Forecasting Period and Cohort Mortality Trends

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Abstract

Examining the pros and cons of period and cohort mortality has a long history in demography. While period measures analyze mortality of synthetic cohorts, cohort measures analyze mortality of real cohorts. Apart from these principal differences, there is a huge amount of literature comparing period and cohort life expectancy, discussing potential distortions due to changing age-specific death rates. To analyze the impact of period and cohort mortality on life expectancy, we extend our period model so that it can also forecast cohort mortality data. We then apply both versions of our model to Danish female mortality. Our results suggest that expected years of life are likely to further increase according to both measures, though cohort life expectancy is forecasted to remain less volatile and, on average, 8.3 years above period life expectancy. Moreover, forecast uncertainty appears to increase faster in the period than in the cohort scenario.

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1 Introduction

Examining the pros and cons of period and cohort mortality has a long history in demography. While period measures analyze mortality of a synthetic cohort, cohort measures analyze mortality of a real cohort. For instance, cohort life expectancy represents survival of one birth cohort at different ages in consecutive calendar years, whereas period life expectancy represents survival in a calendar year across all currently alive birth cohorts. Although cohort life expectancy includes mortality levels of people of only one birth cohort who, therefore, experienced the same conditions over their lifetime, its main drawback is that it can be computed only for cohorts whose last member already died. In contrast, period life expectancy includes mortality levels of people of different birth cohorts, who, therefore, experienced dissimilar conditions over their lifetime, but its main advantage is that it can be computed as soon as a calendar year is over. Apart from these principal differences, there is a huge amount of literature discussing potential distortions of period life expectancy (Barbi et al., 2008; Luy, 2010). For instance, Bongaarts and Feeney (2002) claim that period life expectancy can be biased as soon as age-specific death rates change and suggest, therefore, to adjust it to such tempo biases. Contrary, other demographers argue that period measures are not biased. For instance, Wilmoth (2005) shows that tempo-adjusted period life expectancy is not unbiased, and that it just corresponds to another interpretation similar to, e. g., the cross-sectional average length of life (Guillot, 2003). Wilmoth (2005) as well as Shkolnikov et al. (2011) also show that increases in period life expectancy are smaller than gains in years of life among cohorts. In this paper, we want to explore the trends of period and cohort mortality and how they can be forecasted with our model (Bohk and Rau, 2014).

2 Data, Methods, and Results

To analyze period and cohort life expectancy at birth of Danish women, we (1) examine their mortality data from the Human Mortality Database (2013) and we (2) conduct forecasts with our extended model (Bohk and Rau, 2014).

Observed period and cohort mortality data Life expectancy at birth, death rates and rates of mortality improvement of Danish women are depicted for calendar years 1850 to 2009 in Figure 1 and for birth cohorts 1850 to 2009 in Figure 2. Cohort life expectancy appears to be larger and less volatile than period life expectancy; for instance, with 62 years, life expectancy of the birth cohort 1900 is more than 8 years larger than life expectancy of the respective synthetic cohort in the calendar year 1900 with 53.5 years. We depict death rates and rates of mortality improvement on so-called Lexis surfaces for single ages (0 to 100) on the x-axis and for calendar years or birth cohorts (1850 to 2009) on the y-axis; level of mortality itself and of its annual or inter-cohort change are depicted with a color gradient, which ranges from blue for lower levels over green and yellow to red for higher levels. Moreover, mortality increases are depicted in gray and black for the rates of mortality improvement. A first look reveals that the surfaces of the period mortality data are filled for all ages and calendar years, whereas the surfaces of the cohort mortality data are only completely filled until birth cohort 1909; mortality data of subsequent birth cohorts are incomplete, because their members have not gained oldest ages yet. A second look reveals several cohort and period effects for Danish women, which are especially easy to observe in the surfaces depicting the rates of mortality improvement; for instance, women born between 1920 and 1940 experienced a cohort effect of rising mortality in their adult ages, which is probably due to heavy smoking (e.g., Jacobsen et al., 2002; Christensen et al., 2010). This cohort effect is visible as a gray area along a 45 degree line in Figure 1, and along a vertical line in Figure 2. Although the development of mortality is diverse, we can identify general patterns from the period as well as from the cohort perspective: One general pattern are relatively strong survival improvements, which proceed from younger to older ages with time (and over cohorts); this transition can be occasionally interrupted by period and/or cohort effects, causing long-term trend changes, which appear to be another general pattern; an example is the (above mentioned) temporarily stagnating period life expectancy of Danish women in adult ages between the 1980s and the early 1990s due to a cohort effect.

Forecasted period and cohort mortality data Although dynamic age-shifts of survival improvement as well as long-term trend changes belong to general patterns in the development of mortality, many forecasting approaches cannot capture them appropriately (often due to model-based limitations such as time-invariant improvements among ages over time). To overcome these shortcomings, we proposed a mortality forecasting model (Bohk and Rau, 2014), which combines recently developed concepts. For instance, our model can capture dynamic age-shifts of survival improvements, because it forecasts the rates of mortality improvement instead of the death rates themselves. A similar strategy pursue, for instance, Mitchell et al. (2013) or Haberman and Renshaw (2012), who use the predictor structure of the original Lee-Carter model (1992) to also forecast the rates of mortality improvement, or Li et al. (2013), who extend this predictor structure to let the age pattern rotate with time. Another feature of our model is that it can account for changes in long-term mortality trends by optionally complementing the mortality trend in a country of interest with those of selected reference countries. This goes in a similar direction as the coherent mortality forecasting approaches of, for instance, Li and Lee (2005) or Cairns et al. (2011), who also suggest to jointly forecast mortality of multiple populations.

To analyze the impact of period and cohort mortality data on forecasted life expectancy with our model (Bohk and Rau, 2014), we extend it so that it can forecast not only period, but also cohort mortality data. We then apply both versions of our model to forecast period and cohort mortality of Danish women. In the period mortality forecast for the calendar years 1991 to 2009, we take data of the calendar years 1965 to 1990, and in the cohort mortality forecast for the cohorts 1910 to 2019, we take data of the cohorts 1850 to 2009, which are completely available for all ages only until cohort 1909. In both mortality forecasts, we use Sweden as reference country to complement the Danish mortality trend.

Figures 3 and 4 depict the median and the 90% prediction intervals of the forecasted period and cohort life expectancy at birth of Danish women, respectively. Expected years of life are likely to further increase according to both measures, though cohort life expectancy is forecasted to remain on average 8.3 years above period life expectancy. For instance, the median cohort life expectancy is with 79.5 years for the cohort 1950 roughly 8 years higher than the respective period life expectancy of 71.5 years in the calendar year 1950. Shkolnikov et al. (2011) call this gap the *cohort lifetime survival benefit*. Although a fair comparison of forecast uncertainty is rather difficult, it is striking that uncertainty accumulates at a far slower pace for cohort than for period life expectancy; this effect is mainly due to a substantially different number of ages for whom mortality has to be forecasted as depicted in the bottom of Figures 3 and 4; in the period scenario, we have to forecast mortality for all 110 ages from the first forecast year on, whereas, in the cohort scenario, we have to forecast mortality for one age in the first cohort, for two ages in the second cohort, up to 110 ages from the 110th cohort on. However, once we have to forecast mortality for a similar number of ages for a current calendar year or birth cohort, the level of uncertainty appears to be similar for period and cohort life expectancy. For instance, the 90% prediction interval of period life expectancy spans over 5.8 years (from 79.1 to 84.9 years) in the calendar year 2009, whereas the 90% prediction interval of cohort life expectancy spans over 5.5 years (from 85.6 to 91.1 years) for the birth cohort 2009.

3 Concluding Remarks

Preliminary results of our comparison of period and cohort mortality (trends and forecasts) of Danish women with our model (Bohk and Rau, 2014) suggest that (1) cohort data are less volatile than period data, that (2) cohort life expectancy is likely to remain substantially above period life expectancy and that (3) forecast uncertainty appears to evolve at a far slower pace for cohort than for period life expectancy. We intend to deepen further these analyses in the paper.

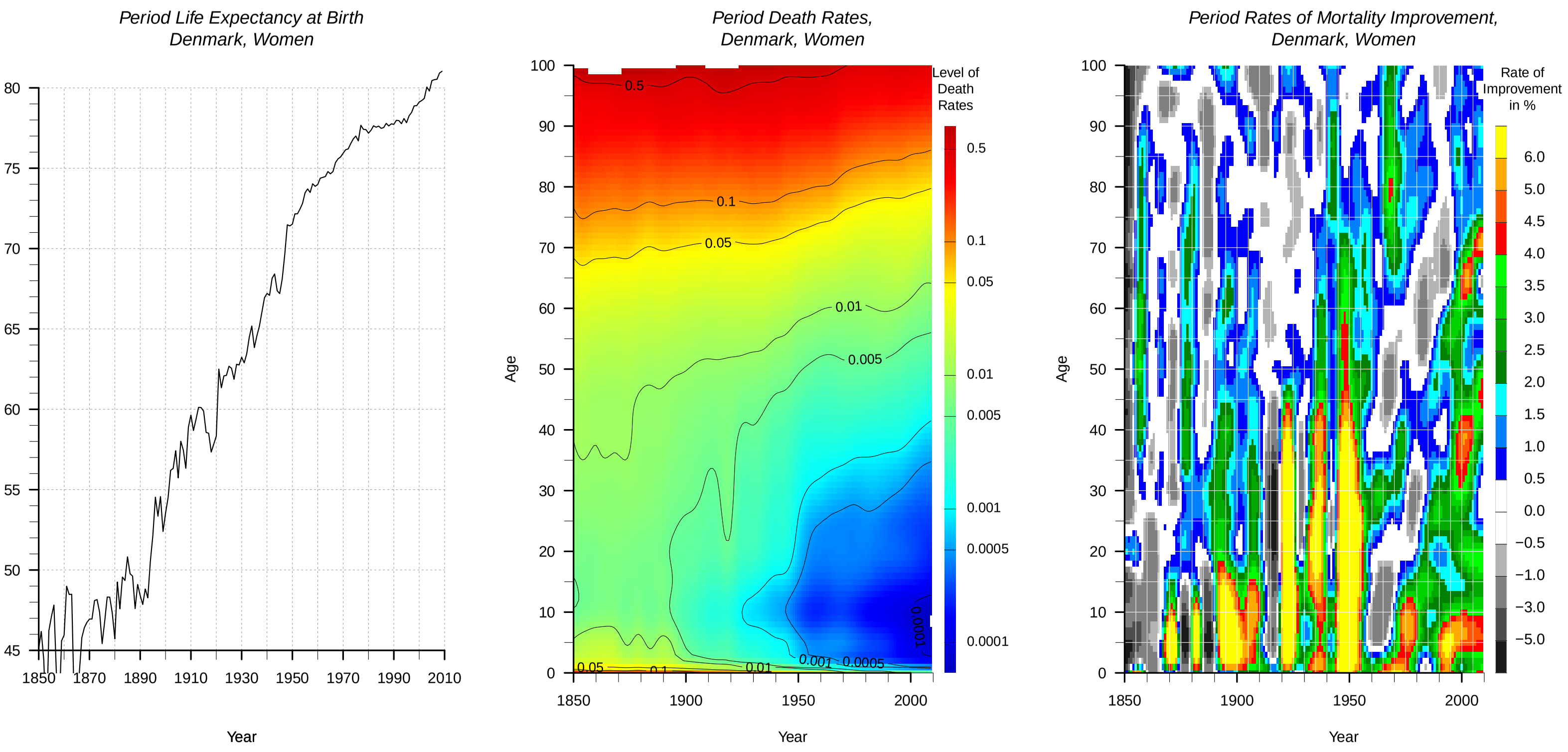

Figure 1. Life expectancy at birth e_0 (left), death rates (center) and rates of mortality improvement (right) by single age (0 to 110) of women in Denmark for the calendar years 1850 to 2009.

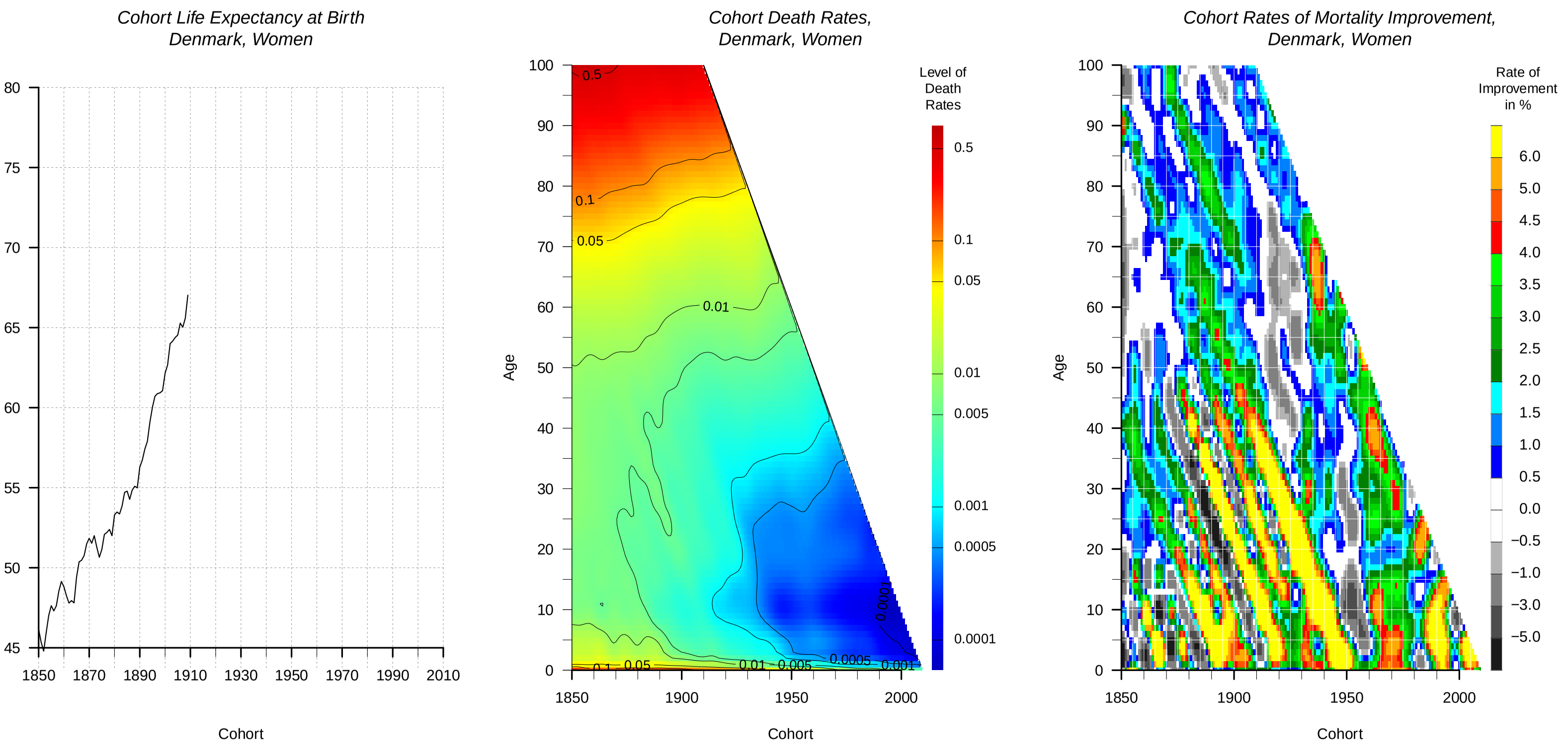

Figure 2. Life expectancy at birth e_0 (left), death rates (center) and rates of mortality improvement (right) by single age (0 to 110) of women in Denmark for the birth cohorts 1850 to 2009.

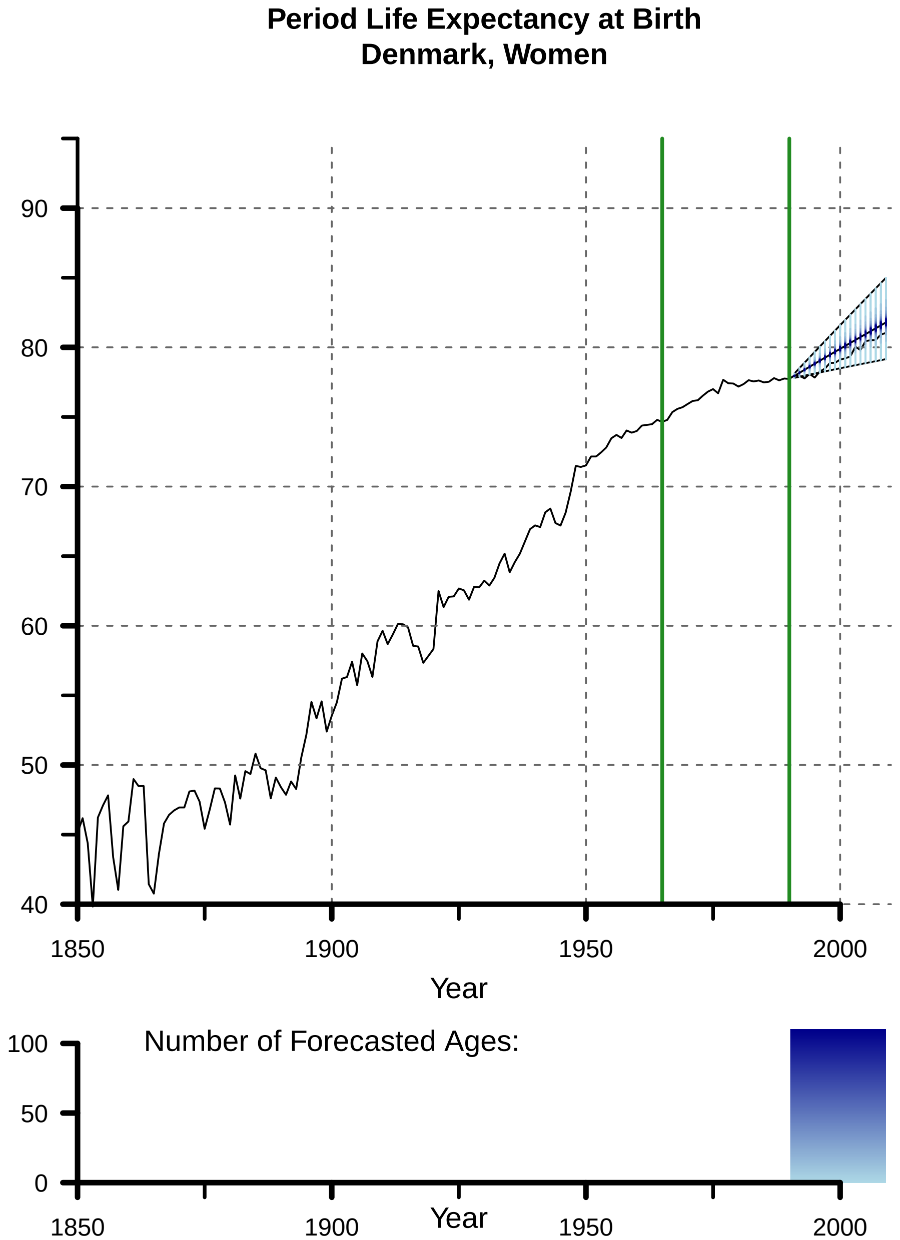

Figure 3. Upper panel: Observed period life expectancy at birth (black line) of Danish women from 1850 to 2009. The median and the 90% prediction intervals of our period forecasts from 1991 to 2009, based on data from 1965 to 1990 (green vertical lines), are depicted in blue. Lower panel: In our period forecast, mortality has to be forecasted for all ages (blue) in each forecast year.

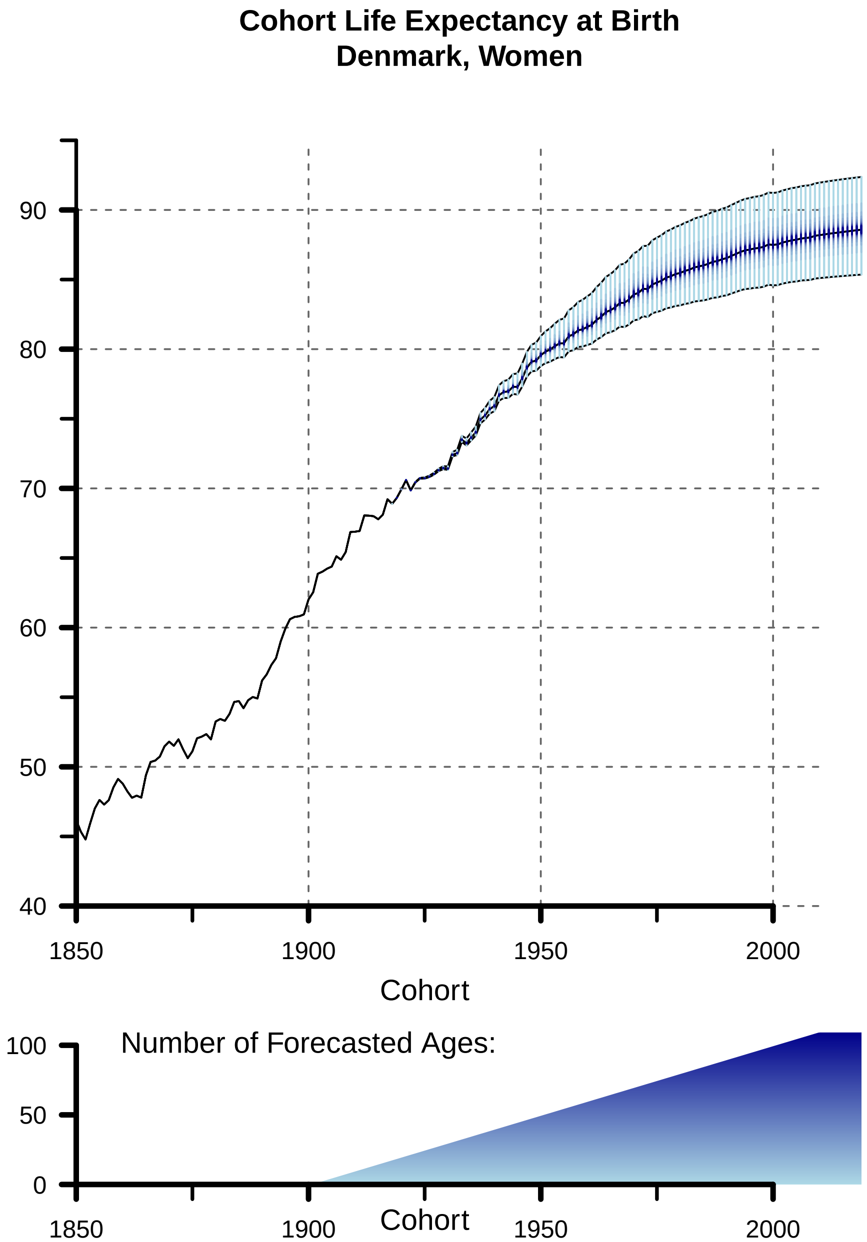

Figure 4. Upper panel: Observed cohort life expectancy at birth (black line) of Danish female birth cohorts 1850 to 1909. The median and the 90% prediction intervals of our forecasts for the cohorts 1910 to 2019 are depicted in blue. Lower panel: In our cohort forecast, mortality has to be forecasted for successively more ages (blue); while mortality has to be forecasted for only one age for the cohort 1910, it has to be forecasted for all ages from cohort 2009 on.

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