Mortality divergences in cardiovascular mortality in the second half of life between US and other high-income countries: at what ages do the differences manifest?

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Abstract

Compared to other high-income countries, the United States underperforms in terms of life expectancy. One key driver of this differential is cardiovascular disease (CVD) mortality, a cause on which the US has had worse trends since around 2008. The differential in CVD mortality has been previously described, however, it's contribution to the widening US life expectancy lag relative to other high-income countries is unknown. In this paper, we measured the contribution of CVD mortality to the post-2010 life expectancy divergence between the US and other countries. Using life table methods in WHO mortality data by cause, we computed life expectancy at age 50 (LE50) and the age in a lifetable at which the first 10% of the population died (p10) considering a counterfactual scenario through cause-deleted life-tables, removing CVD deaths. Results suggest the US has a lowest all-cause e50 and p10 age compared to other high-income countries, and the gap with other countries increased during 2008 and 2019. However, by removing CVD deaths, the magnitude of such gap would have been narrower, indicating the meaningful role of CVD when considering mortality differences between the US and other high-income countries in the last decade. In the full version of this paper we will try to establish the contribution of the first ten percent of deaths that occur after age 50 in life expectancy differences across countries

Extended abstract

Introduction

Life expectancy has increased substantially across the globe due to medical breakthroughs, nutritional improvements, better sanitation, and the adoption of healthier behaviors (Deaton, 2005; Fogel & Costa, 1997). Despite this, it has been acknowledged that life expectancy (LE) has stalled in the United States (US) after years of continuous and sustained growth. Previous findings suggest that U.S. life expectancy stagnated since the year 2010 (Ho, 2022; Ho & Hendi, 2018; Mehta et al., 2020), in the aftermath of the 2008

financial crisis. Therefore, delving further in the reasons behind stagnation and even decline, which imply a major potential public health crisis, is critical to reverse such trend.

It has been speculated that the deaths broadly known as "deaths of despair", a term coined by Case and Deaton (Beltran-Sanchez & Soneji, 2011; Case & Deaton, 2015, 2017) that encompasses drug and alcohol overdoses, suicide and alcoholic liver disease, were the main driver behind stagnation. Such types of deaths have strongly increased since the 2008 economic crisis and the rise of the opioid epidemic in the US. However, other studies suggest that its impact in overall life expectancy as a metric could be considered as rather small when compared with cardiovascular diseases (CVD) (Acosta et al., 2022; Mehta et al., 2020). Deaths of despair tend to be more concentrated in relatively younger adults, while CVD mortality tends to occur at more advanced ages ((Abrams et al., 2023; Acosta et al., 2022; Ho, 2022).

Vallin and Meslé (2004) have proposed the cardiovascular revolution theory as a dynamic force of mortality change, which suggests that declines in cardiovascular mortality are one of the main driving forces behind the increase of life expectancy. High-income countries such as the US have benefited from the adoption (Ford et al., 2007). However, they also argue that a period of divergence should be expected if the causes behind CVD deaths are not truly addressed.

It has been acknowledged that CVD mortality has been linked with the adoption of unhealthy behaviors, ranging from obesity, smoking and second-hand smoking, alcohol consumption and other factors. The US has performed relatively poorly when compared to other High-income Countries (HIC) in the last decade, despite doing a fairly good job in detection and treatment of major CVD risk factors (Preston & Stokes, 2011; Preston & Vierboom, 2021), but it is not clear that such benchmarks have been enough to prevent CVD mortality decline over time. Furthermore, it is not well understood if the divergence between the US and the other HICs can be attributed to a particular moment (or moments) or if it is differences ever present across the life course.

While it is true that the younger the death, the more potential years of life are lost, the sheer force of mortality of CVD due to the amount of deaths has a much larger impact on overall life expectancy as a metric. Therefore, it remains critical to monitor the trends of CVD mortality in the US and understand its singularities and divergent patterns when compared to other high-income countries. More specifically, while CVD deaths are mostly concentrated in the second half of life, middle-age deaths (before age 70) imply a larger loss of life than deaths that occur at more advanced ages. More importantly, these deaths are amenable; meaning a greater gain in public health can be obtained by preventing them. As Abrams et al. mentioned, the US has a strong mortality disadvantage in working ages and particularly older age groups (2023). However, the role of CVD mortality in those age groups is unclear to establish differences with other high-income countries, and its

contribution in life expectancy. Specifically, we expect that if mortality at older age groups is, on general terms, converging, differences in life expectancy between the US and other high-income countries can be sensibly explained by premature mortality after age 50, and specifically attributed to CVD deaths.

In other words, when does the U.S. divergence appear in CVD mortality? If we could identify and prevent where the earliest share of deaths occur, would life expectancy in the US would be similar to other high-income countries?

Methods and Data:

Normalized measures such as age-standardized death rates and LE are often used to estimate average disparities in health. For all the merits these interpretable summary measures of the intensity of mortality have, they do have some limitations. For instance, the metric does not account for heterogeneity of mortality in that neither tells us how it is distributed in a population. In the past, other summary measures of heterogeneity have appeared, broadly defined as "lifespan variability" or "lifespan inequality" (LI) measures (Tuljapurkar & Edwards, 2011; Van Raalte et al., 2018; Vaupel et al., 2011). However, these measures also are an average of disparity, and to not indicate where, meaning at what age, the divergence appears. Hence, by focusing in values of indicators at different quantiles of a lifetable, instead of relying solely on a summary value, we make the case for incorporation of some complementary tools that might be helpful to analyze disparities in longevity during the last decade and to identify some critical points of divergence between countries and between time, that are complementary to age-specific decomposition analysis.

As Beltrán-Sánchez and Soneji summarized, demography has relied in methods that try to estimate gains in life expectancy from hypothetical or observed reductions of mortality (Beltran-Sanchez & Soneji, 2011). In this case, we considered two scenarios: one with all the observed mortality, and other based in a single-associated life table (also known as a cause-deleted life table) to establish gains in longevity and life expectancy without CVD mortality as a counterfactual scenario (in other words, removing the impact of CVD mortality to all the observed deaths). This approach was done in the past to observe expected gains in longevity caused by the absence of certain causes of death (Acosta et al., 2022; Beltran-Sanchez & Soneji, 2011; Zazueta-Borboa et al., 2023).

Instead of only focusing simply in LE_{50} as a summary measure of mortality (present in equation 1) we also complemented age expected estimations of the survival curve for the quantile 10, represented with the letter P (based on the percentile of survivors in a life table) as quantile points in equation 2. In other words, we want to establish if the differences in overall mortality and non-CVD mortality are significant in the earliest stages of survival. Previous studies focusing on the interquartile range (as a difference of

quantiles) as a have mentioned the importance of considering specific quantiles to construct demographic indicators (Rogers et al., 2020; Tuljapurkar & Edwards, 2011; Van Raalte et al., 2018). However, those studies tend to obtain better results when analyzing more extreme ages instead of early age measures.

To obtain an exact value for quantile indicators, instead of a large discrete value derived straight from the life table, we relied on a monotonous cubic spline interpolation on the data (Fritsch & Carlson, 1980) that allowed us to establish with more precision a single point.

$$(1)\ LE_{50} = T_{50} / l_{50}$$

$$(2)\ l_x\,(P_{10},t) = 0.9$$

We resorted to the World Health Organization (WHO) mortality data, that has cause-specific mortality for age groups between 2000 and 2021. However, not all years and not all countries present accurate information with the degree of granularity that this study requires. As a result, we settled on comparing the United States with other 10 high-income countries, that are also among the frontrunners in terms of longevity (Australia, France, Germany, Italy, Japan, the Netherlands, Spain, Sweden, Switzerland and the United Kingdom-UK). For this version we focused on the years 2008 and 2019 (arguably the years in which the CVD mortality divergence started and the year before the COVID-19 pandemic). We considered CVD mortality as all deaths that belonged to the I00-I99 group considering the ICD-10 classification of mortality. As a side note, mortality is truncated until age 85 and plus. To obtain population exposures, we relied on the United Nations's World Population Prospects (WPP) which has population exposures by sex and five age groups for each year. With both death counts and population exposures we computed Life Expectancy conditional to survival at age 50 (LE_{50}), using the classic demographic methods to compute life expectancy (Preston et al., 2001). We did so because we wanted to focus in the age groups in which CVD mortality is the highest.

While it can be argued that somewhat similar results could be obtained with an age-specific decomposition of life expectancy, that would tell us what is the age-specific contribution of mortality differentials, it does not tell us in which percentile of the population these changes occur. And the contributions of a decomposition result are expressed as a difference of life expectancies instead of using a similar magnitude between populations. For this abstract version we presented both LE_{50} and the P_{10} estimations. All calculations were done with the free software R.

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Preliminary results

Figure 1 presents the age-standardized CVD death rates by sex across countries in 2008 and 2019 (using the weights of the five-age groups considering the sum of all countries as a reference to adjust mortality by age). It stands out how Germany, Sweden and the US present the larger levels of mortality in both males and females. However, it is also clear that the levels of CVD mortality have declined for all countries between 2008 and 2019.

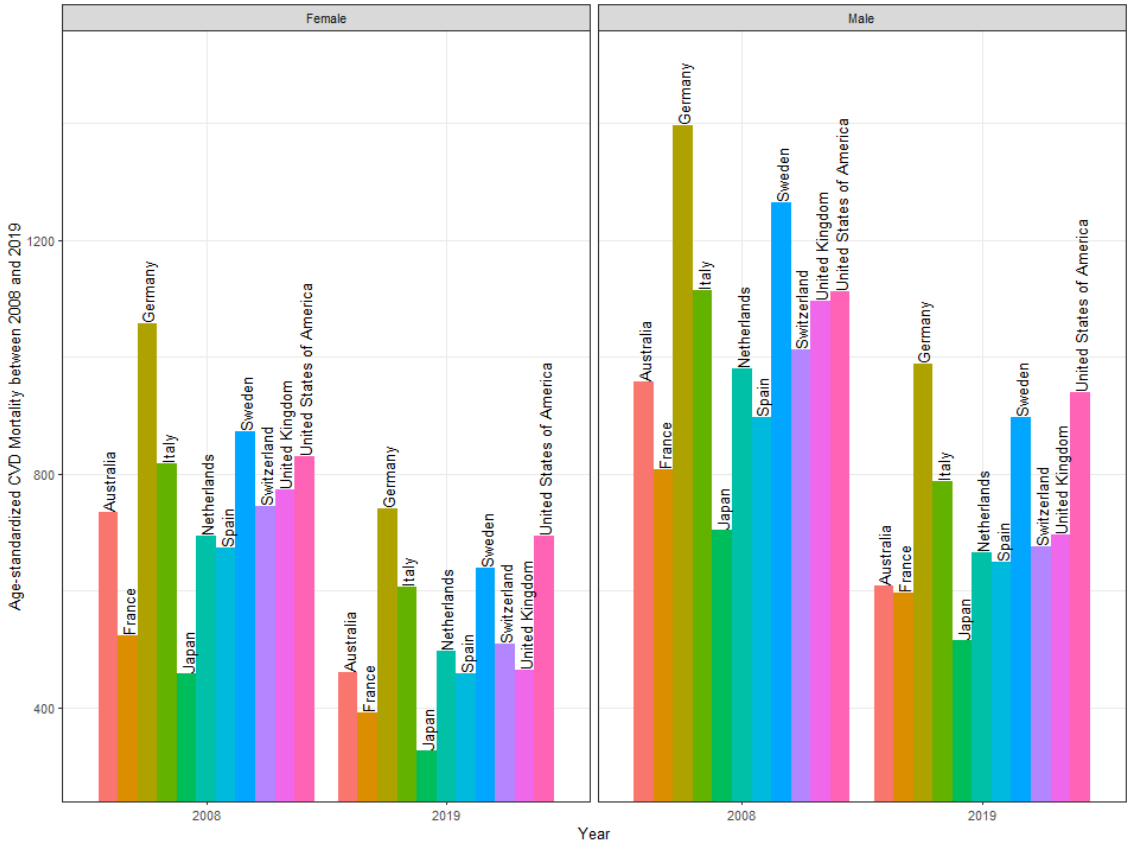

Figure 1: Age-standardized CVD Death Rates (*10000) by country and sex, for years 2008 and 2019.

Figure 2, on the other hand, presents the relative change in the age-standardized mortality between 2008 and 2019. While Figure 1 has shown that mortality declined for all countries, we can observe that clearly the US had lower levels of CVD mortality reduction, with a reduction of near 15% between 2008 and 2019, while the remaining countries presented reductions between 25% and 40% in the same period.

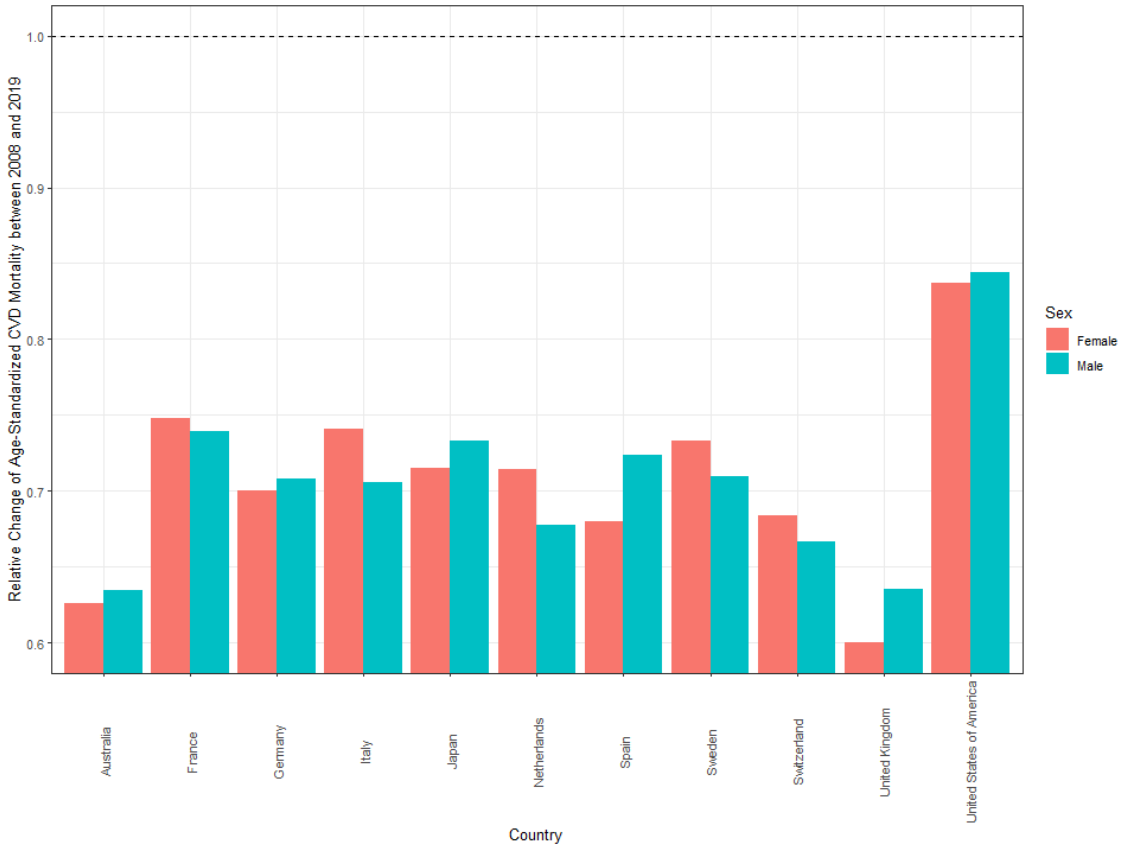

Figure 2: Relative change in Age-Standardized CVD mortality across countries between 2008 and 2019.

Figure 3 presents the values of LE_{50} and the age of P_{10} respectively for the years 2008 and 2019 for both scenarios (considering All Cause Mortality and No-CVD Mortality), at the left half and right half of the figure, respectively.

Among females, the US presented the lowest values for LE50 and P10, while Japan presented the highest ones. However, both in 2008 and 2019 by removing CVD deaths, the values of LE50 for the US would be on par with the UK or the Netherlands.

Among males, differences in LE50 across countries seem to be less pronounced in 2008. However, in 2019, it is clear that the US has become a laggard when compared to the other high-income countries. By removing CVD deaths, however, differences with other countries tend to decrease, having counterfactual LE50 on par with France or Germany.

When establishing the P10 age, in which the first 10% of the surviving population has died, the US presented the lowest values along with France, and Australia and Sweden presented the highest ones not only in 2008 but in 2019 as well. Removing CVD deaths does not seem to present any apparent advantage for the US when compared to the other countries in

2019, but in 2008, it seems to narrow the P10 gap slightly with France, Spain and Germany.

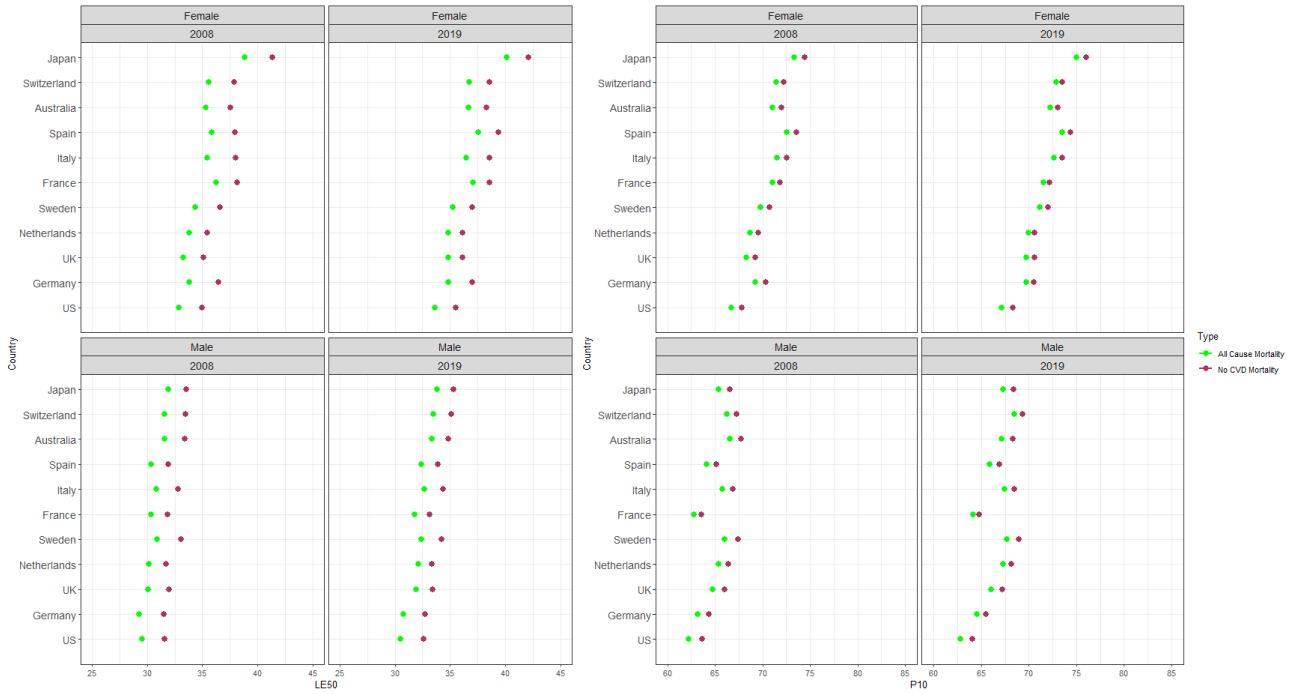

Figure 3: LE_{50} and P_{10} for All Cause and No-CVD mortality across countries between 2008 and 2019.

Figure 4 presents the change in the gap (represented with the corresponding horizontal lines between dots) between the US and the remaining countries for both indicators in the years 2008 and 2019, considering the observed mortality (all cause mortality, with the corresponding green dot) and the counterfactual scenario in which CVD deaths are removed (with the maroon dot). Between 2008 and 2019 the gap in LE_{50} between the US and the other countries has increased, with positive values in all cases both for males and females. However, it is clear from the figure that in all cases the growth in the LE_{50} gap would be lower if not for CVD deaths, and, in some cases such as the difference with Sweden and France for females, the gap would have even diminished. The enlargement in the P_{10} indicator also suggests that the gap in early mortality also increased in most cases, with the exception of Australian males. However, by removing CVD mortality, we can see that not always there is a decrease in the P_{10} gap, possibly suggesting that levels of CVD mortality are similar between those countries in the first decile of deaths.

Overall, the change in gap on the P_{10} might be an indication that those who die earlier in the US do it significantly earlier when compared to the other high-income countries, and

particularly females (as the length of the gap shows), but by removing CVD deaths, the gap with those countries and the US would be narrower.

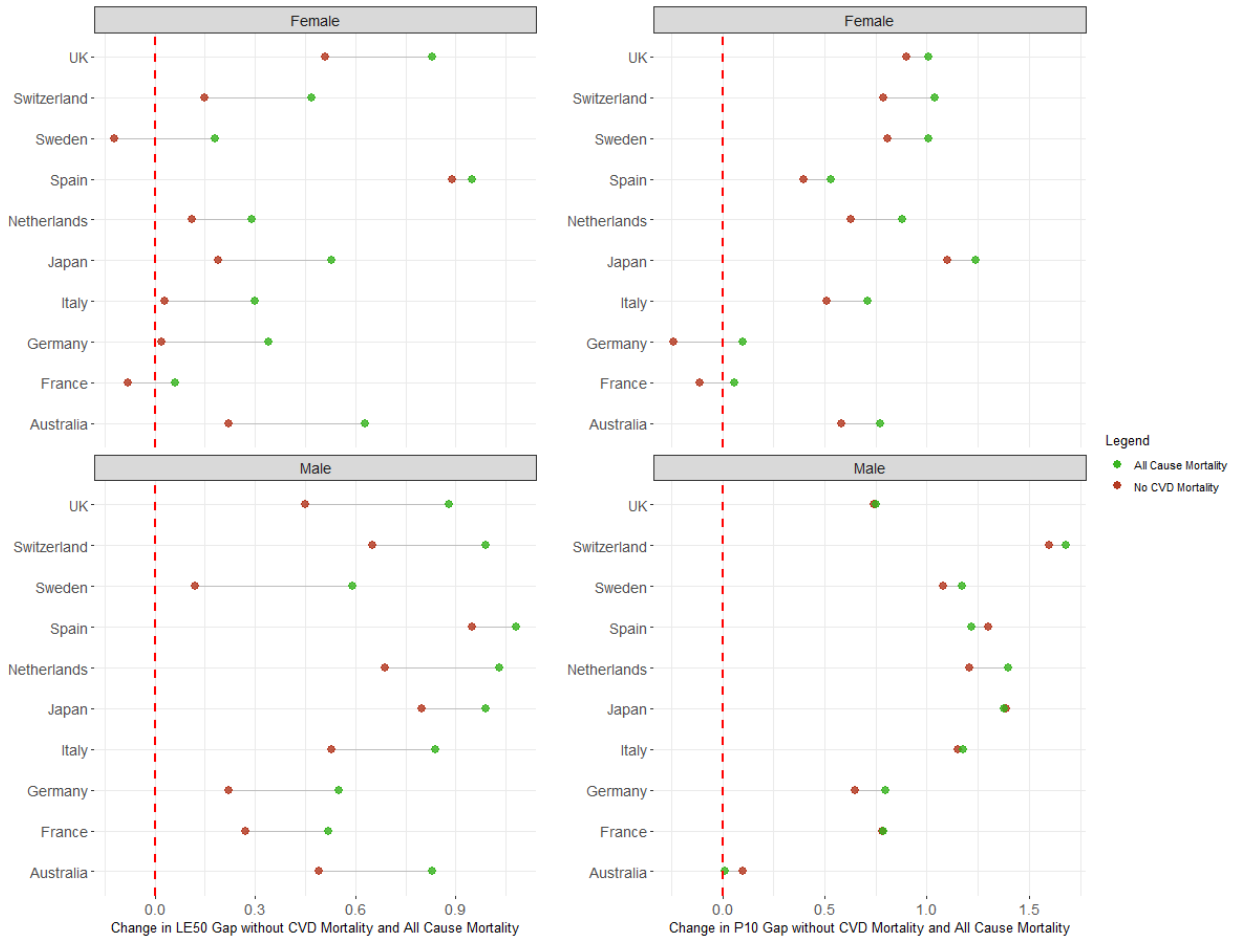

Figure 4: Change in gap of LE_{50} and P_{10} between US and the remaining countries between 2008 and 2019 by sex.

Next Steps

Further analysis in this paper will present the estimates for the remaining high-income countries and years, and also, we will try to obtain P_{25} in order to establish how relevant differences in mortality are at that point. However, it is possible that we will have to delve in other sources such as the Human Mortality Database to do so, and make some interpolation procedures due to the lack of age-specific cardiovascular mortality data after age 85. And also, we want to establish another counterfactual scenario taking advantage of the flexibility of P_{10}: how would LE_{50} would be if the US has the force of mortality that

would be equivalent to the P_{10} (which in a lifetable would be the age in which T_x is corresponding to the value of $l_x = 0.9$) of a different country? How much of the LE50 gap would be reduced that way?

Present results seem to suggest that US and some of the studied countries do have different CVD and non-CVD mortality patterns that could explain part of the observed gap in life expectancy at age 50, that removal of CVD mortality would diminish a part of that gap. And most interestingly, the first ten percent of expected deaths seems to present a large age divergence between the US and the other remaining countries, particularly for females, indicating a particular vulnerability in such group.

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