A best practices composite lifetable for the United States

Tim Riffe*[1], Adrien Remund[2,3], Magali Barbieri[3,4], and Celeste Winant[4]

[1]Max Planck Institute for Demographic Research
[2]Université de Genève
[3]Institut national d'études démographiques
[4]Department of Demography, University of California, Berkeley

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Abstract

We calculate a preliminary series of best-possible lifetables for the United States from 1959 to 2004, defined on the basis of the age-specific aggregate of the lowest observed age-cause specific death rates among the 50 states and the District of Columbia for each year. The resulting highest-possible life expectancy shows a gradual increasing trend over the period, on average 1.9 and 2.2 years higher than the highest state life expectancy in each year for males and females, respectively. We argue that the US states best practices lifetable is a useful gauge of future mortality trends and a good benchmark against which to compare state mortality patterns.

Introduction

The question of limits to life expectancy is fundamental to demography, but it is also practical when projecting mortality. Mortality reductions in past decades have been steady in many populations, and at times linear, which tends to guide projections into predicting the same sort of progress far into the future. Most past attempts to place limits on such projections were shown to be overly conservative within a short period (Oeppen and

*triffe@demog.berkeley.edu

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Vaupel 2002). However, many simple mortality projections will send life expectancy scenarios to very high levels that for a given population may seem unrealistic. In some cases, one seeks an external population that has already achieved a life expectancy as high as that produced by a model, and this gives some assurance that the projection is possible. Japan assumes this role in many cases today. In 2012 life expectancy for Japanese females was 86, while for US females it was 81 (Human Mortality Database 2015). If a US projection turns out to reach 86 we at least know that there exists some set of conditions in the world today that imply that this is indeed possible.

The desire for such external references explains part of the interest in the historical development of world record life expectancy (Oeppen and Vaupel 2002). The maximum life expectancy from a set of populations shows what other populations may one day achieve due to diffusion in practices, technology, and wellbeing (Vallin and Meslé 2010). The highest observed life expectancy in a given moment, which we term the "vanguard" life expectancy, is calculated based on mortality rates undifferentiated by cause of death. All cause mortality may not provide an omnibus signal of what may eventually develop. While the force of mortality governs the lifetable, there is a substantive rationale to conceive of this force as a composite of cause-specific forces of mortality. Vallin and Meslé (2008) separate trends in life expectancy by causes of death, explained in terms of an epidemiological transition that unfolds in progressive stages with respect to particular technologies and risk factors in recent history.

The level and timing of cause-specific responses to particular technological or well-being improvements varies between populations. Therefore, the lowest observed all-cause force of mortality is not necessarily composed of the lowest cause-specific forces of mortality, which means that the vanguard life expectancy may not reflect the best mortality possible given current conditions over a set of populations. For instance, the lowest rate of suicide and heart disease at age 45 will not necessarily be found in the same population. As an alternative to vanguard life expectancy, one could create cause-specific low-mortality benchmarks, or more synthetically, combine the lowest mortality observed by age and cause into a hybrid minimum mortality schedule. This synthetic low mortality lifetable— hybrid with respect to reference population over age and cause— was already suggested by Wunsch (1975) and Vallin and Meslé (2008). These authors investigated trends at the national-level. We refer to such hybrid minimum lifetables as "best practices" lifetables. Eikemo et al. (2014) use the term "best practices" in a similar sense of an ideal mix of condtions, but do so via combining particular risk factors with their estimated mortality impacts to produce best case scenarios. The end effect is quite similar, to the extent that either estimation strategy shows what society could acheive given perfect diffusion of some defintion of best conditions. In the case of a best practices lifetable, we condition on mortality outcomes only, making the endeavor much simpler in practice.

National populations are heterogeneous with respect to many factors, both observed and unobserved, that affect cause-spectific mortality rates. This does not make international mortality comparisons futile, but it may make perfect convergence unimaginable even in the very long run. This is the case for both all cause and cause-specific mortality. When projecting mortality for a given country, we wonder whether mortality from an external population, or set of populations, is the best "sanity check" for mortality forecasts. For this reason, we propose a minimum mortality trend for the United States calculated on the basis of its own territorial subdivisions, the 50 states plus the District of Columbia. This choice limits the sources of unaccounted heterogeneity in international comparisons, and it also guarantees uniformity of data sources. To be clear, we do not necessarily propose using a trend in best practices mortality as a component of coherent mortality forecasts, and we do not undertake such an exercise. Instead, we view the U.S. best practices mortality as indicative of the potential already present in the U.S., a special kind of "nowcast".

Data and methods

All death count data come from the public NCHS mortality microdata files (National Center for Health Statistics 1959–2004).[1] Population denominators come from a beta version of the U.S. States project of the Human Mortality Database (Human Mortality Database 2015). Further processing of population counts into exposures is done according to the HMD Methods Protocol, and all-cause lifetables were calculated by single ages (Wilmoth et al. 2007). Death counts for causes were aggregated into quinquennial age groups by year and sex for eleven large groups that minimize disruptions between ICD transitions, and then converted to fractions. Fractions were then multiplied into the single-age all-cause death rates. The eleven causes of death considered in this abstract version are displayed in Table 1, with their relative percentages.

One caveat of calculating a best practices lifetable is that stochastic zeros occur in particular ages and causes, especially among small populations. The exercise of selecting the minimum death rate for a given age and cause will tend to collect stochastic zeros, producing an excessively optimistic best practices life expectancy. We therefore smooth all death rates using the `MortalitySmooth` package (Camarda 2012) in `R`. The age-period matrix of death rates for each state and sex is smoothed over both margins using a penalized b-spline. Cause fractions are then recalculated, and multiplied

[1]The current analysis is based on the public files with geographic information only up to 2004. We have bene granted access to geographic variables in a NCHS Research Data Center, and will extend analysis through 2013 for the final paper version.

Table 1: Eleven causes of death considered in the current study version, percentages.

	Females	Males
All other	29.91	33.95
Breast	3.73	0.03
Cardiovascular	38.49	38.10
Cerebrovascular	10.50	6.84
Lung	3.55	6.50
Other Cerebrovascular	0.33	0.28
Other Malignant Neoplasms	11.01	9.83
Other smoking	0.57	1.36
Prostate		2.25
Stomach	0.67	0.87
Uterus	1.25	

into the smoothed all-cause death rates. Finally, we calculate lifetables for each sex and state, as well as the best practices lifetable of each year using HMD methodology.

We decompose differences in state life expectancy from the best-practices life expectancy using the pseudo-continuous method proposed by Horiuchi et al. (2008). We prefer this method because it allows for defining life expectancy as a direct function of age-cause-specific rates, $M_{(x,c)}$, thereby eliminating some artifacts present in other methods. Results are summarized by ages, causes and states and can be interpreted directly as the the total lag in years of life expectancy due to excess mortality (anything greater than the minimum) in the given margin.[2]

Vanguard and best practices life expectancy

For the sake of clarity, we define vanguard life expectancy as the highest observed state life expectancy for each sex in a given year. Elsewhere, this quantity is called the record life expectancy (Oeppen and Vaupel 2002), or even the best practices life expectancy (Sanderson and Scherbov 2004), but we apply the term best practices in a different sense. To define the best practices mortality schedule, select the lowest (smoothed) death rate by age, x, and cause, c, from among all the states, s, $m(s,x,c)$, and sum over all causes, C, within ages to define the minimum mortality schedule, $m(x)^{min}$

$$m(x)^{min} = \sum_{c=1}^{C} min(m(s,x,c)) \tag{1}$$

[2]In the final version we may opt to further separate trends from initial differences using the decomposition method recently proposed by Jdanov and Shkolnikov (2014).

The minimum mortality schedule is then used to calculate the best-practices life expectancy, and its cause-specific mortality pattern is used as the benchmark against which to decompose the mortality pattern of each state. While the best practices life expectancy is drawn from the diverse mortality experience of the entire USA, the vanguard life expectancy refers only to a particular state in a given year. We can say, for instance, that Minnesota was the vanguard for females in the year 1959, with a lif expectancy of 75.3, but that the best practices life expectancy in the same year was another 3 years higher at 78.3.

There are limitations to the interpretation of a best practices trend, as defined here. The mix of causes within each age, and the resulting age pattern for each cause may not necessarily reflect a possible or likely mortality pattern. For instance, diseases may compensate each other, especially for diagnostic and reporting reasons. For instance, for decedents that suffered from both condition A and condition B, one state might be more likely to declare A as the underlying cause of death, while another state would more likely declare B to be as the underlying cause. A situation like this would tend to inflate the best practices $e(0)$. The best practices $e(0)$ may be underestimate in instances where reductions in cause A are expected to lead to reductions in cause B (e.g., pneumonia and cardiovascular disease.)

Preliminary results

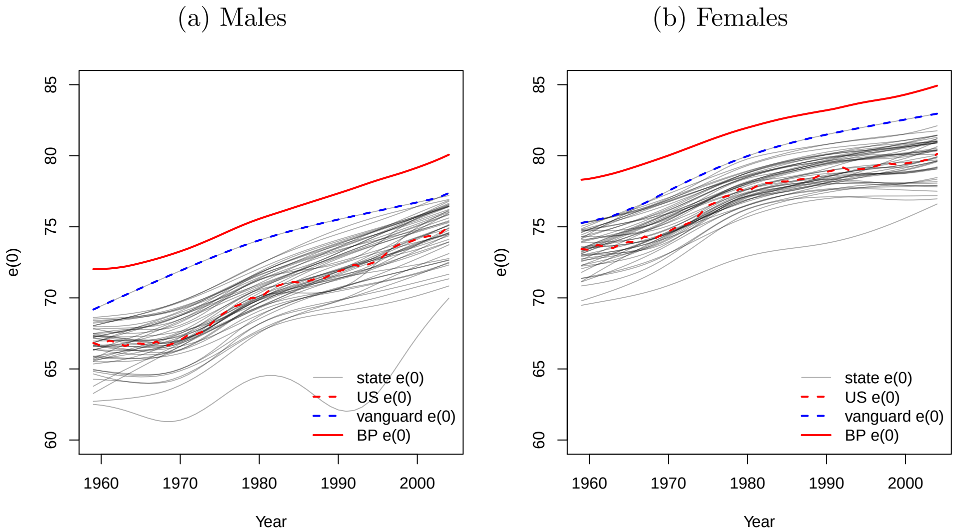
All results at this time are preliminary, but we can report broad trends.[3]

Life expectancy trends

Most states display irregular gradual increasing trends over the 45 years considered, except for males in the District of Columbia, which have been recovering strongly since the 1990s, due both to secular improvements and compositional change. The US aggregate trend is bouncier because death counts were not smoothed, and its rank position among states varies due in part also to compositional changes between states. The vanguard state life expectancy for males is Hawaii until the two most recent years of observation (2003-2004), where Minnesota has taken the lead. For females, Minnesota was vanguard until 1963, followed by North Dakota for five years, and then

[3]The final results will differ in the following ways. At this time we have calculated results using 11 causes of death that were previously from a different research project, and this will change to 30 causes to be consistent and comparable with Vallin and Meslé (2008). Including more causes will increase the best practices life expectancy level. We will also include estimates through 2012 or 2013. At this time, we were only able to produce results through 2004, because geographic information is suppressed in the public microdata for later years. This information is available in secure Research Data Centers, where we will produce cause fractions and all-cause lifetables for the most recent decade.

Figure 1: Trends in US, vanguard, best practices, and state life expectancies at birth ($e(0)$), 1959-2004.



Hawaii for the rest of the period until 2004. The vanguard trend for females has the same overall shape as the cluster of individual state trends, but for males the time trend in vanguard, ergo Hawaiian, life expectancy was different from the bulk of states.

For both males and females, the best practices trend is on average 2 years higher than the vanguard trend, and its progress is steadier than either the vanguard, national, or average state trends, as well as most individual states. The best practices trend has increased each year for males and females, though faster for males. The average annual improvement for males has been 0.1790 years of $e(0)$ per annum, compared with 0.1785 for the male national average life expectancy. The respective rates of improvement for females have been 0.1470 and 0.1456. It is convenient and telling that the respective medium term average rates of improvement between national and best practices life expectancy match so closely, despite the best practices trend having a much more stable trajectory. This artifact may provide some support to conceiving of the best practices trend as indicative of where the U.S. is going in the coming decades.

If we take the mean rate of improvement for national or best practice trends, and compare it with the means of each series, we can roughly conclude that the best practices trend in year t is a decent estimate of the national life expectancy in 30 or so years. This time lag is valid for the present series, but will vary depending on the number of cause groups that enter into the selection of minimum mortality rates. Clearly, if the population units were counties rather than states, the level of best practices life expectancy would increase even further, but we opine that cause-specific smoothing at the county level is more of a modelling gesture than sound practice, due to very low counts of deaths in most counties in the U.S. In the final paper we will aim to test the cause set proposed by Vallin and Meslé (2008) and compare it with other reasonable configurations for the U.S., and so recommend a rule of thumb grouping.

For the sake of comparison with the presentlt calculated best practices series. The $e(0)$ value in 2004 for males and females was 80 and 84.9, respectively. In the same year, the observed all-cause $e(0)$ in Japan were 78.6 for males and 85.5 for females. That is, the U.S. best practices trend is ahead of observed life expectancy for Japanese males, and behind for Japanese females. We may also compare with the official $e(0)$ projections of the U.S. Social Security Administration (SSA). The SSA projects projects male $e(0)$ passing 80 in the year 2058, and female $e(0)$ passing 84.9 in the year 2075 (Bell and Miller 2005). These projections are a full 54 and 71 years after 2004, in both cases much farther in the future than a simple extrapolation of the best practices trend would predict, circa 2034.

State differences by cause

Since the trend in the best practices $e(0)$ is so stable over time, it is also a convenient moving benchmark against which to compare state patterns — a kind of potential mortality for each state. We decompose the state departures in life expectancy from the best practice trend in each year and sex, over both age and cause. Part of the attraction of decomposing with respect to the best practices life expectancy is that contributions are always of the same sign, which makes heatmaps more intuitive than would otherwise be the case.[4] We therefore summarize state trends in a series of heatmaps representing the 50 states plus the District of Columbia. In these heat maps, states are represented as identically-sized square cells, while preserving rough spatial relationships from a standard map projection. For orientation, we present a state guide to the heatmaps in Figure 2.[5] Deeper shades of red indicate larger departures, i.e., larger $e(0)$ shortcomings.

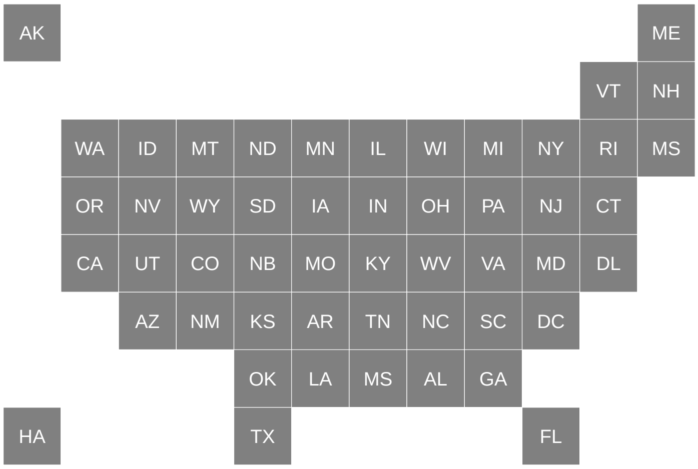
In Figures 3 and 4 we represent the average $e(0)$ shortcoming from each cause and state, and average within decades to summarize the total contribution to the departure from best practices.[6] Major causes of death are in

[4]Typically age and/or cause-specific contributions to a difference in $e(0)$ are represented in stacked bar charts, which in the present case would not be a practical way to distill information.

[5]This configuration is inspired by a tile grid map on the NPR blog (DeBelius 2015), which itself was inspired by various commonly used maps in the New York Times, Washington Post, and others. DeBelius notes that grid panels are not meant for displaying population quantities, since each state has a different population size. Since lifetable quantities are purged of population size and structure, the visual instrument is adequate, and the equalization of state size and form adds legibility to our results.

[6]The 2000s results are based on the average for the years 2000-2004 only.

Figure 2: A guide to tiled heatmaps of U.S. states.



rows, and decades are organized in columns. For the case of cardiovascular disease and other causes, grouping departures into the 2+ group blends out much interstate variation, since some contributions range as high as 4 years, but broad patterns are still visible.[7]

Glancing over the lung diseases and cancer rows of the maps, it is evident that the District of Columbia had high excess mortality for these causes over all five decades, peaking in the 1980s. Lung diseases display a clear mortality basin in the Southern states for males, although the absolute maginitude of these departures from ideal mortality has diminished over time. The same mortality basin occurs in cariovascular causes over all five decades, but is clearly visible in this display only since the 1990's, due to the 2+ grouping.

Since the cause groupings available at the time of submission are not the final groupings, and because the causes included in the study contribute such varying magnitudes to state differences, trends are dominated by Cardivascular diseases and the large aggregate group of all other causes. The 11 original causes were grouped into five so as to make state patterns more visible. These results will be commented at greater length when the final results are prepared.

[7]This visual display may be significantly adapted when we add more causes to the decomposition. We will also do a similar small multiples display for grouped age patterns.

Figure 3: U.S. males, state departures from best practices $e(0)$ by large cause groups, 1959-2004.

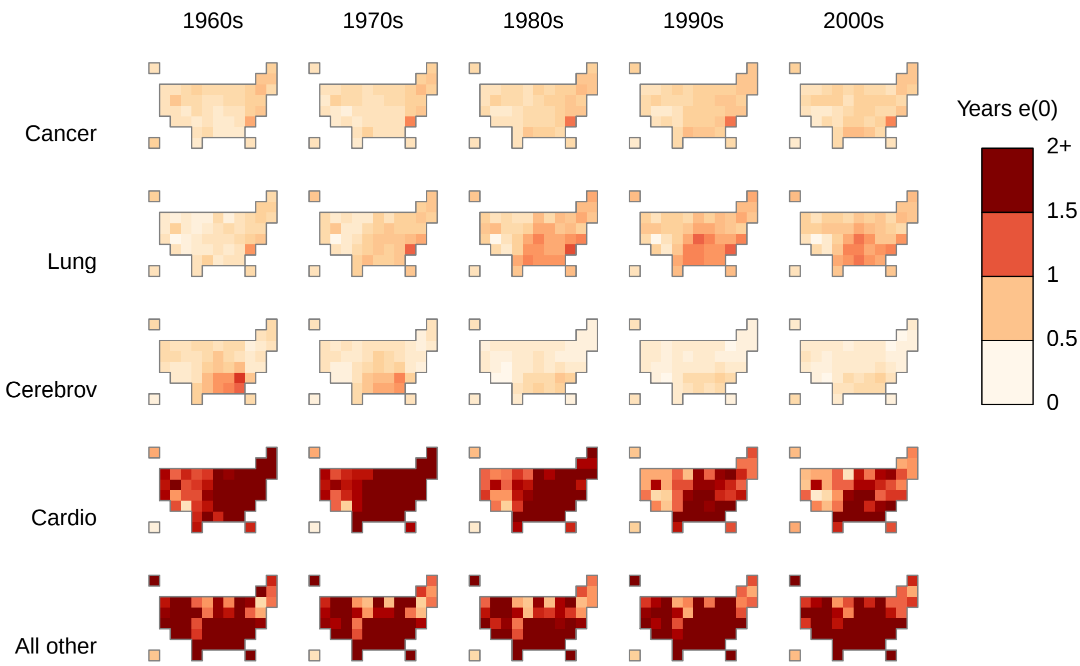
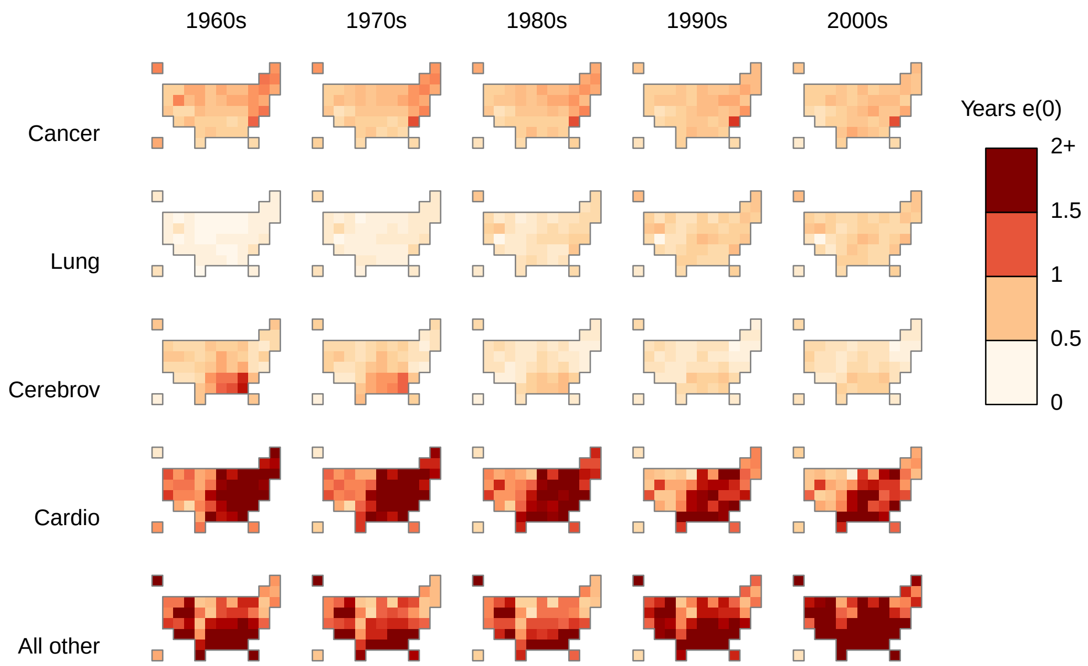


Figure 4: U.S. feales, state departures from best practices $e(0)$ by large cause groups, 1959-2004.



Discussion

In this paper, we have given an intuitive rationale for calculating a best practices trend in the United States. First, the best practices trend in life expectancy at birth can be interpreted as the mortality potential present in the United States at a given point in time. It is an indication of the mortality conditions that would come to be if local conditions, practices, technologies, and behaviors were perfectly diffused from those places with the best age and cause-specific performance in the year. While it is difficult to imagine that pressing a magic button to activate this perfect cocktail of mortality risk factors would actually bring about this minimum mortality instantaneously— for instance, cumulative risk factors in population stocks that are distributed unevenly over space would stymie such a thought experiment— we do observe catch-ups with past best practices values for many states, and for the U.S. national $e(0)$, on average after a period of 30 years. It remains to be seen how this lag scales to the number of causes ocnsidered and size and distribution of subpopulations. At this time, we are rather attracted to the idea of a period weathervane that points us to where period mortality is going.

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