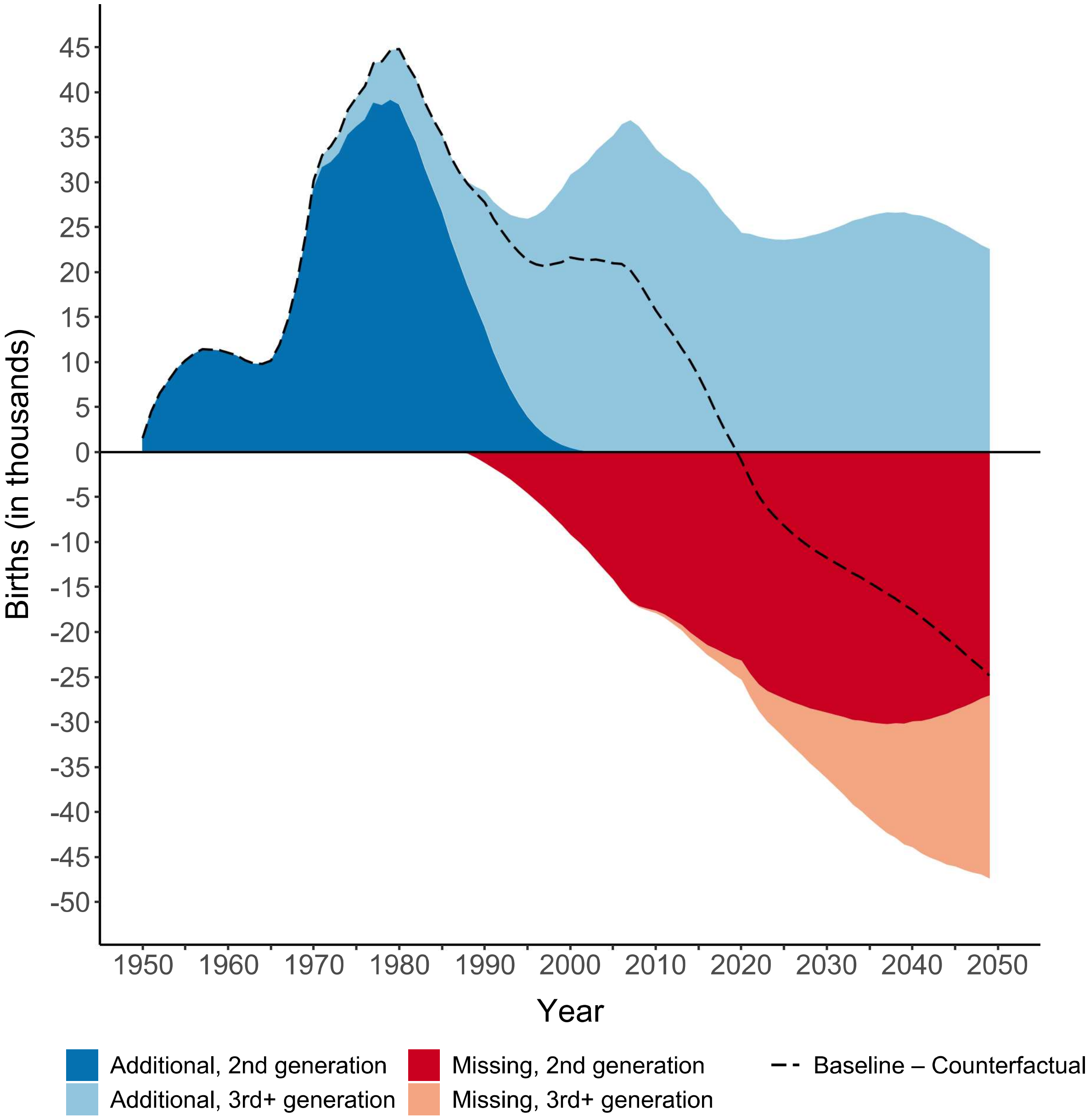

Figure 4-S9. Additional births and missing births in the USA, 1950–2049. *Notes*: Areas=children that were only (pointing upward) or were not (pointing downward) born in the USA each year because the country did not experience the mortality conditions of 21 other wealthy nations beginning in 1950. *Source*: Authors' calculations based on data from United Nations World Population Prospects 2022.

References

Arriaga, E. E. (1984). Measuring and explaining the change in life expectancies. *Demography*, *21*(1), 83–96. https://doi.org/10.2307/2061029

Bearak, J. M., Popinchalk, A., Beavin, C., Ganatra, B., Moller, A.-B., Tunçalp, Ö., & Alkema, L. (2022). Country-specific estimates of unintended pregnancy and abortion incidence: A global comparative analysis of levels in 2015–2019. *BMJ Global Health*, *7*(3), e007151. https://doi.org/10.1136/bmjgh-2021-007151

Billari, F. C. (2022). Demography: Fast and slow. *Population and Development Review*, *48*(1), 9–30. https://doi.org/10.1111/padr.12464

Bongaarts, J., & Guilmoto, C. Z. (2015). How many more missing women? Excess female mortality and prenatal sex selection, 1970–2050. *Population and Development Review*, *41*(2), 241–269. https://doi.org/10.1111/j.1728-4457.2015.00046.x

Bor, J., Stokes, A. C., Raifman, J., Venkataramani, A., Bassett, M. T., Himmelstein, D., & Woolhandler, S. (2023). Missing Americans: Early death in the United States—1933–2021. *PNAS Nexus*, *2*(6), pgad173. https://doi.org/10.1093/pnasnexus/pgad173

Canudas-Romo, V., Liu, L., Zimmerman, L., Ahmed, S., & Tsui, A. (2014). Potential gains in reproductive-aged life expectancy by eliminating maternal mortality: A demographic bonus of achieving MDG 5. *PLOS ONE*, *9*(2), e86694. https://doi.org/10.1371/journal.pone.0086694

Charles-Edwards, E., Wilson, T., Bernard, A., & Wohland, P. (2021). How will COVID-19 impact Australia's future population? A scenario approach. *Applied Geography*, *134*, 102506. https://doi.org/10.1016/j.apgeog.2021.102506

Finer, L. B., & Zolna, M. R. (2016). Declines in unintended pregnancy in the United States, 2008–2011. *New England Journal of Medicine*, *374*(9), 843–852. https://doi.org/10.1056/NEJMsa1506575

Gemmill, A., Berger, B. O., Crane, M. A., & Margerison, C. E. (2022). Mortality rates among U.S. women of reproductive age, 1999–2019. *American Journal of Preventive Medicine*, *62*(4), 548–557.

Gietel-Basten, S., Rotkirch, A., & Sobotka, T. (2022). Changing the perspective on low birth rates: Why simplistic solutions won't work. *BMJ*, *379*, e072670. https://doi.org/10.1136/bmj-2022-072670

González-Leonardo, M., & Spijker, J. (2022). The impact of Covid-19 on demographic components in Spain, 2020–31: A scenario approach. *Population Studies*. https://doi.org/10.1080/00324728.2022.2138521

Keilman, N., Tymicki, K., & Skirbekk, V. (2014). Measures for human reproduction should be linked to both men and women. *International Journal of Population Research*, *2014*, 908385. https://doi.org/10.1155/2014/908385

Lewes, F. M. M. (1984). A note on the origin of the net reproduction ratio. *Population Studies*, *38*(2), 321–324. https://doi.org/10.2307/2174080

Liu, A., Akimova, E. T., Ding, X., Jukarainen, S., Vartiainen, P., Kiiskinen, T., Koskelainen, S., Havulinna, A. S., Gissler, M., Lombardi, S., Fall, T., Mills, M. C., & Ganna, A. (2023). Evidence from Finland and Sweden on the relationship between early-life diseases and lifetime childlessness in men and women. *Nature Human Behaviour*. https://doi.org/10.1038/s41562-023-01763-x

Margerison, C. E., Roberts, M. H., Gemmill, A., & Goldman-Mellor, S. (2022). Pregnancy-associated deaths due to drugs, suicide, and homicide in the United States, 2010–2019. *Obstetrics & Gynecology*, *139*(2), 172–180.

Mehra, R., Boyd, L. M., Magriples, U., Kershaw, T. S., Ickovics, J. R., & Keene, D. E. (2020). Black pregnant women “get the most judgment”: A qualitative study of the experiences of Black women at the intersection of race, gender, and pregnancy. *Women's Health Issues*, *30*(6), 484–492. https://doi.org/10.1016/j.whi.2020.08.001

Moseson, H., Fix, L., Hastings, J., Stoeffler, A., Lunn, M. R., Flentje, A., Lubensky, M. E., Capriotti, M. R., Ragosta, S., Forsberg, H., & Obedin-Maliver, J. (2021). Pregnancy intentions and outcomes among transgender, nonbinary, and gender-expansive people assigned female or intersex at birth in the United States: Results from a national, quantitative survey. *International Journal of Transgender Health*, *22*(1–2), 30–41.

Moseson, H., Zazanis, N., Goldberg, E., Fix, L., Durden, M., Stoeffler, A., Hastings, J., Cudlitz, L., Lesser-Lee, B., Letcher, L., Reyes, A., & Obedin-Maliver, J. (2020). The imperative for transgender and gender nonbinary inclusion: Beyond women’s health. *Obstetrics & Gynecology*, *135*(5), 1059–1068.

Murphy, M. (2021). Use of counterfactual population projections for assessing the demographic determinants of population ageing. *European Journal of Population*, *37*(1), 211–242.

Muszyńska, M. M., & Rau, R. (2009). Falling short of highest life expectancy: How many Americans might have been alive in the twentieth century? *Population and Development Review*, *35*(3), 585–603.

National Academies of Sciences, Engineering, and Medicine. (2021). *High and rising mortality rates among working-age adults*. Washington, DC: The National Academies Press.

National Research Council. (2013). *U.S. health in international perspective: Shorter lives, poorer health*. Washington, DC: The National Academies Press.

Ní Bhrolcháin, M. (2011). Tempo and the TFR. *Demography*, *48*(3), 841–861. https://doi.org/10.1007/s13524-011-0033-4

Parr, N. (2021). A new measure of fertility replacement level in the presence of positive net immigration. *European Journal of Population*, *37*(1), 243–262. https://doi.org/10.1007/s10680-020-09566-w

Pennington, A., Maudsley, G., & Whitehead, M. (2023). The impacts of profound gender discrimination on the survival of girls and women in son-preference countries – a systematic review. *Health & Place*, *79*, 102942. https://doi.org/10.1016/j.healthplace.2022.102942

Preston, S. H., Heuveline, P., & Guillot, M. (2001). *Demography: Measuring and modeling population processes*. Malden, MA: Blackwell Publishers.

Preston, S. H., & Vierboom, Y. C. (2021). Excess mortality in the United States in the 21st century. *Proceedings of the National Academy of Sciences*, *118*(16), e2024850118. https://doi.org/10.1073/pnas.2024850118

Preston, S. H., & Wang, H. (2007). Intrinsic growth rates and net reproduction rates in the presence of migration. *Population and Development Review*, *33*(4), 657–666.

Sen, A. (1990). More than 100 million women are missing. *The New York Review of Books*, *37*(20), 61–66.

Shryock, H. S., Siegel, J. S., & Stockwell, E. G. (1998). *The methods and materials of demography* (Condensed ed., [15. print.]). New York: Academic Press.

Sobotka, T., & Lutz, W. (2011). Misleading policy messages derived from the period TFR: should we stop using it? *Comparative Population Studies*, *35*(3), 637–664. https://doi.org/10.12765/CPoS-2010-15

Starrs, A. M., Ezeh, A. C., Barker, G., Basu, A., Bertrand, J. T., Blum, R., Coll-Seck, A. M., Grover, A., Laski, L., Roa, M., Sathar, Z. A., Say, L., Serour, G. I., Singh, S., Stenberg, K., Temmerman, M., Biddlecom, A., Popinchalk, A., Summers, C., & Ashford, L. S. (2018). Accelerate progress—Sexual and reproductive health and rights for all: Report of the Guttmacher–Lancet Commission. *The Lancet*, *391*(10140), 2642–2692.

Stevenson, A. J. (2021). The pregnancy-related mortality impact of a total abortion ban in the United States: A research note on increased deaths due to remaining pregnant. *Demography*, *58*(6), 2019–2028.

Tilstra, A. M., Polizzi, A., Wagner, S., & Akimova, E. T. (2024). Projecting the long-term effects of the COVID-19 pandemic on U.S. population structure. *Nature Communications*, *15*(1), 2409. https://doi.org/10.1038/s41467-024-46582-4

United Nations, Department of Economic and Social Affairs, Population Division. (2022). *World Population Prospects 2022.* Https://Population.Un.Org/Wpp/.

Wang, F., Cai, Y., Shen, K., & Gietel-Basten, S. (2018). Is demography just a numerical exercise? Numbers, politics, and legacies of China's one-child policy. *Demography*, *55*(2), 693–719.

White, K. M., & Preston, S. H. (1996). How many Americans are alive because of twentieth-century improvements in mortality? *Population and Development Review*, *22*(3), 415–429. https://doi.org/10.2307/2137714

Woolhandler, S., Himmelstein, D. U., Ahmed, S., Bailey, Z., Bassett, M. T., Bird, M., Bor, J., Bor, D., Carrasquillo, O., Chowkwanyun, M., Dickman, S. L., Fisher, S., Gaffney, A., Galea, S., Gottfried, R. N., Grumbach, K., Guyatt, G., Hansen, H., Landrigan, P. J., … Venkataramani, A. (2021). Public policy and health in the

Trump era. *The Lancet*, *397*(10275), 705–753. https://doi.org/10.1016/S0140-6736(20)32545-9

Chapter 5
Discussion

Chapter word count: 5,817

5.1. Summary of this dissertation

5.1.1. Research aim of this dissertation

In the broader historical context, life expectancy trends in the 21st century have been unusual. Widespread slowdowns in life expectancy gains in the decade 2010–2019 were followed by extreme life expectancy losses during the COVID-19 pandemic. By 2023, few countries had fully recovered from the pandemic mortality shocks, let alone returned to their pre-pandemic life expectancy trajectories. Some countries, such as the United States of America (USA) and the United Kingdom (UK), have experienced particularly pronounced slowdowns, losses, and delayed recoveries in life expectancy and have fallen far behind in international life expectancy rankings.

To date, most demographic research has focused on changes in life expectancy within countries over time (the *stagnation* perspective) or on differences in the level of life expectancy between countries at a given point in time (the *shortfall* perspective), leaving a gap in our understanding of how these life expectancy *shortfalls* have changed over time (the *divergence* perspective). Moreover, most sociological, demographic, and epidemiological research on the exceptional life expectancy dynamics of recent years has focused on developments in the USA, missing worrisome trends in other countries such as the UK. As a result, our understanding of mortality trends outside the USA remains limited, especially how these trends have contributed to the rising shortfalls of life expectancy laggards from their better-performing peers. In addition, the existing literature has focused primarily on the *causes* of recent life expectancy trends, overlooking the fact that growing life expectancy shortfalls may have *consequences* beyond the premature death of individuals.

This dissertation aimed at assessing recent life expectancy trends in the USA and the UK relative to other low-mortality countries before, during, and after the COVID-19 pandemic in terms of their *causes*, as well as their *consequences* for population composition. It addressed two research questions across three empirical chapters, as shown in Box 5-1.

Box 5-1. Main research questions investigated in this dissertation.

1. A) How have external and substance-related mortality, cardiometabolic mortality, and COVID-19 mortality contributed to the growing life expectancy shortfall of the USA and the UK before, during, and after the COVID-19 pandemic?

   B) Which age groups drive the influence of external and substance-related mortality and cardiometabolic mortality on life expectancy divergence?

   C) What is the contribution of alcohol, drug, and suicide mortality ("deaths of despair") to the life expectancy divergence of the USA and the UK from other low-mortality countries?
2. How did the growing life expectancy divergence between the USA and the UK and other low-mortality countries affect population-level birth outcomes?

5.1.2. Main contributions of this dissertation

Drawing on classical demographic analysis, this dissertation made three main contributions to the literature. **First**, this dissertation emphasized the value of applying an underrepresented *divergence* perspective to the field of demography—in addition to the more common *stagnation* perspective. By combining a variety of up-to-date, high-quality data sources and state-of-the-art demographic decomposition and counterfactual methods, this dissertation argued (a) that both types of mortality trends—stagnation and divergence—are warning signs that population health is not developing as well as it could; and (b) that the *stagnation* and *divergence* perspectives often complement each other by leading to different—but not contradictory—conclusions about the *causes* and the *consequences* of recent life expectancy dynamics.

Second, following the *divergence* approach, this dissertation provided novel empirical evidence on the role of different age groups and causes of death in the widening life expectancy gaps between the USA and the UK and other low-mortality countries. Focusing on different time periods of varying lengths, it identified the contributions of external and substance-related mortality, cardiometabolic mortality, and COVID-19 mortality to life expectancy dynamics in the USA and the UK relative to other countries in the short, medium, and long term.

Third, building on the well-established "population renewal" framework and recent developments in "kinship demography," this dissertation underscored the importance of continued research efforts *across* the disciplinary subfields of demography. Guided by the concept of the *mortality–fertility nexus*, it highlighted how population-level mortality and fertility dynamics can affect each other and that a narrow focus on “excess mortality” does not capture the full consequences of life expectancy divergence.

In summary, by applying the *divergence* approach at the intersection of mortality and fertility research and across different geographical and historical contexts, this dissertation uncovered critical population dynamics in the USA and the UK that had previously gone unnoticed in the sociological, demographic, and epidemiological literature. The following subsection provides a detailed summary of the key findings and contributions of the three empirical chapters.

5.1.3. Summary of the empirical dissertation chapters

Using the proposed *divergence* perspective, the three empirical dissertation chapters provided new empirical insights into the *causes* and the *consequences* of the growing life expectancy shortfalls of the USA and the UK relative to their better-performing peers before, during, and after the COVID-19 pandemic.

Chapter 2 focused on England and Wales, two of the four constituent nations of the UK. A previous study highlighted the divergence of England Wales life expectancy from the median life expectancy in 22 other high-income countries between 2011 and 2016 (Leon et al., 2019). While Leon et al. identified adult ages as important contributor to the growing life expectancy shortfall of England and Wales relative to the median, it was unclear whether this divergence would be observed more universally when England and Wales was compared to individual countries. Moreover, while there has been ample research on the causes of death underlying the life expectancy stagnation of England and Wales over time, the drivers of its divergence from other countries were less known.

Chapter 2 decomposed life expectancy gaps between England and Wales and 20 individual high-income countries (19 European countries + USA) in 2019 using the contour method. Using this method, Chapter 2 split the life expectancy gaps in 2019 into three additive components: (1) due to mortality differences that already existed in 2011; (2) due to mortality trends in England and Wales in 2011–2019; (3) due to mortality trends in the peer country in 2011–2019. In line with the focus of this dissertation on growing life expectancy shortfalls, Chapter 2 provided an in-depth examination of the country-specific trend components.

Chapter 2 found that life expectancy gaps between England and Wales and most peer countries worsened for both sexes in 2011–2019, except when compared to the USA and the fellow UK constituent nations Northern Ireland and Scotland. While most peer countries saw sustained mortality improvements across all adult age groups, England and Wales saw virtually no improvements in the age group 15–44 and only minor improvements in the age group 45–64. External and substance-related mortality improved in most peer countries but increased in England and Wales, while cardiometabolic mortality improved less in England and Wales and dementia mortality increased more.

Before this dissertation, it was not clear how COVID-19 and non-COVID-19 causes of death contributed to life expectancy dynamics during the COVID-19 pandemic in an internationally comparative perspective. Using cause-of-death data for 24 countries, **Chapter 3** identified the contributions to changes in life expectancy before (2015–2019) and during (2019–2020, 2020–2021, and 2021–2022) the pandemic. Chapter 3 found that mortality from causes of death other than COVID-19 increased in many countries during the pandemic, often driven by a rise in external and substance-related as well as cardiovascular mortality.

An **Addendum to Chapter 3** utilized these decomposition results to also estimate the contributions of external and substance-related mortality, cardiovascular mortality, and COVID-19 mortality to (a) the life expectancy stagnation of the USA and England and Wales during the period 2019–2022; and (b) the growing life expectancy gaps between the USA and England and Wales relative to Sweden before (2015–2019) and during (2019–2022) the pandemic. In the Addendum to Chapter 3, COVID-19 mortality emerged as the most important cause of death for male life expectancy stagnation in the USA, whereas external and drug-related mortality combined was the most important cause for divergence from Sweden before and during the pandemic. In contrast, cardiometabolic mortality was the most important cause for both stagnation and divergence among males in England and Wales in both periods, even exceeding the role of COVID-19 mortality.

Finally, **Chapter 4** built on the analysis by Polizzi and Dowd (2024) reviewed in the Introduction of this dissertation, which demonstrated that working-age mortality was the main driver of the life expectancy divergence of the USA from other low-mortality countries in 2010–2019. Using a counterfactual population projection approach and fertility indicators from the population renewal framework, Chapter 4 estimated the number of “missing births” in the USA: children that were never born because their potential mothers or (great-)grandmothers died prematurely between 1950–2049. Following Bor et al. (2023), “early death” in Chapter 4 was defined as all deaths before age 50 that could have been avoided if the USA had experienced the average mortality trajectory of 21 “other wealthy nations.” Chapter 4 estimated that around 200,000 children were not born in the decade 2010–2019 alone because their potential mothers or (great-)grandmothers died prematurely. Based on forecasts of the USA life expectancy shortfall into the post-pandemic period, the number of "missing births" is expected to increase even further by 2050.

In summary, this dissertation demonstrated the value of adopting a *divergence* perspective alongside a *stagnation* perspective when examining the *causes* and the *consequences* of recent life expectancy trends in the USA and the UK. External and substance-related mortality and cardiometabolic mortality emerged as important *causes* of life expectancy divergence in the USA and the UK relative to better performing peer countries—even if they were not always the most important factors in life expectancy stagnation over time. Moreover, consistent with the concept of the *mortality–fertility nexus*, this dissertation found that the divergent trends in working-age and reproductive-age mortality in the USA have had important implications for birth outcomes at the population level. These new empirical findings and conceptual contributions of this dissertation will be important for future theoretical and empirical work in sociology, demography, and epidemiology, as I discuss next.

5.2. Discussion of the main findings of this dissertation

5.2.1. The divergence *perspective*

The application of the *divergence* perspective is a unifying element across the three empirical chapters of this dissertation. The *stagnation* and *divergence* perspectives use different benchmarks to assess life expectancy trends in a population, assuming either that life expectancy (a) could improve like in an earlier period (*stagnation*); or (b) could improve like in other populations (*divergence*). Both benchmarks are meaningful and can help identify warning signs that population health may not be developing as well as it could.

While at first glance, it appears that the two approaches should identify similar age groups and causes of death as most important, often enough, this may not be the case. The *stagnation* perspective picks up mortality trends that vary across time, whereas the *divergence* perspective picks up mortality trends that vary across populations. Thus, from the *divergence* perspective, mortality trends that are shared across populations, such as the international slowdowns in retirement-age mortality shown by Polizzi & Dowd (2024), are assumed to be less problematic and are often not identified as critical to life expectancy dynamics. The case of the COVID-19 pandemic illustrates a potential shortcoming of the *divergence* perspective, where an exceptional mortality development was identified as relatively less important because it was shared across populations, as illustrated in the Addendum to Chapter 3. In contrast, the *stagnation* perspective may overstate the importance of less problematic mortality trends just because they represent a departure from previous trajectories, whereas the approach will correctly identify mortality shocks as relevant even if they are shared across populations. Given the different perspectives of the *stagnation* and *divergence* approaches, the joint application of the two approaches should become more common practice in demographic analysis.

The application of the *divergence* perspective in demography has been facilitated by the development of new decomposition methods, such as the contour method applied in Chapter 2. The use of this method is still limited in demographic research, possibly due to difficulties related to the presentation and visualization of the more complex decomposition output. An extension of the contour method that identifies contributions from both age and cause of death has only recently been developed, and this dissertation contains the first empirical application of this two-dimensional contour decomposition. While the two-dimensional method is computationally intensive and only allows for the inclusion of a few broad cause-of-death categories, less computationally demanding algorithms can also be used to identify the age- and cause-specific contributions to changing life expectancy gaps, as shown in the Addendum to Chapter 3. While these simpler algorithms may be less appropriate if the aim is to obtain the *additive* contributions of baseline mortality differences *and* mortality trends—like in the contour decomposition—they may lead to similar conclusions if the focus is solely on the trend component(s) (Abrams et al., 2021).

In addition to decomposition analysis, the *divergence* perspective may also be applied within a counterfactual framework, as in Polizzi & Dowd (2024). To my knowledge, there has been no systematic comparison of different decomposition and counterfactual approaches to identify the *causes* of life expectancy divergence. However, existing counterfactual and decomposition studies appear to point to similar conclusions about the relative importance of different age groups and causes of death in life expectancy divergence (Ho, 2019, 2022). This suggests that both decomposition and counterfactual approaches can be used when investigating the *causes* of growing life expectancy shortfalls.

5.2.2. Ages and causes of death

Working ages. With very few exceptions, working-age mortality generally improved in low-mortality countries during 2010–2019, but stagnated or increased in the USA and the UK (see Figure 1-4, for example). Consistent with the unique strength of the *divergence* approach to identify internationally exceptional mortality trends, the contributions of working ages to the international life expectancy rankings of the USA and the UK were substantively larger than suggested by the *stagnation* perspective. This underscores the added value of benchmarking mortality developments against those seen in other countries. The working-age mortality trends in the USA and the UK are clearly concerning. Working-age mortality in these two countries ranked nowhere near the top in international comparisons, eliminating potential “floor effects”—where mortality levels are already so low that further reductions cannot be expected—as excuse for these problematic trends. In addition, working-age mortality even *increased* in the USA in 2010–2019, an altogether unjustifiable development.

Retirement ages. For retirement-age mortality, I observed patterns opposite to those for working-age mortality. The contributions of these age groups were large for life expectancy change and stagnation, but smaller for life expectancy divergence—although mortality improvements were still smaller in the USA and the UK than in the comparison countries. Slowdowns in mortality improvements at retirement ages in 2010–2019 were more widely observed across high-income countries, and slowdowns in the USA and the UK were not too obviously different from those in other countries (see Figure 1-4), explaining their smaller contributions to divergence vs. stagnation. Because improvements in retirement-age mortality were small across the board, the implicit assumption of the *divergence* approach is that they should be seen as less problematic, even if they represent less favorable trends relative to an earlier decade.

Based on forecasts of historical mortality rates, Djeundje et al. (2022) found that slowdowns in mortality improvements above age 50 would have been expected in many countries after 2010. However, observed slowdowns were often even smaller than forecast in their models. This implies that the *divergence* perspective proposed in this dissertation may understate the importance of the slowdowns in mortality improvements at retirement ages. This underscores again the benefit of applying the *stagnation* and *divergence* perspectives *jointly* to better assess life expectancy trends. As discussed below, several *causes* of the extraordinary slowdowns in mortality improvement at retirement ages in high-income countries have been proposed. However, we still require a better understanding of these *causes* and an assessment of how problematic the recent slowdowns in retirement-age mortality really are in a historical perspective.

External and substance-related mortality. This dissertation focused on recent dynamics in external and substance-related as well as cardiometabolic mortality and their role for life expectancy stagnation and divergence. Changes in external and substance-related mortality in the USA and the UK have mostly been concentrated at working ages. As a result, trends in external and substance-related mortality mirrored trends in all-cause mortality for that age group: while external and substance-related mortality increased in the USA and the UK in 2010–2019, most peer countries saw continued improvements. Thus, trends in external and substance-related mortality generally contributed more to life expectancy divergence than to life expectancy stagnation in the USA and the UK.

Research on the USA has often analyzed trends in deaths from alcohol, drug, and suicide mortality together, arguing that they reflect “deaths of despair” (Case & Deaton, 2021). Some other work has challenged the usefulness of a joint analysis of “deaths of despair,” arguing that the three causes of death have different aetiologies and follow different trends across population subgroups (Masters et al., 2018; Simon & Masters, 2021; Tilstra et al., 2021). For this reason, my analysis of these three causes of death followed two strategies:

(a) "deaths of despair" were analyzed together with other external causes as "external and substance-related causes" (Chapter 2); or (b) alcohol, drug, and suicide mortality and mortality from other external causes were analyzed separately (Chapter 3). The analyses in Chapter 3 and the Addendum to Chapter 3 support arguments that "deaths of despair" should be analyzed separately. The three causes of death did not always trend in the same direction and showed different patterns for males and females, even in an economically challenging period like the COVID-19 pandemic. Particularly concerning were the large increases in alcohol-related mortality during 2019–2022 across countries, while corresponding increases in drug and suicide mortality were not always seen. Further research on how closely alcohol, drug, and suicide mortality are tied to short- or long-term feelings of "despair" (Gutin et al., 2023) and which role "structural determinants of health" (Bambra et al., 2019), such as fiscal austerity (Walsh & McCartney, 2025), financial relief (Simon & Masters, 2024), and regulation of prescriptions drugs (Simon & Masters, 2024), play for short- or long-term trends of these causes of death remains necessary.

Trends in "deaths of despair" in the USA were overwhelmingly driven by drug-related deaths. My findings suggest that the role of drug-related mortality has not lost its relevance for explaining the life expectancy divergence of the USA from better-performing peers. In the period 2003–2013, drug-related mortality alone explained on average 34% (females) and 19% (males) of the widening life expectancy gap between the USA and 17 high-income countries (Ho, 2019). Similarly, I found that, the contribution of drug-related mortality to the widening gap with Sweden was 18.0% (female) and 40.7% (male) in 2015–2019. In 2019–2022, the respective contributions were 16.2% and 24.9%. There are now some signs that drug-related mortality is levelling off in the USA and Scotland (Angus et al., 2023; Spencer et al., 2024), though the mechanisms behind this trend change are not well explored yet. Continuous monitoring of the role of drug-related mortality for life expectancy divergence between the USA and the UK and other countries will remain important in the future.

Cardiometabolic mortality. In the UK, slowdowns in cardiometabolic mortality have also contributed to adverse working-age mortality trends. A previous study found that slowdowns in mortality improvements in coronary heart disease below age 54 were particularly pronounced in the UK and hypothesized that the rising prevalence of obesity and diabetes across birth cohorts may be responsible for this trend (Nichols et al., 2013). Another study found that shifts in the BMI distribution over the last decades may have substantially contributed to life expectancy stagnation in the UK (Walsh et al., 2022). Similarly, research on the USA has suggested that the high obesity prevalence in the country may explain a large part of its (growing) shortfall from life expectancy levels seen in other countries (Olshansky et al., 2005; Preston & Stokes, 2011). Limited additional gains from smoking reductions in the USA and the UK, where smoking prevalence is already quite low, have also been suggested as explanations for the slowdown in cardiometabolic mortality improvements, including at retirement ages (Lopez & Adair, 2019). However, existing empirical evidence does not provide strong evidence for the smoking hypothesis so far (Acosta et al., 2022). Some authors have also argued for potentially detrimental effects of financial hardship on cardiometabolic mortality as a result of financial austerity in the UK, potentially mediated through stress and related behavioral pathways (Walsh & McCartney, 2025). Potential floor effects due to reaching low cardiometabolic mortality are most likely not an explanation, since some countries with lower cardiometabolic mortality levels than the USA and the UK have seen continued large improvements (Ho & Hendi, 2024).

Cardiometabolic mortality trends during the COVID-19 pandemic, and their contributions to life expectancy stagnation and divergence, are hard to interpret. Evidence from the USA points to substantial misreporting of COVID-19 deaths as cardiometabolic deaths (Paglino et al., 2024). However, we still lack comparable evidence from other countries. Moreover, previous COVID-19 infection is linked to higher risk of incident cardiovascular disease (Xie et al., 2022), suggesting that improvements in cardiometabolic mortality may continue to stall in the future, with heterogeneous trends across countries reflective of their COVID-19 burden. On the other hand, development of GLP-1 agonist drugs for diabetes and weight loss may contribute to a reduction in obesity prevalence and cardiometabolic mortality in the future (Mehta & Dowd, 2024).

Overall, the contributions of cardiometabolic mortality to recent life expectancy trends are an active field of research (Abrams et al., 2021; Acosta et al., 2022; Mehta et al., 2020). Nonetheless, many open questions remain, particularly about the contributions of cardiometabolic mortality to life expectancy changes during the COVID-19 pandemic. Until more reliable data become available, including internationally comparable cohort data and data on cardiometabolic risk factors, conclusive statements about the drivers of recent cardiometabolic mortality trends will remain difficult (Dowd et al., 2024).

5.2.3. The mortality–fertility nexus

Chapter 4 of this dissertation used formal demographic indicators and counterfactual population projections to quantify the mortality–fertility nexus. Formal demographic indicators of the mortality–fertility nexus have a long history in demography but are rarely used in low-mortality contexts because mortality before the end of the reproductive period is often considered too low to affect these indicators in meaningful ways. While this may be true in absolute terms, the negative impact of early mortality on fertility in the USA is large compared to other high-income countries. Thus, one important contribution of Chapter 4 of this dissertation is to argue for the more widespread use of mortality–fertility indicators, such as the reproduction–survival ratio, and counterfactual methods to identify the indirect effects of mortality on population-level birth outcomes—especially from a comparative *shortfall* perspective.

The usefulness of mortality–fertility indicators is not restricted to mortality analysis. A recent study by Baudisch & Polizzi (2024) compared mortality–fertility indicators to classical fertility indicators that do not incorporate mortality information. They found that classical fertility indicators provide biased estimates of fertility age patterns at the population level. Thus, the more widespread use of mortality–fertility indicators from the population renewal framework offers the potential to improve the accuracy of demographic analysis across disciplinary subfields.

In a similar vein, a recent follow-up study to Chapter 4 of this dissertation applied a *stagnation* perspective to estimate the *consequences* of the COVID-19 pandemic for population composition. Assuming that demographic conditions had continued to develop like they would have in the absence of the COVID-19 pandemic, Tilstra et al. (2024) estimated the number of people missing from the USA population because of the pandemic's joint effects on mortality, fertility, *and* migration. Inclusion of migration into the mortality–fertility nexus proposed in Chapter 4 represents an important advancement and a step towards an even more holistic demographic analysis. For example, some previous work has extended indicators from the population renewal framework, such as the net reproduction rate (NRR), to account for the influence of migration (Preston & Wang, 2007). Along with Chapter 4 of this dissertation, this work emphasizes the importance of considering the interplay between different demographic processes when assessing how change in one process affects population composition.

5.3. Evaluation of data and methods

This dissertation took a largely historical perspective—using mortality data observed through 2022—to understand drivers of mortality trends in the USA and the UK relative to other low-mortality countries. This focus on past mortality trends is an inherent characteristic of the discipline of demography. We are only able to analyze mortality trends after the underlying deaths have been registered by national authorities and the associated death rates have been distributed through openly accessible databases. Several authors have criticized this delay in data reporting and dissemination for hindering timely analysis of and response to short-term changes in population health (Ho & Hendi, 2018).

For example, while Chapter 2 argued to go beyond comparisons using median life expectancy as the only benchmark, the lack of available international cause-of-death data through 2022 restricted the analysis in the Addendum to Chapter 3 to a comparison of the USA and the UK with Sweden. Thus, the results of this *divergence* analysis may have been driven by the specific patterns of life expectancy change in Sweden. It remains to be seen whether the findings presented in the Addendum to Chapter 3 will generalize beyond the specific comparison with Sweden as more recent data on causes of death become available.

However, even if more timely cause-of-death data were available, international analyses of these data would be affected by cross-country differences in reporting, that is, the propensity to assign a particular cause of death to a particular decedent. In addition, the

World Health Organization Mortality Database—probably the most widely used database for comparative cause-of-death analysis—provides data only by underlying cause. Thus, comparative analysis is further confounded by differences in the propensity to assign a particular cause of death as underlying vs. contributory.

For example, the increase in dementia mortality seen for England and Wales and the 20 comparison countries in Chapter 2 was most likely due to changes in dementia reporting (dementia being more common on the death certificate) and coding practices (dementia being more common as the underlying cause of death). Since the additional dementia deaths would have otherwise been assigned to different causes of death, such as cardiometabolic mortality, trends over time in these other causes may have appeared more favorably than they actually were. Changes in cause-of-death reporting may distort the results of *divergence* analysis if they occur at different speeds across populations. For example, a country with an early increase in dementia awareness may reach a point where cardiometabolic deaths are no longer coded as dementia deaths sooner than other countries. After this point, cardiometabolic mortality trends for this country may appear less favorable in international comparisons. Whether this phenomenon accounts for some of the unfavorable trends in cardiometabolic mortality in the USA or the UK compared with other high-income countries would be an interesting avenue for further research.

Variations in cause-of-death reporting also emerged as a potential source of bias in the analysis of mortality trends during the COVID-19 pandemic in Chapter 3. Research based on USA data suggests that COVID-19 deaths were often assigned to other natural causes, such as CVD. Consistent with this, I observed large life expectancy losses in the USA and the UK due to non-COVID-19 mortality, particularly CVD mortality. Even larger declines due to CVD were observed in some Central and Eastern European countries such as Bulgaria. In contrast, other countries showed continuous improvements in CVD mortality. Whether these patterns reflect differences in COVID-19 testing capacity, willingness to assign COVID-19 as the underlying cause of death, and/or true increases in CVD mortality cannot be determined from the data in Chapter 3 alone. This highlights the need for further comparative analyses of the propensity to code COVID-19 deaths as due to other causes and to adjust the analysis of life expectancy change, stagnation, and divergence based on these findings to reveal the true burden of COVID-19 and non-COVID-19 mortality.

Because of the aforementioned lag in data dissemination, the extraordinary life expectancy trends before and during the COVID-19 pandemic are still poorly understood, especially from a comparative perspective. Curiosity about what's coming and what to prepare for have led demographers and actuaries to develop sophisticated methods for forecasting mortality, fertility, and migration conditions into the future (Basellini et al., 2023; Booth & Tickle, 2008). Chapter 4 of this dissertation used forecasts from the United Nations World Population Prospects to estimate the long-term *consequences* of the growing USA life expectancy shortfall. However, most forecasting methods are extrapolative, meaning that they largely assume a continuation of past mortality trends. The data used in Chapter 4 explicitly include the assumption that life expectancy will return to its pre-pandemic trajectory within a few years after the COVID-19 pandemic. Available evidence suggests that life expectancy in many countries had not returned to pre-pandemic levels by the end of 2023 (Huang et al., 2024). Moreover, the return to pre-pandemic levels of life expectancy appears to be somewhat slower for the USA than for other high-income countries (Schöley et al., 2022). At the time of writing this dissertation—in January 2025—it is still difficult to know whether this had changed by 2024. If USA life expectancy remains below the levels projected by the United Nations, the estimates of the mortality-related fertility loss in Chapter 4 may be too conservative. Deviations from forecasted mortality trends could also be exacerbated by unanticipated deteriorations in population health in the future, such as a further escalation of the opioid crisis or the potential negative health consequences of a second Donald Trump presidency (Woolhandler et al., 2021). At the time of writing this dissertation, there is also a growing concern that President Trump may restrict federal funding for population health research as well as the dissemination of timely population health data. To the best of their ability, demographers should continue their research within these constraints to draw attention to a potential further deterioration of population health and its consequences for population composition in the post-pandemic era.

The individual dissertation chapters discussed potential legal, political-economic, and commercial drivers (Montez et al., 2021) of the life expectancy divergence of the USA (e.g., overprescription of opioids) and the UK (e.g., fiscal austerity) from their better-performing peers. However, this dissertation did not empirically test these factors or provide an assessment of their relative importance. As such, this dissertation is predominantly concerned with the "symptoms" (Zajacova & Montez, 2017) of poor population health. Investigating the "structural determinants" (Bambra et al., 2019) of the growing life expectancy shortfalls of the USA and the UK will require different (individual-level) data and methods than those used in this dissertation but will further aid our understanding of the manifold factors causing life expectancy in some countries to lag behind, as well as the consequences that these growing life expectancy shortfalls have for population-level outcomes, such as birth counts.

Future research on the *causes* and the *consequences* of growing population health shortfalls will also need to consider additional indicators beyond life expectancy at birth. While period life expectancy is one of the most widely used indicators of population health, it only takes into account mortality information, whereas health is a more complex construct that can be measured using objective data (e.g., diagnosed diseases) or self-reports of individuals (Wu et al., 2013). In the USA and the UK, improvements in healthy life expectancy, the expected number of years spent in good health, have not kept pace with improvements in life expectancy (Permanyer & Bramajo, 2023; Welsh et al., 2021), suggesting that people in these two countries are spending an increasing proportion of their lives unhealthy and that the population health shortfalls in these two countries are potentially even larger than shown in this dissertation.

Through examining growing life expectancy shortfalls and the *causes* and the *consequences* of why some countries are doing so much worse than others, this dissertation took a quite pessimistic perspective. However, it is equally important to explore more optimistic perspectives, such as why some countries are doing exceptionally well and converging with previously better-performing peers. For example, Figure 1-1 in the Introduction shows that life expectancy at birth in the Republic of Korea increased by about three years between 2010 and 2019, moving South Korea from 18th to 5th place among the 37 countries in the Human Mortality Database. In addition, the Republic of Korea experienced low mortality from COVID-19 in 2020 and 2021 (Figure 1-2). Demographers are only beginning to understand the reasons for Korea's exceptional life expectancy improvement (Yang et al., 2010). The *divergence* perspective proposed in this dissertation, combined with the high-quality cause-of-death data and state-of-the-art decomposition methods, could also be used to identify the factors relevant to Korea's rapid gains in life expectancy relative to other countries. Knowledge of these factors could potentially help life expectancy laggards such as the USA and the UK close existing gaps with their better-performing peers.

To summarize, this dissertation used a previously underutilized *divergence* perspective in combination with the most recent mortality data available at the time of writing to provide novel empirical evidence on the *causes* and the *consequences* of growing life expectancy shortfalls in the USA and the UK. Questions about some of the mortality trends uncovered in this thesis remain, but these will require more up-to-date, internationally comparable data on multiple causes of death, preferably at the individual rather than the population level. Thus, this dissertation serves as starting point for important future sociological, demographic, and epidemiological work on mortality trends among life expectancy laggards such as the USA and the UK, but also among life expectancy leaders such as Japan, Hong Kong, and the Republic of Korea.

5.4. Conclusion

The USA and the UK are in the midst of various social and mortality crises. Population health in these countries is deteriorating—or at least improving more slowly than in comparable countries—claiming many preventable deaths every day. If anything, the COVID-19 pandemic has only exacerbated these trends. Better life expectancy levels have long been achievable, and former life expectancy laggards in Central and Eastern Europe and Asia have proven that rapid gains in life expectancy are possible. The road to better population health may be long and require additional public health efforts. This dissertation presented novel and robust evidence on the factors currently keeping the USA and the UK from achieving better life expectancy levels faster. Hopefully, we will soon be able to investigate the *causes* and *consequences* of the extraordinarily rapid reductions in the life expectancy shortfalls of these two countries.

References

Abrams, L. R., Myrskylä, M., & Mehta, N. K. (2021). The growing rural–urban divide in US life expectancy: Contribution of cardiovascular disease and other major causes of death. *International Journal of Epidemiology*, *50*(6), 1970–1978. https://doi.org/10.1093/ije/dyab158

Acosta, E., Mehta, N., Myrskylä, M., & Ebeling, M. (2022). Cardiovascular mortality gap between the United States and other high life expectancy countries in 2000–2016. *The Journals of Gerontology: Series B*, *77*(Supplement_2), S148–S157. https://doi.org/10.1093/geronb/gbac032

Angus, C., Buckley, C., Tilstra, A. M., & Dowd, J. B. (2023). Increases in 'deaths of despair' during the COVID-19 pandemic in the United States and the United Kingdom. *Public Health*, *218*, 92–96. https://doi.org/10.1016/j.puhe.2023.02.019

Bambra, C., Smith, K. E., & Pearce, J. (2019). Scaling up: The politics of health and place. *Social Science & Medicine*, *232*, 36–42. https://doi.org/10.1016/j.socscimed.2019.04.036

Basellini, U., Camarda, C. G., & Booth, H. (2023). Thirty years on: A review of the Lee–Carter method for forecasting mortality. *International Journal of Forecasting*, *39*(3), 1033–1049. https://doi.org/10.1016/j.ijforecast.2022.11.002

Baudisch, A., & Polizzi, A. (2024). *An integrated formal demographic fertility framework*. SocArXiv. https://doi.org/10.31235/osf.io/mr726

Booth, H., & Tickle, L. (2008). Mortality modelling and forecasting: A review of methods. *Annals of Actuarial Science*, *3*(1–2), 3–43. https://doi.org/10.1017/S1748499500000440

Bor, J., Stokes, A. C., Raifman, J., Venkataramani, A., Bassett, M. T., Himmelstein, D., & Woolhandler, S. (2023). Missing Americans: Early death in the United States—1933–2021. *PNAS Nexus*, *2*(6), pgad173. https://doi.org/10.1093/pnasnexus/pgad173

Case, A., & Deaton, A. (2021). *Deaths of despair and the future of capitalism*. Princeton, NJ, & Oxford, UK: Princeton University Press.

Djeundje, V. B., Haberman, S., Bajekal, M., & Lu, J. (2022). The slowdown in mortality improvement rates 2011–2017: A multi-country analysis. *European Actuarial Journal*, *12*, 839–878. https://doi.org/10.1007/s13385-022-00318-0

Dowd, J. B., Polizzi, A., & Tilstra, A. M. (2024). Progress stalled? The uncertain future of mortality in high-income countries. *Population and Development Review*. https://doi.org/10.1111/padr.12687

Gutin, I., Copeland, W., Godwin, J., Mullan Harris, K., Shanahan, L., & Gaydosh, L. (2023). Defining despair: Assessing the multidimensionality of despair and its association with suicidality and substance use in early to middle adulthood. *Social Science & Medicine*, *320*, 115764. https://doi.org/10.1016/j.socscimed.2023.115764

Ho, J. Y. (2019). The contemporary American drug overdose epidemic in international perspective. *Population and Development Review*, *45*, 7–40. https://doi.org/10.1111/padr.12228

Ho, J. Y. (2022). Causes of America's lagging life expectancy: An international comparative perspective. *The Journals of Gerontology: Series B*, *77*(Supplement_2), S117–S126. https://doi.org/10.1093/geronb/gbab129

Ho, J. Y., & Hendi, A. S. (2018). Recent trends in life expectancy across high income countries: Retrospective observational study. *BMJ*, *362*, k2562. https://doi.org/10.1136/bmj.k2562

Ho, J. Y., & Hendi, A. S. (2024). Inequalities in life expectancy and cardiometabolic disease mortality across and within high-income countries. *Cell Metabolism*, *36*(2), 224–228. https://doi.org/10.1016/j.cmet.2023.11.002

Huang, G., Guo, F., Liu, L., Taksa, L., Cheng, Z., Tani, M., Zimmermann, K. F., Franklin, M., & Silva, S. S. M. (2024). Changing impact of COVID-19 on life expectancy 2019–2023 and its decomposition: Findings from 27 countries. *SSM - Population Health*, *25*, 101568. https://doi.org/10.1016/j.ssmph.2023.101568

Leon, D. A., Jdanov, D. A., & Shkolnikov, V. M. (2019). Trends in life expectancy and age-specific mortality in England and Wales, 1970–2016, in comparison with a set of 22 high-income countries: An analysis of vital statistics data. *The Lancet Public Health*, *4*(11), e575–e582. https://doi.org/10.1016/S2468-2667(19)30177-X

Lopez, A. D., & Adair, T. (2019). Is the long-term decline in cardiovascular-disease mortality in high-income countries over? Evidence from national vital statistics. *International Journal of Epidemiology*, *48*(6), 1815–1823. https://doi.org/10.1093/ije/dyz143

Masters, R. K., Tilstra, A. M., & Simon, D. H. (2018). Explaining recent mortality trends among younger and middle-aged White Americans. *International Journal of Epidemiology*, *47*(1), 81–88. https://doi.org/10.1093/ije/dyx127

Mehta, N. K., Abrams, L. R., & Myrskylä, M. (2020). US life expectancy stalls due to cardiovascular disease, not drug deaths. *Proceedings of the National Academy of Sciences*, *117*(13), 6998–7000. https://doi.org/10.1073/pnas.1920391117

Mehta, N. K., & Dowd, J. B. (2024). *Anti-obesity medications: Allies or adversaries in population health?* Milbank Memorial Fund. https://doi.org/10.1599/mqop.2024.0114

Montez, J. K., Hayward, M. D., & Zajacova, A. (2021). Trends in U.S. population health: The central role of policies, politics, and profits. *Journal of Health and Social Behavior*, *62*(3), 286–301. https://doi.org/10.1177/00221465211015411

Nichols, M., Townsend, N., Scarborough, P., & Rayner, M. (2013). Trends in age-specific coronary heart disease mortality in the European Union over three decades: 1980–2009. *European Heart Journal*, *34*(39), 3017–3027. https://doi.org/10.1093/eurheartj/eht159

Olshansky, S. J., Passaro, D. J., Hershow, R. C., Layden, J., Carnes, B. A., Brody, J., Hayflick, L., Butler, R. N., Allison, D. B., & Ludwig, D. S. (2005). A potential decline in life expectancy in the United States in the 21st century. *New England Journal of Medicine*, *352*(11), 1138–1145. https://doi.org/10.1056/NEJMsr043743

Paglino, E., Lundberg, D. J., Wrigley-Field, E., Zhou, Z., Wasserman, J. A., Raquib, R., Chen, Y.-H., Hempstead, K., Preston, S. H., Elo, I. T., Glymour, M. M., & Stokes, A. C. (2024). Excess natural-cause mortality in US counties and its association with reported COVID-19 deaths. *Proceedings of the National Academy of Sciences*, *121*(6), e2313661121. https://doi.org/10.1073/pnas.2313661121

Permanyer, I., & Bramajo, O. (2023). The race between mortality and morbidity: Implications for the global distribution of health. *Population and Development Review*, *49*(4), 909–937. https://doi.org/10.1111/padr.12582

Polizzi, A., & Dowd, J. B. (2024). Working-age mortality is still an important driver of stagnating life expectancy in the United States. *Proceedings of the National Academy of Sciences*, *121*(4), e2318276121. https://doi.org/10.1073/pnas.2318276121

Preston, S. H., & Stokes, A. (2011). Contribution of obesity to international differences in life expectancy. *American Journal of Public Health*, *101*(11), 2137–2143. https://doi.org/10.2105/AJPH.2011.300219

Preston, S. H., & Wang, H. (2007). Intrinsic growth rates and net reproduction rates in the presence of migration. *Population and Development Review*, *33*(4), 657–666.

Schöley, J., Aburto, J. M., Kashnitsky, I., Kniffka, M. S., Zhang, L., Jaadla, H., Dowd, J. B., & Kashyap, R. (2022). Life expectancy changes since COVID-19. *Nature Human Behaviour*, *6*, 1649–1659. https://doi.org/10.1038/s41562-022-01450-3

Simon, D. H., & Masters, R. K. (2021). Do deaths of despair move together? County-level mortality changes by sex and urbanization, 1990–2017. *American Journal of Epidemiology*, *190*(6), 1169–1171. https://doi.org/10.1093/aje/kwab015

Simon, D. H., & Masters, R. K. (2024). Institutional failures as structural determinants of suicide: The opioid epidemic and the Great Recession in the United States. *Journal of Health and Social Behavior*. https://doi.org/10.1177/00221465231223723

Spencer, M. R., Garnett, M. F., & Miniño, A. M. (2024). *Drug overdose deaths in the United States, 2002-2022* (NCHS Data Brief 491). https://doi.org/10.15620/cdc:135849

Tilstra, A. M., Polizzi, A., Wagner, S., & Akimova, E. T. (2024). Projecting the long-term effects of the COVID-19 pandemic on U.S. population structure. *Nature Communications*, *15*(1), 2409. https://doi.org/10.1038/s41467-024-46582-4

Tilstra, A. M., Simon, D. H., & Masters, R. K. (2021). Trends in “deaths of despair” among working-aged White and Black Americans, 1990–2017. *American Journal of Epidemiology*, *190*(9), 1751–1759. https://doi.org/10.1093/aje/kwab088

Walsh, D., & McCartney, G. (2025). *Social murder? Austerity and life expectancy in the UK*. Bristol, England: Policy Press.

Walsh, D., Tod, E., McCartney, G., & Levin, K. A. (2022). How much of the stalled mortality trends in Scotland and England can be attributed to obesity? *BMJ Open*, *12*, e067310. https://doi.org/10.1136/bmjopen-2022-067310

Welsh, C. E., Matthews, F. E., & Jagger, C. (2021). Trends in life expectancy and healthy life years at birth and age 65 in the UK, 2008–2016, and other countries of the EU28: An observational cross-sectional study. *The Lancet Regional Health – Europe*, *2*, 100023. https://doi.org/10.1016/j.lanepe.2020.100023

Woolhandler, S., Himmelstein, D. U., Ahmed, S., Bailey, Z., Bassett, M. T., Bird, M., Bor, J., Bor, D., Carrasquillo, O., Chowkwanyun, M., Dickman, S. L., Fisher, S., Gaffney, A., Galea, S., Gottfried, R. N., Grumbach, K., Guyatt, G., Hansen, H., Landrigan, P. J., … Venkataramani, A. (2021). Public policy and health in the Trump era. *The Lancet*, *397*(10275), 705–753. https://doi.org/10.1016/S0140-6736(20)32545-9

Wu, S., Wang, R., Zhao, Y., Ma, X., Wu, M., Yan, X., & He, J. (2013). The relationship between self-rated health and objective health status: A population-based study. *BMC Public Health*, *13*(1), 320. https://doi.org/10.1186/1471-2458-13-320

Xie, Y., Xu, E., Bowe, B., & Al-Aly, Z. (2022). Long-term cardiovascular outcomes of COVID-19. *Nature Medicine*, *28*(3), 583–590. https://doi.org/10.1038/s41591-022-01689-3

Yang, S., Khang, Y.-H., Harper, S., Davey Smith, G., Leon, D. A., & Lynch, J. (2010). Understanding the rapid increase in life expectancy in South Korea. *American Journal of Public Health*, *100*(5), 896–903. https://doi.org/10.2105/AJPH.2009.160341

Zajacova, A., & Montez, J. K. (2017). Macro-level perspective to reverse recent mortality increases. *The Lancet*, *389*(10073), 991–992. https://doi.org/10.1016/S0140-6736(17)30186-1