VARIATION AS A THEME:
VARIABILITY TRENDS DURING MORTALITY TRANSITIONS

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Abstract. An inverse relationship between life expectancy and the variance of the age of death is a corollary of mortality rectangularization. In this paper, we examine the variability around life expectancies at birth and for those surviving to post-reproductive ages, comparing within- and cross-national trends in variability during major mortality transitions in industrialized nations. While the variance of the full distribution of life-table ages at death has decreased markedly with rising life expectancy, the variance of adult ages at death has remained fairly constant over time, with slight recent increases in some nations. We contrast the divergence in life expectancies at birth and in the post-reproductive years with the convergence observed in their associated measures of variability. Persistent heterogeneity at older ages due to delayed mortality selection may partially explain why the variation in the adult ages at death has not diminished.

INTRODUCTION

As life expectancy rises and the majority of deaths shift to older ages, the survival curve becomes increasingly rectangular and variation in the full distribution of ages of death declines. Full rectangularization in human survival is unlikely to be achieved, however, as it would require both a true maximum lifespan and a complete lack of variability in ages of death. While the existence of an ultimate limit to human life spans continues to be a matter of debate, the persistence of some variability in the ages of death is clearly observable. In fact, differences in the variances of adult ages at death have been shown to account for much of the current differences in the age-pattern of mortality in countries with similarly high levels of life expectancy (Edwards &Tuljapurkar, 2005).

While life expectancy has been used as a key indicator for examining mortality change, until recently relatively less attention was been paid to mortality variation in the context of mortality transitions. This paper examines the variability around life expectancies at birth and for those surviving to post-reproductive ages, comparing within- and cross-national trends in variability during major mortality transitions. It aims to show that recognizing variability in life spans is key to understanding the implications of selection and heterogeneity for mortality compression and, ultimately, health and morbidity patterns in later life. The study empirically explores this potential relationship across a diverse range of geographic settings, incorporating a comparative historical perspective as long and as broad as the available data allow.

DATA AND METHODS

Using period life-tables for 46 countries included in the Human Mortality Database (HMD, www.mortality.org) and the Human Lifetable Database (www.lifetable.de), we investigate patterns of variability both within and across population groups. Our analysis focuses on the relationship between life expectancy at birth (e_0) and life expectancy conditional on survival to age 45 (e_{45}) as well as trends in their respective variation across geographic and historical contexts.

Numerous indicators have been used to analyze changes in the survival curve over time, each measuring a somewhat different aspect of the concentration of ages at death around a central value (e.g. mean or median). To explore the variability around mean life durations, we calculated standard deviations from the mean age at death for males and females. Following Edwards and Tuljapurkar (2005), we use life table deaths, indexed by the function ${}_nd_x$ as weights for the distribution of ages at death, and examine the dispersion in full and adult (conditional on survival to age 45) lifespans. The standard deviations from the mean age at death for the entire population (denoted as S_0), as well as the standard deviation from the mean age at death for those surviving into old age (denoted as S_{45}) is traced across successive periods and compared across countries. Given that the pattern of mortality change usually involves reductions in early-life causes of deaths (e.g. infections) before reductions in causes of death that operate in later-life, both S_0 and S_{45} offer valuable insights regarding possible changes in the influence of selection.

We use age 45 as a cut point because, given both historical life expectancies and human reproductive schedules, 45 represents a threshold between young and aged mortality, differentiating mortality associated with early stages of the demographic and epidemiologic transitions (when mortality in infancy and the reproductive years are high) from the chronic disease mortality that gains prominence in later transition stages. Changes in mortality rates and patterns above age 45 may thus be more closely linked to the underlying diversity of the population surviving to old age than to factors in early and mid-life. Still, the choice of a specific age at which to divide aged from non-aged mortality may have to be adjusted for specific contexts, and I intend to explore alternative age cutoffs, and to assess the sensitivity of selected cutoffs across periods and countries.

In addition to s45, changes in the modal age of adult death over time, as well as in the length of four standard deviations from the modal age of adult death (Cheung *et al.,* 2005) will be used to examining changes in the right tail of the distribution of ages at death. Finally, age variation in mortality will be examined and compared across countries using the life table aging rate (LAR), which measures the relative acceleration or deceleration of mortality rates with age and is particularly useful for testing hypotheses about the relationship between compositional changes and observed mortality trends at older ages (Horiuchi & Wilmoth, 1998).

PRELIMINARY RESULTS

Figures 1 and 2 show contrasting trends in the relationship between e_0 and e_{45} and the relationship between their respective standard deviations in nine industrialized nations. Life expectancy at birth and at age 45 have both been increasing over time, though the rise in e_{45} has been more recent and gradual, leading the two measures to diverge increasingly over time even as they follow similar rising trends. In contrast, the sharp decline in S_0 (the standard deviation around e_0) has led it to converge with S_{45} as life expectancy rises and the majority of lifespan variation shifts to older and older ages. It is interesting, however, to observe that the level of the conditional standard deviation S_{45} in the HMD countries has remained notably consistent over the course of national mortality transitions, with even a slight recent *increase* in some nations with very high life expectancy at birth. As survival improves, the ratio of variation around e_{45} to variation around e_0 increases. We may thus expect that as mortality continues to be reduced, variation in the full distribution of death will approach variation in old-age mortality and then stabilize.

Persistent heterogeneity among those surviving to older ages due to delayed mortality selection may partially explain why the variation in the adult ages at death has not diminished over time to allow "full" rectangularization of the survival curve. While deaths become concentrated at older ages and selection is pushed to increasingly later ages, demographic frailty may nonetheless prevent the variation of aged mortality from declining past a certain threshold, and improved survival in older ages may also be contributing to its recent increases in some nations. We investigate selection's role in shaping mortality patterns, examining links between measures of frailty in mid- and later-life and the pattern of variation around the mean (and mode) age of adult deaths using cohort data. By comparing trends across countries, we examine the relationship between diverse demographic trajectories and variation in old age mortality, comparing, for example, trends in Western Europe and the US with those in countries experiencing reversals in the epidemiologic transition (e.g. the former Soviet republics).

Taken together, these analyses can contribute to a conceptual framework connecting mortality transitions with shifts in the underlying heterogeneity in the older population, with particular implications for the debates surrounding the compression of mortality and morbidity.

References

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Cheung S.L.K., J.M. Robine, E.J.C. Tu, and G. Caselli. 2005. Three dimensions of the survival curve: horizontalization, verticalization, and longevity extension. *Demography* 42(2): 243-252.

Horiuchi S., and J. Wilmoth. 1998. Deceleration in the age pattern of mortality at older ages. *Demography* 35(4):391-412.

Figure 1. Trends in Women's Life Expectancy 1850-2006: e0 (Red) and e45 (Blue)

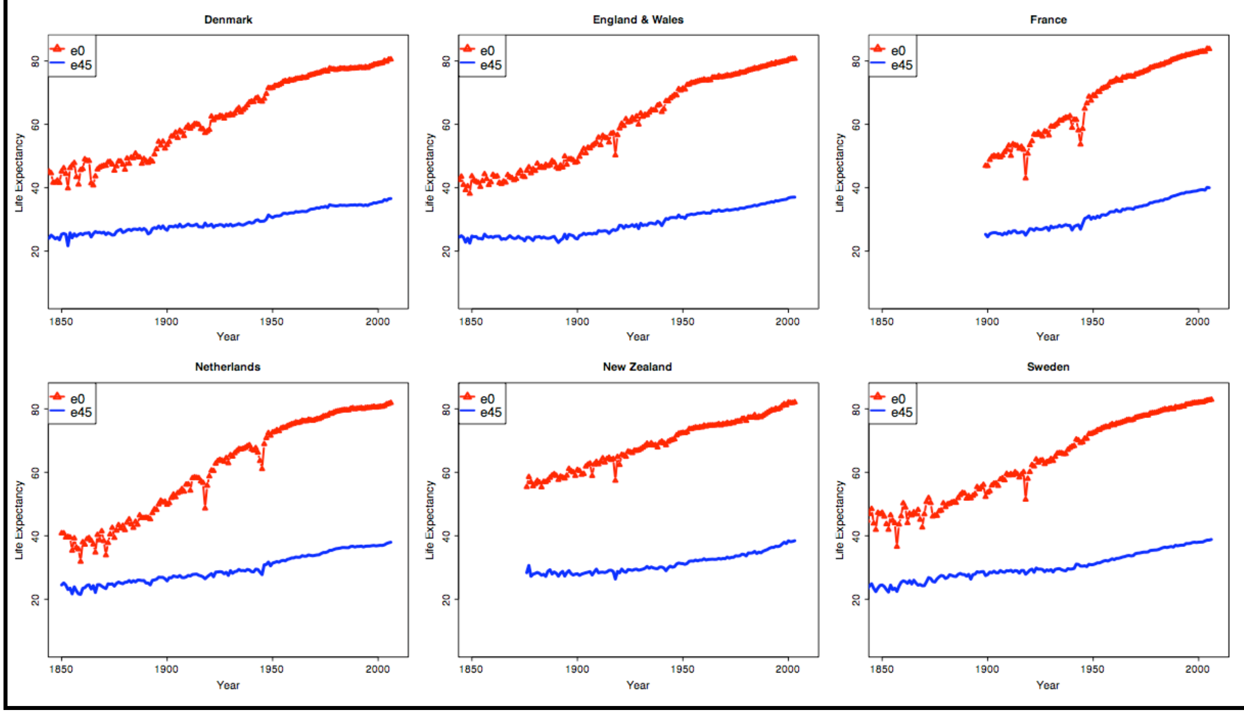
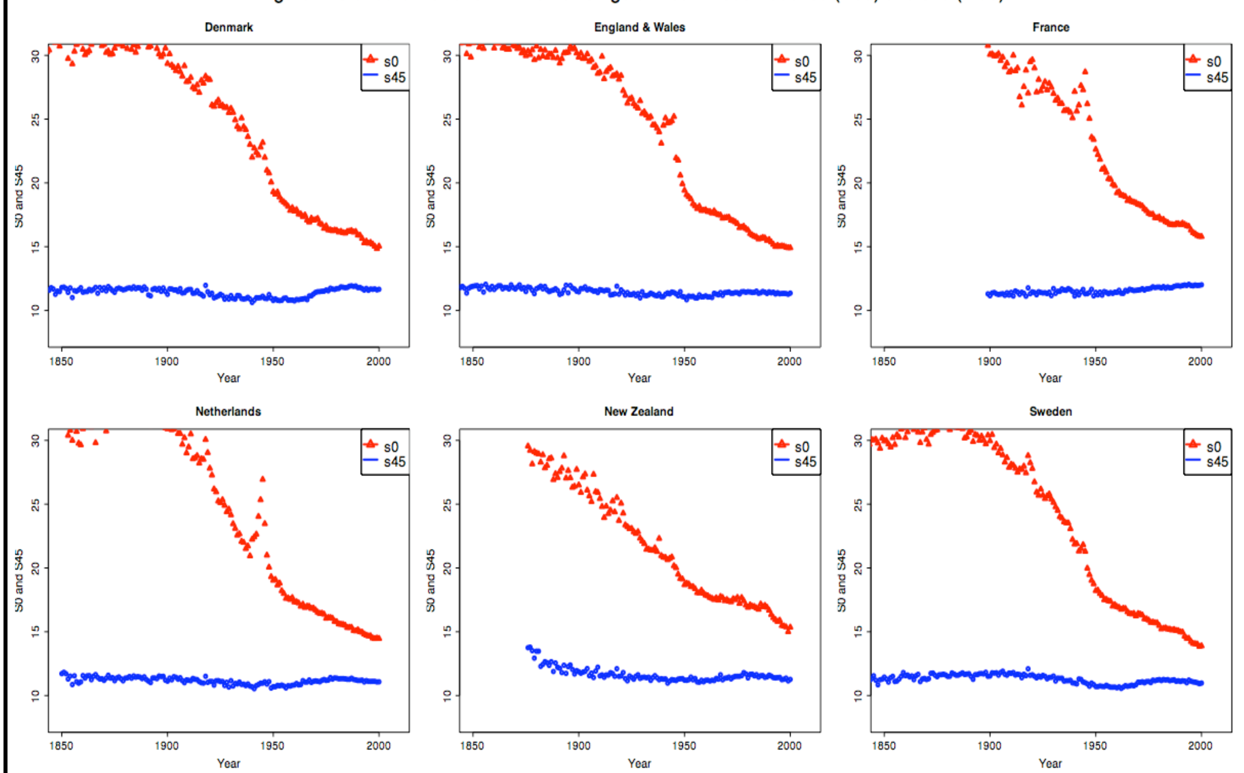


Figure 2. Standard Deviation in Women's Age at Death 1850-2006: s0 (Red) and s45 (Blue)



Source: Human Mortality Database