Coherent mortality forecasting in an economic crisis context

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Abstract

The economic crisis witnessed in Europe, especially in the south, might disturb demographic evolutionary trends and affect negatively the extraordinary mortality convergence across industrialized countries to low mortality rates. We make use of Oeppen's (2008) proposal of expressing the Lee-Carter method in compositional form to forecast mortality trends by cause of death over time and to evaluate the impact of the economic crisis in human lifespan and causes of death. For different selected countries we study the evolution of observed/estimated mortality patterns and its impact on life expectancy dynamics, gender differences, causes of death (CODs), and mortality improvement or deterioration at different ages. Preliminary results revealed high accuracy and that the economic crisis established in Europe in 2008 might effectively decelerate life expectancy increase over time (especially in Portugal), but it's very likely that males keep catching up. With this study we intend not only to study present mortality trends, but also produce a coherent mortality forecast, for overall mortality and by COD, in order to answer to three main hypotheses: after the economic crisis in Europe 1) Can we expect life expectancy at birth to increase at the same rate than in the past?, 2) Is this crisis affecting negatively the recent mortality convergence between males and females?, 3) Can we observe major changes across CODs?

Key words: Economic crisis; forecast; mortality; life expectancy; cause of death; coherent.

1. Background and aim of study

Across time profound changes occurred in demographic paradigms. Some resulted in extraordinary life expectancy increase and now the high rates of mortality of the past are being experienced later in life. Currently, the economic crisis witnessed in Europe, especially in the south, might disturb demographic evolutionary trends. Mortality convergence to low mortality rates across industrialized countries is being widely studied (e.g. Wilson, 2011) but we can still observe an expressive male-female gap in life expectancy.

In Japan, the best-practice country in what concerns female lifespan, a female born in 2012 could expect to live slightly more than 86 years, resulting from an average 0.5 yearly increase since 1947 (HMD, 2015). It is well known that this increase is only possible due to significant improvements in health and consequent reductions in mortality rates (Vaupel, 2010).

Several approaches have been created to model the different changes observed over time. One example is the method developed by Lee and Carter (1992). This method reduces the APC (*age-period-cohort*) complexity by introducing a bi-linear model for logarithmic mortality-rates: $\ln m_{x,t} =$

$a_x + b_x * k_t + \varepsilon_{x,t}$. Since then, this methodology has been widely used in demography and it can be considered the standard in modeling and forecasting death rates (Camarda, 2008), even with the inclusion of some variants (Lee and Miller, 2001; Booth et al., 2002; Hyndman and Ullah, 2007), or expressed in a Compositional Data Analysis equivalent definition (Oeppen, 2008). Nonetheless, in modeling mortality rates for two or more subpopulations it is required that forecasts do not diverge from the ones obtained from total population, being coherent. A very recent example of a coherent method is the product-ratio method developed by Hyndman, Booth and Yasmeen (2013). This method achieves coherence through the convergence to a set of appropriate constants of forecast age-specific ratios of death rates for any two subpopulations.

As is well known, the estimation stage of Lee-Carter is a special case of principal component analysis, where the log-mortality data is summarized using only the first principal component (Girosi and King, 2007) and that makes the model not appropriate for all causes of death independently. Nevertheless, in a theoretical perspective many authors support that breaking down mortality forecasts by cause results in higher accuracy but practice also proves the opposite (Booth and Tickle, 2008). Studies like the one from Wilmoth (1995) found that decomposing mortality forecasts result not-rarely in higher mortality forecasts, however, expressing the Lee-Carter model in a conditional form results in very similar estimates in both approaches (Oeppen, 2008).

2. The Lee-Carter CoDa equivalent mortality forecasting model

The CoDa equivalent Lee-Carter method for forecasting mortality trends suggested by Oeppen (2008) allows not only forecasting mortality trends for overall changes mortality rates (*single-decrement forecast*), but also disaggregate those by cause of death (*multiple-decrement forecast*). In opposition to most known approaches, Oeppen suggested using the life-table distribution of deaths d_x and once that its sum equals the life-table radix (l_0) we end up with compositional data. d_x for overall mortality and d_x^i for cause-specific mortality can be obtained by single and multiple-decrement life-tables, respectively.

Despite the existence of some studies ensuring that independent forecast of cause of death mortality do not produce plausible results (e.g., Wilmoth, 1995), the constraint imposed by the sum to the unit of each of the d_x^i compositional vector, ensures that *changes in the density by age and cause have to be compensated by changes in other ages and causes* (Oeppen, 2008).

3. Data

Data on *overall death counts* $D(x, y)$ and *exposures* $E(x, y)$ derived from the *Human Mortality Database* (HMD, 2015: www.mortality.org) and *deaths by COD $D_i(x, y)$* from the *World Health Organization Mortality Database* (WHOMD, 2015).

To avoid low subpopulation sizes and any lack of representativeness or big disruptions between ICD classifications, we work with major COD groups: 1) Neoplasms, 2) Ischaemic Heart Diseases; 3) Cerebrovascular Diseases; 4) Remaining Diseases of the Circulatory System; 5) Diseases of the Respiratory System; 6) Diseases of the Digestive System; 7) External Causes of death; and 8) Remaining Causes of death.

We used five selected countries to follow a concise and complementary analysis: France, Portugal, Sweden, Spain and Japan (only for comparison proposes). Portugal, is a special case here, once that on the WHOMD Portuguese data for both ICDs presents some changes in the classification over time, we make use of EUROSTAT, where COD data is available between 1994 and 2010. Consequently, Portugal is here the country with the smallest time series (1994 to 2010), while Japan (1979 to 2011),

France (1979 to 2011) and Spain (1980 to 2012) present the largest ones. Lastly, Sweden is in intermediary position, with data available between 1987 and 2012.
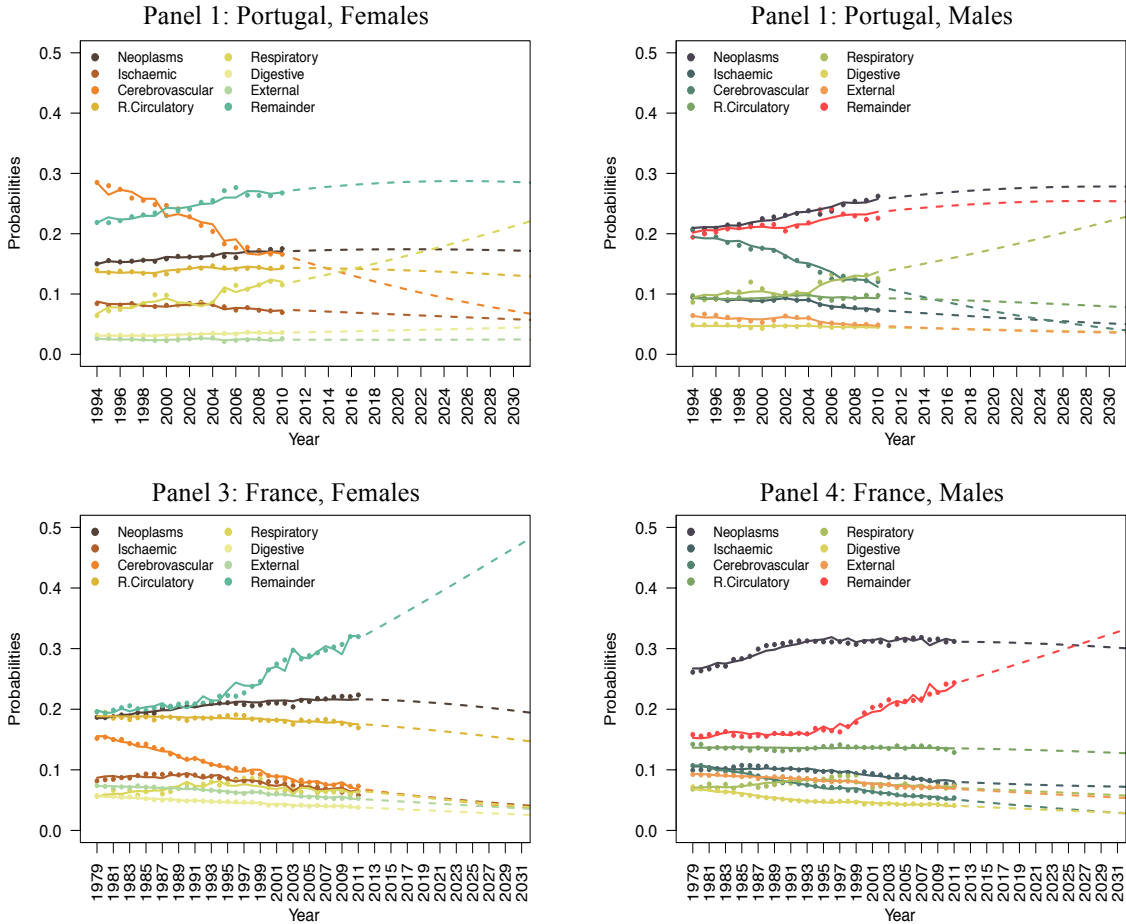
4. Preliminary results: Portugal *Vs.* France

Figure 1 shows period life-table probability that a newborn has to die from a specific cause, where circles correspond to the used data to fit the model (observed), continuous lines represent the rank-r approximation, and dashed lines are the forecasted trends.

For both countries, it's possible to realize that forecasted trends follow previous evolution and seem to progress accordingly. Obtained results suggest that the probability of dying from neoplasms is going to be kept constant over time, but there are very different CODs (i.e., the remaining COD group) that need some intervention once that they are already leading death probabilities for females in Portugal and France.

Portugal presents a very distinctive evolutionary pattern in what concerns to diseases of the respiratory system. Obtained results strongly suggest that if not controlled, the diseases of the respiratory system will become one of the biggest death contributors.

**Figure 1:** Period life-table probability at birth of dying from a specific COD

Panel 1: Portugal, Females   Panel 1: Portugal, Males

Panel 3: France, Females   Panel 4: France, Males

Source: WHOMD, HMD and EUROSTAT 2015, own elaboration

Figure 2 presents observed life expectancy at birth (circles), estimated (continuous lines) and forecasted (dashed lines), from the multiple-decrement approach for countries under observation and by sex. Obtained results suggest that the multiple-decrement model is able to estimate with high accuracy the already observed life expectancy at birth. From an overall point of view, obtained results

suggest that life expectancy at birth gap that differentiates both sexes tends to decline with time and even with a possible negative impact (especially observed in Portugal) of the economic crisis, life expectancy at birth will increase continuously. It is also important to refer that females seem to be the most affect since the beginning of the economic crisis in 2008.

Figure 2: Observed and forecast e_0 by country and sex

Panel 1: Portugal   Panel 2: France
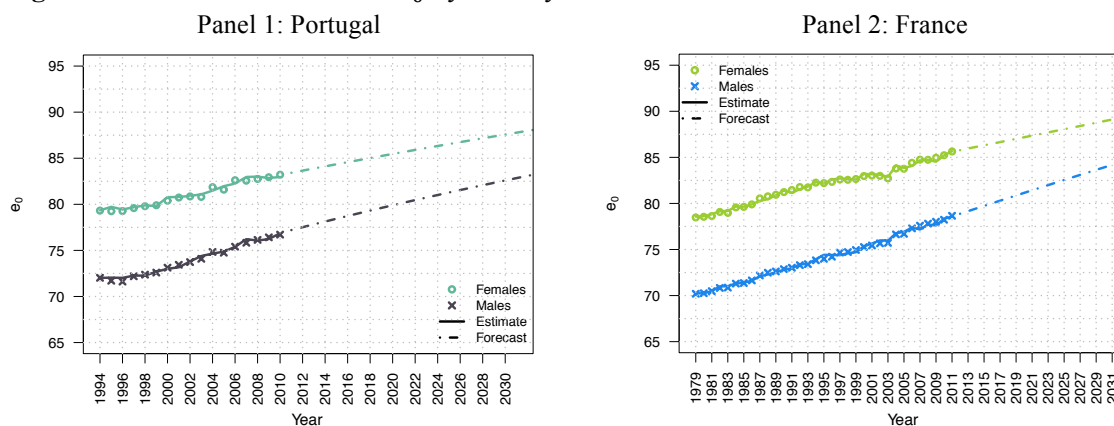
Source: WHOMD, HMD and EUROSTAT 2015, own elaboration

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