What is Premature Mortality?

Trying to reconcile two views

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Abstract

What is Premature Mortality? There are two different approaches to measure it, an absolute one (setting a unique age threshold dividing deaths into premature and adult) and a relative one (deriving the share of premature deaths from the age distribution of deaths), both having pros and cons. The main disadvantage of the absolute approach is that of using a unique threshold for different mortality patterns, while the main disadvantage of the relative approach is that the estimate of premature mortality it conveys strongly depends on how the adult deaths distribution is defined in each country. In this work, we try to reconcile the two approaches by means of a hierarchical model, where adult deaths distribution is kept fixed for each country as a pivotal quantity and the

premature mortality floats around it. In this way, adult mortality is the same for each country and premature mortality estimates are more comparable across countries.

keywords: premature mortality, mixture model, hierarchial model

1 Introduction

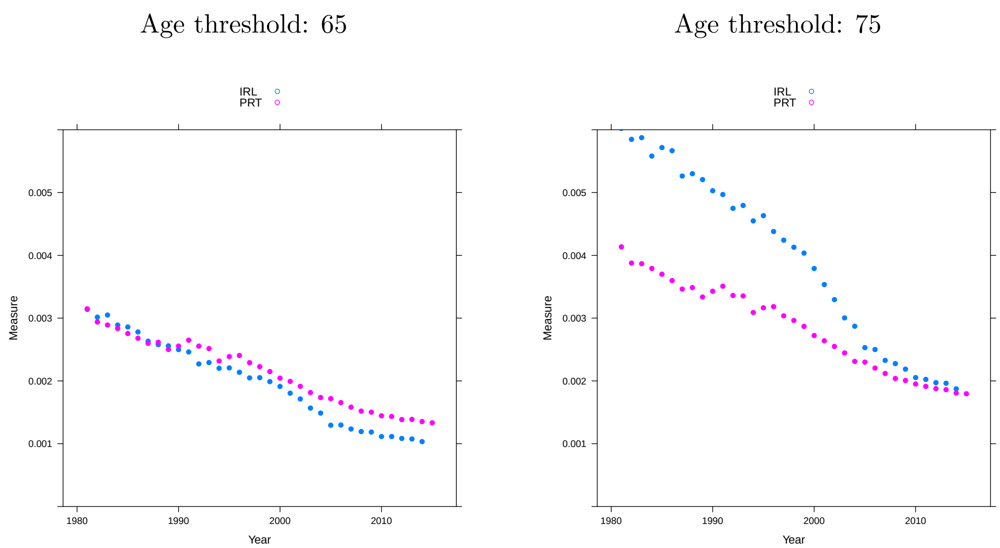
Overall mortality is made of several components: infant and child mortality mortality are ones often considered when developing countries are object of study, while old age mortality is the main focus of studies concerning developped countries. Another importat component, that is usually referred to as "premature mortality", is more difficult to study due to its latent nature. Thus we have not a widely agreed definition what a "premature" death is, and this leads to several measures of premature mortality prevalence. In this paper, we consider two different approaches in defining and measuring premature mortality, calling them "absolute" and "relative" approaches. The "absolute" approach uses an age threshold to distinguish between "premature" and "senescent" deaths, while the "relative" approach does not define any age threshold, but measure preamture mortality basing on the age distribution of deaths. We will show that both approaches have strong points and weaknesses and propose a third way, which can be considered as a compromise between the two. The measure of premature mortality brought about this latter approach passes thorugh an estimation of a hierarchical model of mortality age schedules.

2 Premature Mortality: An absolute view

What we call "absolute approach" to measure premature mortality, is the approach used by main institute that provides health and mortality measures for several countries: WHO, OECD (2011), Eurostat (2016). Basically an age threshold is fixed, and every death occurring below that threshold is deemed as "premature". However there is no clear consensus on what this threshold should be: some use 65 (Best et al., 2018), other 70[1] and other 75 (Mackenbach et al., 2015). Figure 1 shows that changing the threshold might change the ranking of countries: while in Ireland below 75 death rate and below 65 are very close to each other, we notice a greater gap between the two measures in Portugal, meaning that when using 75 threshold Portugal shows a lower rate of pramture deaths than Ireland, but if we use a 65 threshold, we got the opposite ranking. More generally, a fixed threshold does not take into account the specific features of

[1] Sustainable Development Goal 3 refers to "premature deaths" as those occurring under the age of 70.

Figure 1: Premature mortality, Ireland and Portugal with different age threshold (source: Own elaborations from HMD)



overall mortality of a country: a 65 age threshold might seem unedequate for countries characterised by high life expectancy (e. g. Sweden or Japan) while a 75 threshold is not suited for countries with a life expectancy lower than 75. Some authors focus on related measures, i. e. "Midlife mortality" (see Case and Deaton, 2015) which is mortality rate at age 45–54, and "Amenable" and "Preventable" deaths (see Eurostat, 2016; OECD, 2011)

3 Premature Mortality: A relative view

A different approach to measure premature mortality traces back to Lexis (1878) who suggest that premature mortality can be measured by considering the age distribution of death curve (i. e. the function d_x of the life table): according to Lexis, in absence of premature mortality this curve should have a symmetric shape. Thus the last part (from the modal age at death up to the end) can be "unfolded" to left to get the hypothetical curve without premature death, and preamture mortality can be measured as the difference between the actual curve and the hypothetical one (see Cheung et al., 2005). This is a "relative" measure as the share[2] of "premature" deaths depends on the whole distribution of deaths by age. Lexis idea was further elaborated by Pearson (1897), who highlighted that the hypothetical d_x curve can be skewed, and not necessarily symmetric. More recently Zanotto et al. (2016) implemented a mixture model following the reasoning by Pearson. This model is as follows:

$$f_M(x, \xi_M, \omega_M, \lambda_M) = \overbrace{\frac{2}{\omega_M}\phi\left(\frac{x-\xi_M}{\omega_M}\right)\Phi\left(\lambda_M\frac{x-\xi_M}{\omega_M}\right)}^{\text{Adult mortality}} \tag{1}$$

$$f_m(x, \xi_m, \omega_m, \lambda_m) = \overbrace{\frac{2}{\omega_m}\phi\left(\frac{x-\xi_m}{\omega_m}\right)\Phi\left(\lambda_m\frac{x-\xi_m}{\omega_m}\right)}^{\text{Premature mortality}} \tag{2}$$

$$f_I(x) = \overbrace{\frac{\sqrt{2}}{\pi}\exp\left(-x^2\right)}^{\text{Infant mortality}} \tag{3}$$

Note that f_m and f_M are fitted by a skew normal distribution, a generalization of normal distribution, allowing for skewness (see Azzalini, 1985). These components are then mixed to fit the age distribution of deaths, in formula:

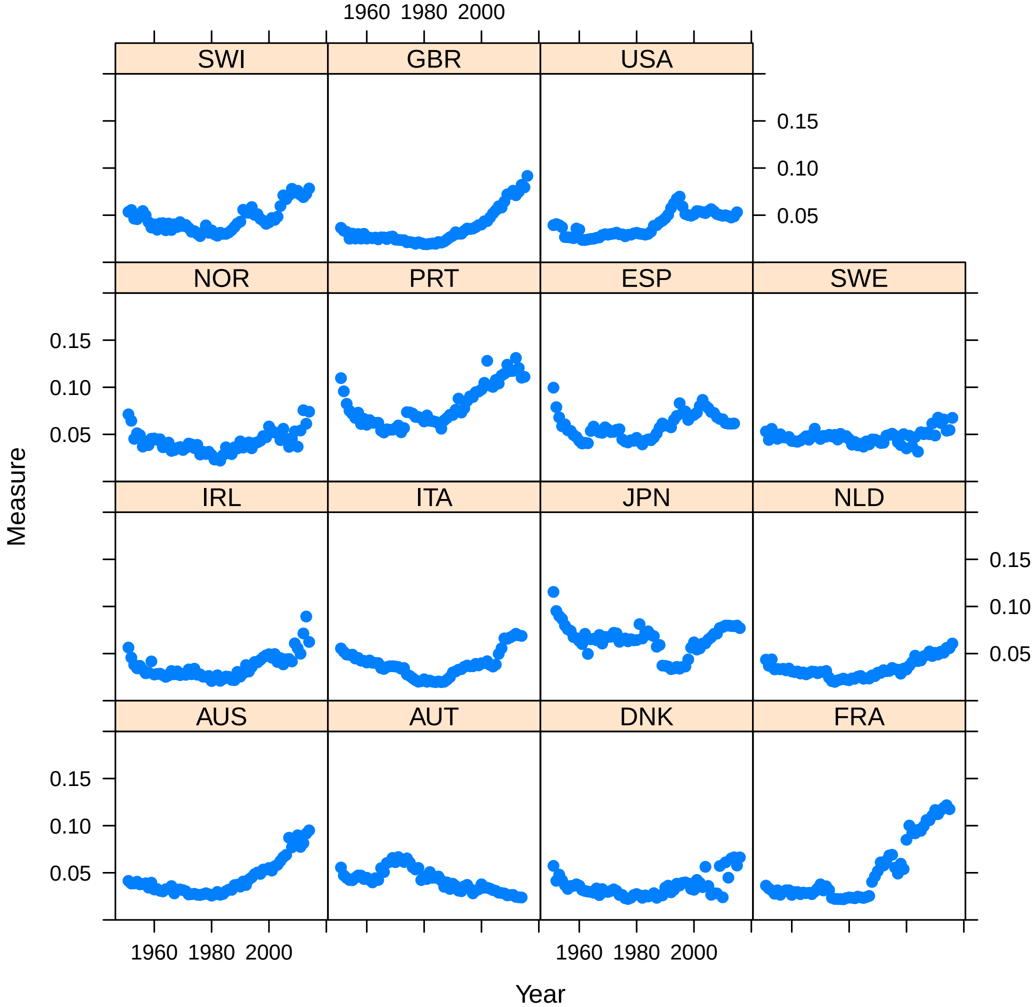
$$\begin{aligned} d(x) &= \eta \cdot f_I(x) + \\ &+ (1-\eta)\cdot\alpha\cdot f_m(x, \xi_m, \omega_m, \lambda_m) + \\ &+ (1-\eta)\cdot(1-\alpha)\cdot f_M(x, \xi_M, \omega_M, \lambda_M) \end{aligned}$$

The share of premature mortality is given by the estimate of parameter α. Figure 2 shows that, surprisingly, the relative measure definded by (4), suggest an increasing trend of premature mortality. Even more striking is that France is one of the countries showing the sharpest increase of premature mortality in last years, while USA share of premature deaths stabilises.

So on the one hand, the relative approach avoid to chose a age threshold, seeming more suited for comparing countries with different levels of life expectancy, but on the other hand, it turns out that it produces counterintuitive results. The explanation of them

[2]Note that in this way premature deaths are not individually identified, but only the total share is calculated

Figure 2: Prevalence of Premature Mortality in some countries, using relative approach (source: HMD)



is that with this approach, the share of premature deaths depends also on the shape and location of senescent curve (f_M). So if f_M has a relatively large variance and low mean (as we observe in USA), it might be that the "premature" curve is hidden by the senescent one and so underestimated, while in countries where senescent deaths shifts to the right and are highly compressed (like in France) the premature curve "emerges" and, probably overestimated.

4 Reconciling two views?

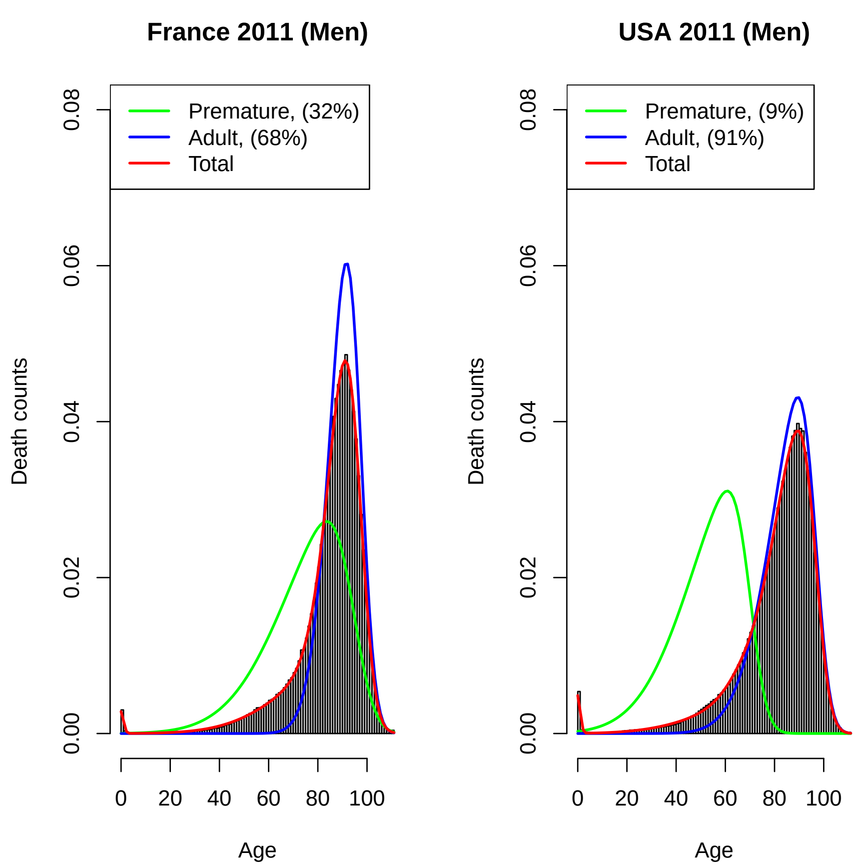
The problem with relative approach is that across countries both adult and premature deaths distributions are changing so the value of α we get is determined by both. This is not a bad thing per se, it is actually what the relative approach is used for: measuring premature mortality also in different contexts. However, the comparison between France and USA shows that we are not only changing the shape and location of premature mortality but also those of senescent one. We then propose to group some comparable countries and assume that all of them have the same senescent mortality curve, while premature mortality curve varies across countries. This choice can be seen in line with what proposed by Li and Lee (2005) for mortality forecasting, who add a common factor for all countries in the Lee-Carter model. This choice is justified by the rapid diffusion that innovations on public health sector can have, so a longevity improvement in one country is assumed to diffuse also in the others. Here, we consistently assume that countries of the group should have the same definition of senescent mortality, and premature component is basically its complement.

In order to do that, a hierchical model is defined, premature mortality coefficients are allowed to vary across countries, while adult mortality ones remain fixed, according the formula[3]

$$d_j(x) = \alpha_j \cdot f_j^m(x, \mu_j^m, \sigma_j^m, \gamma_j^m) + (1 - \alpha_j) \cdot f^M(x, \mu^M, \sigma^M, \gamma^M).$$

[3] for simplicity infant mortality component is disregarded and model has been fitted only on death occurring at age 5 and higher.

Figure 3: France and USA 2011, Mixture model (source: HMD)



Model (4) is estimated with a Bayesian approach, so prior (and hyper-priors) distributions are defined as follows:

$$
\begin{aligned}
\alpha_j &\sim \mathcal{U}(0, 0.9) \\
\mu_j^m &\sim \mathcal{N}(60, \sigma_{\mu^m}^2)T[-\infty, 75] \\
\sigma_j^m &\sim \mathcal{U}(0, 20) \\
\gamma_j^m &\sim \mathcal{N}(0, \sigma_{\gamma^m}^2)T[-0.8, 0.995] \\
\mu^M &\sim \mathcal{N}(87, 4) \\
\sigma^M &\sim \mathcal{U}(0, 9) \\
\gamma^M &\sim \mathcal{SN}(-1, 0.5, 1)T[-0.995, 0.995] \\
\sigma_{\mu^m} &\sim \mathcal{U}(0, 2.5) \\
\sigma_{\gamma^m} &\sim \mathcal{U}(0, 0.2)
\end{aligned}
$$

Note that most of the priors are non-informative, although some of them have a low variance to avoid identification and label-switching problems. The results[4] are summarized by figure 4, which, in comparison to figure 3 show that France has a much lower share of premature mortality with respect to USA. If we look at results we get for all considered countries (figure 5) we notice that using this approach US premature mortality is much higher than other countries. A particularly high premature mortality is recorded also in Denmark and – albeit the level is much lower, but increasing, in Netherlands. These results are more sensible: The high prevalence of premature mortality in USA is in line with what has been show by Case and Deaton (2015, 2017). We also know that Denmark underwent a stagnation of life expectancy (Lindahl-Jacobsen et al., 2016) between 1980 and 2000 (in particular for women), and a similar one was observed in the Netherlands (Mackenbach et al., 2003). Thus this apporach via hierarchical model not only provides a "reconciliation" between "relative" and "absolute" approaches, but also provides a measure of premature mortality that is more in line with literature.

[4]Estimation have been implemented in STAN.

Figure 4: France and USA 2011, Hierarchical model (source: HMD)

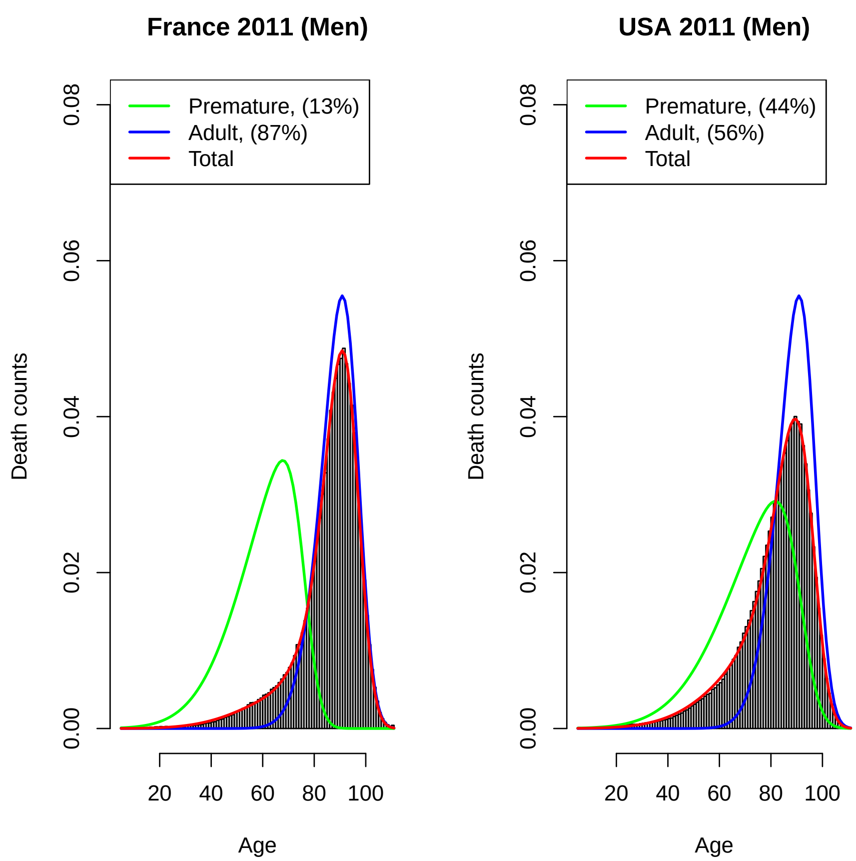
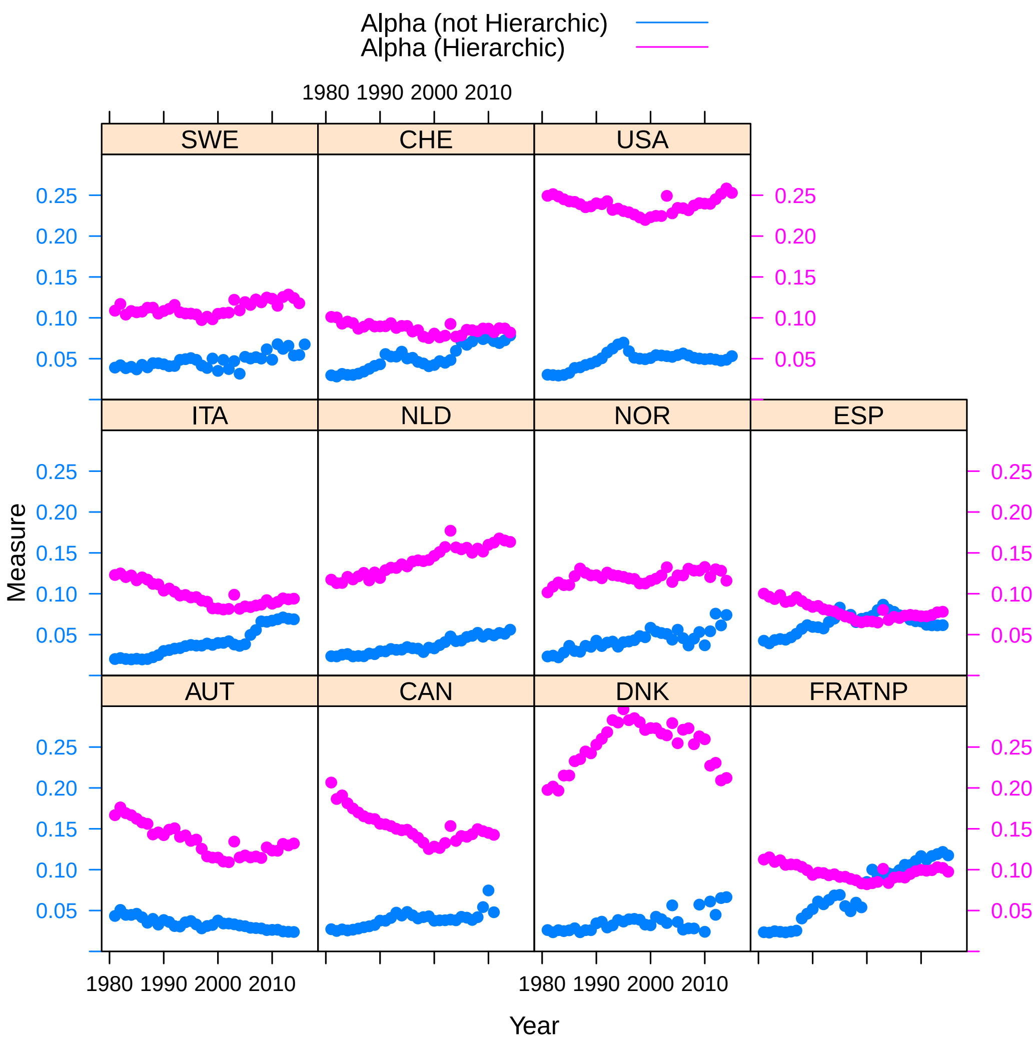


Figure 5: Prevalence of Premature Mortality in some countries, using relative and hierarcihcal approach (source: HMD)



5 Concluding Remarks

Model (4) can be seen as a compromise between absolute and relative approach to measure premature mortality: while senescent mortality schedule is assumed to be fixed for all the considered countries, premature mortality curve may vary across countries.
In this way, we get a seemingly more senslbe measure of premature mortality. However, the main issue that should be considered in the future is how to include countries in the same group and whether – and to what extent, different grouping solutions provide different results. Moreover more accurate evaluation of goodness of fit should be undertaken. At the moment, we can say that the model fit for all countries is rather good (see figure 4) but this evaluation is, up to now, only based on visual inspection.

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