

How Tempo Distortions Affect the Analysis of Changing Mortality: The Case of Mortality Trends in West and East Germany

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Abstract

The divergence and convergence of survival conditions in West and East Germany offer a unique possibility to understand the causes of current changes in mortality. In recent years, several studies based on observed trends in life expectancy between West and East Germany have been done, but the leading determinant is still undetected. Following Bongaarts and Feeney's approach I argue that this kind of data is an imperfect base for examining mortality changes because of severe tempo distortions. Adjustment for tempo effects shows that the differences in survival conditions between West and East Germany are still considerably higher than expected and that the survival gap between West and East Germany started to close considerably later than trends in conventional life expectancy suggest. This indicates that the search for the causes of changing mortality in East Germany might have been based on inappropriate measures and thus led to the wrong direction. The example of mortality trends in Germany shows the importance of considering tempo effects in order to understand common phenomenon of differential mortality.

Introduction

The demographic changes and developments in Eastern and Western Germany are generally seen to offer a unique possibility to understand the interaction between societal, social respective economic conditions and population processes. Thus, the German experience can also serve in order to understand the causes of recent changes in mortality. Almost identical demographic composition and behaviour until 1945 were followed by 45 years of life under different political and socio-economic structures resulting in completely different demographic conditions (Dinkel, 1992, 1994, 1999; Gjonca et al., 2000). With Reunification in 1990 the population in Eastern Germany returned to the Western societal and economic system what caused sudden changes in all its demographic developments. These special preconditions – leading some scholars to describe the Eastern German population as a kind of “natural experiment” (Dinkel, 1999; Vaupel et al., 2003) – generated a large number of researches about changes in Eastern German demography. In the field of mortality research especially the rapid convergence of survival conditions since 1990 following roughly two decades of continuous divergence are subject of central interest. The fact that both, the former increase and the recent decrease of the life expectancy gap between West and East Germany were mainly caused by age groups between 60 and 80 led to the central message that “it’s never too late” for increasing length of life (Vaupel et al., 2003).

The general and most important intention of all studies on mortality differences between West and East Germany is to find the factor or the factors responsible for causing such a change in East German’s survival conditions within only one or two years. There is good reason to assume that those conditions which were responsible for the increase of West-East German mortality differences before Reunification could also have been responsible for or contributed to their later decrease. In the late 1980s, some speculations were formulated about the potential nature of the widening West-East differential in mortality already visible at that time (for an intensive discussion see Dinkel, 1992, 1994, 1999; Heinemann et al. 1996; Luy 2004). The most factors discussed are the same that are assumed to be responsible for the general mortality gap between Western and Eastern European countries (e.g. Bobak and Marmot, 1996a, 1996b; Hertzman et al., 1996) making the search for the causes of mortality trends in East Germany to a subject of important interest exceeding the borders of Germany.

Since after Reunification East Germany was so distinctly removed from the former Eastern European mortality pattern, the prime candidates for an explanation are expected to be those where conditions in East Germany now are different from what was experienced around and before 1990. This limits the number of possible decisive factors to the progress in medical care, the increased availability of nursing care, and the changes in lifestyles and cardiovascular risk factors of Eastern German women and men connected with the new economic conditions after Reunification. Especially the first factor is by most scholars expected to be mainly responsible for the observed mortality trends in East and West Germany before and after Reunification (Chruszcz, 1992; Dinkel, 1994, 1999; Schott et al., 1994; Becker and Boyle, 1997; Gjonça et al., 2000). In the same way medical technology is thought to be responsible for the general West-East mortality gap in Europe (Boys et al., 1991; Mackenbach et al., 1996; Velkova et al., 1997; McKee and Nolte, 2004). Regarding Germany, this explanation is confirmed by the fact that during the whole 1990s mortality in Eastern Germany was lowest in its agglomeration and urban areas where access to medical care is considerably better than in rural areas (Bucher, 2002; Mai, 2004).

However, direct examinations of the impact of the new and improved medical conditions in Eastern Germany do not support this hypothesis. Using Rutstein et al.'s (1976) until today continuously improved concept of causes of death that are considered to be responsive to medical care (the so-called "amenable deaths"), Nolte et al. (2002) and Luy (2004b) independently analysed the impact of those causes on the closing of the West-East German mortality gap in the 1990s. Both studies came to the same result that the changes in medical conditions in Eastern Germany seemed not to influence the steady decline in Eastern German excess overall mortality. Almost the same holds for lifestyles and cardiovascular risk factors of Eastern German women and men. The analysis of follow-up health survey data showed that health-related behaviours of Eastern German women and men are indeed adjusting the Western German lifestyles and that some of these cardiovascular risk factors in fact do influence survival probabilities. However, the results of deeper event history analysis do not provide any indicator for a significant contribution of cardiovascular risk factors to mortality differences between Western and Eastern Germany (Luy, 2004a, 2005). As Luy (2004a) demonstrated in a recent article, the only factor that shows a converging trend between Eastern and Western Germany comparable to the trends in life expectancy is the availability of nursing care. During the 1990s the West-East differences in nursing care diminished being now on almost the same level in the two parts of Germany.

The weak point of this hypothesis might be that the absolute number of people being affected by these changes seems to be insufficient to cause an increase in life expectancy at birth as occurring in the East German population. However, following the tempo-approach of Bongaarts and Feeney (2002) I will argue that trends in conventional life expectancy at birth are an imperfect base for examining mortality differences between West and East Germany. Sudden increases in average age at death as occurred in different years in West and East Germany lead to severe tempo distortions in unadjusted life expectancy. I will show that the differences in survival conditions between West and East Germany are still considerably higher than expected and that the survival gap between West and East Germany started to close not before the second half of the 1990s and, moreover, is still far away from an adjustment of survival conditions. The intention of this paper is not to test the nursing care hypothesis but to show to which extent tempo distortions might affect the analysis of changing mortality. As far as I know this paper contains the first direct application of Bongaarts and Feeney's tempo approach in mortality exceeding the present methodological discussion that is exclusively based on theoretical population models.

Life expectancy trends in West and East Germany from 1950 to 2000

Figure 1 shows the trends in period life expectancy at birth e_0 using standard life table techniques for West and East German women and men for each single calendar year from 1950 to 2000. The life table calculations are based on official population statistics, i.e. numbers of the living population and deaths for each calendar year and single age groups (see description in Luy 2004a). Regarding mortality differences between West and East Germany the observed time span can be subdivided into four stages:

- The first stage from 1950 to roughly 1960 is characterized by irregular fluctuations with several years of mortality crossing over. These trends correspond with the waves of influenza that circulated in different years in East and West Germany (Luy 2004a). Thus, during these years no mortality differences can be stated between the two Germanys, neither for men nor for women.
- In the second stage approximately covering the period 1960 to 1975 the development of life expectancy in West and East Germany became more regularly, with a slightly higher mortality of East German women but a significantly lower mortality of East German men

as compared to their West German counterparts. The differences in favour of East German men increased until the first half of the 1970s and reached a maximum of roughly one year in life expectancy at birth. However, this disadvantage of West German men is mainly affected by different definitions of live birth in East and West Germany which caused lower infant mortality rates in the former GDR for purely statistical reasons.¹ An analysis of age-specific differences between West and East German mortality clearly shows that the higher life expectancy of East German men in these years was mainly (but not only) resulting from lower infant mortality (Luy 2004a).

- The third stage of life expectancy trends in West and East Germany starting in the middle of the 1970s is characterized for both sexes by a continuous divergence in the development of survival conditions in favour of West Germany. This development corresponds to the general divergence in mortality trends between all Western and Eastern European countries (see e.g. Caselli and Egidi, 1980; Bourgois-Pichat, 1985; Bobak and Marmot, 1996a, 1996b; Hertzman et al., 1996; Meslé and Hertrich, 1997; Vallin and Meslé, 2001; Meslé and Vallin, 2002). Figure 1 shows that this opening of the survival gap was caused by the fact that East German life expectancy at birth increased with a lower gradient for both sexes, while life expectancy in West Germany rose more rapidly (Höhn and Pollard, 1990, 1991; Scholz, 1996; Gjonça et al., 2000; Nolte et al. 2000a). The differences peaked in 1988 for women (almost 3 years) and in 1990 for men (roughly 3.5 years).
- These peaks – virtually concurring with German Reunification – were followed by a continuous closing of the gap in West-East German mortality differences until 2000, where the difference in e_0 was about 0.5 years for women and about 1.5 years for men. As can be seen in figure 1, with the beginning of this stage the differences in life expectancy trends between West and East Germany reversed as compared to the trends in the third stage. The now observable convergence of mortality levels is due to the fact that life expectancy rises faster in Eastern Germany since the beginning of the 1990s as compared to the West.

Figure 1 additionally visualizes the striking increase in mortality of East German men in 1990 that has been described as East German “mortality crises” (Dorbritz and Gärtner, 1995; Riphan, 1999; Nolte et al., 2000a, 2000b) and as one characteristic of a “demographic shock”

¹ In West Germany, the result of a delivery is defined as a live birth if one of the three signs of life, namely heart-beat, natural respiration, or pulsating umbilical cord, is recognised. According to East German statistics, a live birth was defined only by the joint existence of heartbeat and natural respiration (Müller, 1976). Consequently, all deaths of new-borns showing only one of the three signs of life are registered as live births, and thus as infant deaths only in West Germany, while in East Germany such cases were registered as stillbirths, and did not enter infant mortality statistics.

East Germany's in connection with the changes caused by Reunification (Eberstadt, 1994). However, long-term trends in survivorship completely contradict to such a description and rather call for an explanation of the rapid closing of the gap. The decisive question is: which factor or which factors could be responsible for the reversing of trends in mortality differences between West and East Germany within only one or two years of time?

It seems to be clear, as already described in the introduction, that an answer to this question will be a decisive step in gaining a better understanding of general mortality differentials and especially of mortality differences between Western and Eastern Europe. A huge and continuously increasing number of studies follow this path based on the trends in life expectancy as shown in figure 1. However, in two recent articles Bongaarts and Feeney (2002, 2003) claimed that period life expectancy based on annual death rates is an imperfect solution for reflecting period mortality conditions, because period life expectancy calculated in the standard way is distorted whenever it is changing. The authors showed that when the mean age at death rises (mortality decline), the death rates are biased downward and when the mean age at death falls (mortality increase), they are biased upward. As described above, both decisive changes in the development of mortality differences between West and East Germany coincided with considerably different trends in life expectancy in the two parts of Germany: in stage 3, life expectancy increased successively in West Germany while it increased only slightly or remained constant in the East and in stage 4, life expectancy rose with a considerably higher pace in Eastern Germany as compared to the West. If these different trends in West and East Germany are causing tempo distortions in the sense of the Bongaarts/Feeney-approach, all researches on causes of East German excess mortality might be based on data leading to a distorted picture of mortality conditions in West and Germany and thus to the differences between them.

How mortality tempo affects period death rates

The existence of mortality tempo effects was only recently detected and described in two papers by Bongaarts and Feeney (2002, 2003). The idea derives directly from the idea of fertility tempo effects, which are known since more than half a century and which are widely accepted. In this connection Bongaarts and Feeney (1998) proposed a new method for estimating the tempo bias in period fertility rates and provided a formula to adjust the TFR for these

distortions. Despite some critics, this formula made its way successfully into demographic research as can be seen in a continuously increasing number of papers applying this formula or confirming its effectiveness (e.g. Kohler and Philipov, 2001; Philipov and Kohler, 2001; Zeng Yi and Land, 2001, 2002; Sobotka 2004). However, Bongaarts and Feeney's successive work on mortality tempo effects is far away from broad acceptance. The explanation of this may be that mortality tempo effects have implications that seem to be in variance with established ways of modelling and analyzing mortality. The common critics against the Bongaarts/Feeney-approach to adjust life expectancy are based on the argument that life expectancy itself is a pure tempo measure and thus cannot be adjusted for tempo effects (Guillot, 2003b; Wilmoth, 2005). This is, however, not the claim of Bongaarts and Feeney who focus their idea on tempo distortions in age-specific death rates, i.e. the base of life table techniques, and not on the measures that are derived from them. Another problem for the acceptance of the tempo approach in mortality might be that it seems as if tempo effects have an even bigger impact on the most common measure for period mortality (that is life expectancy at birth) than on the most common measure for period fertility (TFR). At least the results presented in this paper should change completely what we thought to know about mortality differences between West and East Germany.

In order to demonstrate the idea of tempo effects in mortality I use a simple illustration given by Feeney (2003) in his unpublished paper with the apt title "mortality tempo: a guide for the sceptic". Consider a population in which all births occur intermittently at 0.2 year intervals and in which all deaths occurring during some base year occur at exactly the midpoint of a single year of age. Suppose that, at the end of this base year, age at death within a certain age group begins to increase linearly at the rate of 0.2 years per year for all persons, and ceases increasing at the end of the year. This situation is graphically shown in the Lexis diagram in figure 2 for age 62, where the life lines of each cohort are traditionally represented by an arrow moving through time and age. In the base year t_0 all deaths in age 62 occur exactly at age 62.5. During year t_1 the age at death increases linearly with the given annual rate from 62.5 to 62.7. This level is reached in year t_2 and remains constant from then on. Assume further, that annual numbers of births to the population have been constant and that the proportion of deaths in any birth cohort that occur at the i -th age at death is constant over all cohorts (that means unchanged mortality conditions until the base year t_0). These two assumptions imply that each dot in figure 2 represents the same number of deaths and that each arrow represents the same number of persons surviving until age 62.5.

The decisive aspect is what happens with the number of deaths in year t_1 , the year of changing mortality. The five cohorts in t_1 reaching age 62.5, the exact age at which those who do not survive the given age group die according to the old conditions, are marked with the letters A to E. Thus, cohort A is the oldest cohort reaching age 62.5 in year t_1 and cohort E the youngest. Due to the assumed changes in mortality conditions during year t_1 , the ages at death of cohorts A to E increase steadily and cohort E is the first to reach the new age at death level of 62.7 years. Since each of these five cohorts lives somewhat longer than the preceding cohort, the intervals between deaths are longer than the intervals between births (before the year of changing mortality conditions t_1 these intervals are identical). As a consequence, the deaths to the five cohorts that reach age 62.5 during year t_1 are spread over a period longer than one year. This leads to the effect that the deaths of persons belonging to cohort E are shifted to year t_2 as shown by the thick grey arrow in figure 2. The number of deaths in year t_1 declines by 20 percent as compared to the situation before mortality conditions changed. This can clearly be seen in figure 2, where only four black dots are lying in year t_1 . If mortality would not have changed during that year, there would be five dots in year t_1 as is demonstrated with the unfilled dots representing the age at death to cohorts according to the old mortality conditions until year t_0 . Figure 2 shows that this decline in the annual number of deaths is transitory in the sense that it disappears when age at death stops rising. From year t_2 on, the intervals between births and deaths are identical again and there are five dots in each subsequent calendar year.

It is clear that the decrease in the number of deaths in year t_1 leads to a decrease in the age-specific mortality rate. The decisive argument making an adjustment for tempo effects necessary is that the period death rate for year t_1 will be lower than the period death rate for year t_2 , although the age at death is higher in t_2 than it is in t_1 . Let N_x denote the number of persons reaching exact age x during each of the three years shown in figure 2, and let D_x denote the annual number of deaths during years t_0 and t_2 (the years with five “dots” of deaths). As already described, the number of deaths in year t_1 is 20 percent less than D_x . Person years lived at age x in completed years for years t_0 to t_2 are $N_x - 0.5D_x$, $N_x - 0.4D_x$, and $N_x - 0.3D_x$. Consequently, the age-specific death rates for age $x = 62$ for the three years are

$$M_{x,t_0} = \frac{D_x}{N_x - 0.5D_x}, \quad M_{x,t_1} = \frac{0.8D_x}{N_x - 0.4D_x}, \quad \text{and} \quad M_{x,t_2} = \frac{D_x}{N_x - 0.3D_x}.$$

The subtracted terms in the denominators represent person years not lived by the persons who die at age x in completed years. Because of the rise in age at death, this term declines each year. The quantities for the three age-specific death rates can be expressed as

$$M_{x,t0} = \frac{1}{1/q_x - 0.5}, \quad M_{x,t1} = \frac{0.8}{1/q_x - 0.4}, \quad \text{and} \quad M_{x,t2} = \frac{1}{1/q_x - 0.3},$$

where q_x denotes the probability of dying in age x , thus D_x / N_x . In a population with high life expectancy at birth, q_x -values for young and middle adult ages will be close to 0.01 or 0.001, the value of $1/q_x$ will be 100 to 1,000, and the impact of the subtractions in the denominators will be negligible. This shows that, for the hypothesized model population, age-specific death rates for all but the oldest ages and infancy will decline by approximately 20 percent between year $t0$ and year $t1$ and rise by approximately 25 percent between year $t1$ and year $t2$. According to Bongaarts and Feeney's approach, this temporary decline in age-specific death rates is a tempo effect. It results from the fact, that in situations of increasing age at death the number of deaths in the numerator of the death rates declines by a considerable higher relative extent than do the risk years lived in the denominator of the death rates. The logic of this argument is neither limited to the simple assumptions of this example (constant number of births, birth intervals of 0.2 years) nor to one single age group. If we would increase the number of age groups and assume that ages at death in these age groups increase at different rates, different numbers of deaths will be shifted and the magnitude of the tempo effect will vary from one age group to another (for deeper descriptions see Feeney, 2003).

Since conventional life expectancy at birth is based on age-specific death rates calculated from annual number of deaths and risk years lived there should be no doubt that this measure might be considerably affected by such tempo distortions. The most illuminating paper about the consequences of such distortions on the interpretation of period data was written by Vaupel (2002) who called for a distinction between "life expectancy at current rates" and "life expectancy at current conditions".² The origin of all these problems can be found in the basic assumption of stable (or even stationary) conditions which is underlying all demographic pe-

² In the mentioned paper Vaupel (2002) connected the distortions inherent in current mortality rates as a consequence of a changed timing of death rather with effects of heterogeneity than with effects of mortality tempo. Regardless the specific sight of the origin of distortions in period mortality rates Vaupel's message is universe for all kinds of demographic period measures.

riod measures. The papers of Bongaarts and Feeney show that these assumptions do not only influence the possible interpretation of period measures, what we were already aware of. Much more important, the conventional way of calculating period measures could lead to a completely wrong message whenever the assumptions of stability respective stationary are not satisfied in the analysed year or period. In the case of life expectancy one can generalize: if mortality declines, life expectancy will overestimate current conditions and if mortality is rising, life expectancy underestimates current survival conditions. This distortion is the more marked the more intensive the changes are during the observed period. Bearing in mind the simple example presented above, where the usual death rate for year t_1 provides a much lower value than actual mortality conditions should produce raises the question what meaning at all period measures based on current rates do have in a world of continuous demographic changes. This holds especially when populations with completely different demographic developments are compared, like the populations of West and East Germany. To assure that conventional period measures do not lead into a wrong direction it is necessary to look at tempo-adjusted measures, regardless if fertility, mortality, or any other demographic process is analysed.

Methods for estimating the tempo distortion

In order to estimate tempo-adjusted life expectancy for West and East Germany I follow the approach of Bongaarts and Feeney (2002), who defined the tempo effect $S(t)$ in life expectancy in a year t as the absolute difference between the observed life expectancy at birth $e_0(t)$ and the tempo-adjusted life expectancy at birth $e_0^*(t)$ (by Bongaarts and Feeney called “average age at death”), thus

$$S(t) = e_0(t) - e_0^*(t). \quad (1)$$

The measure $e_0^*(t)$ is defined as the average age at death in a constant birth population and can be directly estimated by using cohort-specific data for numbers of births, deaths, and migration until the observation year t . This measure is similar to the “cross-sectional average length of life” (CAL) as introduced by Brouard (1986) and Guillot (2003a) but not being absolutely identical (see Guillot 2003b). In a subsequent paper, Bongaarts and Feeney (2003) presented three different possibilities to estimate tempo-adjusted period life expectancy from

complete cohort data. However, for the West and East German populations such detailed data does not exist. In such a case where cohort data about births, numbers of death and migration cannot be used (at least not for a time span long enough), $e_0^*(t)$ can be estimated by solving the equation

$$e_0(t) = e_0^*(t) - \frac{1}{b} \ln \left(1 - \frac{de_0^*(t)}{dt} \right) \quad (2)$$

for $e_0^*(t)$ from conventional life table estimates, based on the assumptions that mortality under age 30 can be neglected and that the annual changes in the force of mortality follow a shifting Gompertz function.³ For the detailed derivation of this formula see Bongaarts and Feeney (2002). As proposed by the authors the value b is estimated by fitting a Gompertz model to single-year age-specific death rates for ages 30-90.⁴ Table 1 presents the estimates of the parameter $\mu_0(t)$ and the average of the parameter b for the analysed populations from 1975 to 2000. The estimates for b for the whole series of single observation years can be found in appendix (c) and (d) of this paper. Corresponding to the observed death rates, $\mu_0(t)$ declines over time for all four populations. Similar to what is known for several other countries, the estimated values of b are close to 0.11 among males and 0.12 among females for both, West and East Germany. The annual estimates of b vary only little over time in each of these populations during the observation period, as can be seen from the standard deviation of b in table 1 or from the single values in appendix (c) and (d). Like in the case of the populations analysed by Bongaarts and Feeney (2002), the Gompertz model fits the observed adult death rates very well, with the average variance explained (R^2) being more than 99 percent. On the base of these data, I used a three-step procedure similar to the procedure proposed by Bongaarts and Feeney (2002). First, I calculated annual estimates of $e_0(t)$ from 1950 to 2000 (enumerated from year 0 to year 50) with life tables in which mortality under age 30 was set to 0. Next, I smoothed these estimates by fitting a sixth degree polynomial using the computer program R (see appendix (e) for the specific coefficients). The resulting values for the smoothed time series for life expectancy $e_0(t)^S$ are given in appendix (c) and (d), and in figure 3 the corresponding functions are shown together with the original estimates for $e_0(t)$ with no mortality

³ The application of a Gompertz model requires the assumption that mortality under age 30 is negligible since the Gompertz model does not fit to the pattern of mortality in ages below 30. Since this assumption is close to reality in modern populations with high life expectancy it can be accepted as sufficiently satisfied in the case of West and East Germany from 1975 to 2000. However, this method cannot be used in populations with high mortality in infancy as well as in childhood and young adult ages.

⁴ Bongaarts and Feeney (2002) fitted the age-specific death rates until age 100, but in the case of West and East Germany official population and death data is only available until age 90.

under age 30. It can be seen that the trends in $e_{30} + 30$ (what corresponds to setting mortality below age 30 to 0) are very similar to the trends in e_0 shown in figure 1. Only in the years 1950 to 1970 the trends differ slightly as a consequence of the fact that mortality below age 30 (especially infant mortality) had a higher impact on overall life expectancy than it has in more recent years. Note that the significant decrease in life expectancy at birth $e_0(t)$ for East German men in 1990 diminishes in the smoothed values $e_0(t)^S$.

For estimating tempo-adjusted life expectancy $e_0^*(t)$ the original values for $e_0(t)$ are substituted by the values $e_0(t)^S$ derived from the polynomial functions. To finally solve equation (2) for $e_0^*(t)$ I used the so-called Euler's method as described in its general form in appendix (a) of this paper, using $S(1950) = 2$ as the initial condition for the differential equation. From equation (1) then follows that $e_0^*(1950)$ can be directly estimated from $e_0(1950) - S(1950)$. For instance for West German males follows $e_0^*(1950) = 71.28 - 2.00 = 69.28$. This value represents the assumed tempo distortion for mortality changes until the year 1950 that was equally set for all observed populations, thus the female and male populations of West and East Germany. It is important to note that the results for the analysed years after 1975 are insensitive to this assumed initial condition for the year 1950. Applying Euler's method leads to an estimate for the tempo-adjusted life expectancy $e_0^*(1951)$ for the next year from the equation

$$e_0^*(1951) = e_0^*(1950) + \left\{ 1 - \exp \left[-b(1950) \cdot \left(e_0(1950)^S - e_0^*(1950) \right) \right] \right\} ,$$

or generally written from

$$e_0^*(t+1) = e_0^*(t) + \left\{ 1 - \exp \left[-b(t) \cdot \left(e_0(t)^S - e_0^*(t) \right) \right] \right\} . \quad (3)$$

Equation (3) was used for estimating a complete time series of values for tempo-adjusted life expectancy at birth (with no mortality under age 30) until the year 2000 for the females and males of West and East Germany. The detailed derivation of equation (3) can be found in appendix (b).

Trends in tempo-adjusted life expectancy in West and East Germany

Figure 4 shows the trends in conventional and tempo-adjusted life expectancy at birth (both with no mortality under age 30) from 1975 to 2000 for females and males of West and East Germany. The graph for West German females (figure 4c) is very similar to the figures for US and Japanese women presented by Bongaarts and Feeney (2002: 24). As can be seen in figure 3(c), West German females are the only of the four analysed populations where the observed life expectancy at birth increased almost constantly since 1950. Thus, the tempo distortion $S(t)$ (what is defined as the difference between observed and tempo-adjusted life expectancy) is almost constant among West German females during the observation period from 1975 to 2000. Since among the other three populations improvements in life expectancy developed considerably later (West and East German males) or with significantly changing pace (East German females), tempo distortions must vary considerably as compared to West German females. This is perfectly reflected in the gained results for $e_0^*(t)$ and $S(t)$ as can clearly be seen in figure 4. In all cases the estimated tempo distortions agree perfectly with the logic of mortality tempo effects.

This becomes especially clear by a comparison of figures 3 and 4. Among West German men the tempo distortion $S(t)$ was very low in 1975 and increased then steadily until the second half of the 1980s when the difference between observed and tempo-adjusted life expectancy reached an almost constant level (figure 4a). Since it becomes clear from figure 3(a) that life expectancy of West German men remained more or less unchanged between 1950 and 1970 there cannot be expected a noticeable tempo distortion in the mid 1970s. The increasing life expectancy after 1970 is caused by a shift in average age at death and consequently also the tempo-adjusted life expectancy starts to increase, but with a lower pace than observed life expectancy (what is absolutely consistent with the cause of mortality distortions described above). Among East German males, life expectancy remained constant or even decreased slightly until the end of the 1980s before it started to increase with a much higher pace than in any stage of life expectancy trends in West Germany (figures 3a and 3b). Consequently, tempo-adjusted life expectancy $e_0^*(t)$ does not differ from unadjusted life expectancy until the beginning of the 1990s and then started to increase with a considerably lower speed as compared to $e_0(t)$. The annual increase in tempo-adjusted life expectancy after 1990 seems similar among West and East German males. Also among East German females the extent of tempo distortions in conventional life expectancy increased during the observation period. From fig-

ure 3(d) we know that life expectancy of East German females already rose before Reunification but with a lower pace than it did among their West German counterparts. Consequently, tempo distortions, i.e. the difference between tempo-adjusted and unadjusted life expectancy, remained at an almost constant level between 1975 and 1990. However, the difference between $e_0(t)$ and $e_0^*(t)$ started to increase at the end of the 1980s when conventional life expectancy rose with an increased speed similar to what can be observed among East German males (figures 4b and 4d).

The interesting question is how life expectancy differences between West and East Germany developed in the observation period 1975 to 2000 once adjusted for tempo distortions. The corresponding results are given in figure 5 for males and figure 6 for females, the single values can be found in table 2. The thinner lines in the two graphs represent the absolute difference between West and East Germany in conventional life expectancy and the bold lines those in tempo-adjusted life expectancy. Figure 5 depicts again the rapid decrease in conventional life expectancy differences after 1990 following an almost continuous increase since the beginning of the observation period. While West German males had a higher life expectancy according to conventional calculation methods since 1976, East German men showed a higher tempo-adjusted life expectancy until 1981. Note that the different definitions of live birth do not affect the results presented in this chapter and thus there seemed to be a “real” East German survival advantage among men. Only after 1981 the differences switched to an advantage of West German males, but to a much lower extent as compared to the results based on conventional life expectancy. The graph shows clearly that the increasing trend of West-East differences occurred with a considerable lower pace once life expectancy is adjusted for tempo effects. In 1990, when the difference in conventional life expectancy between West and East German men reached its peak of 3.08 years, the difference in tempo-adjusted life expectancy was nearly two years less with only 1.22 years. Even more interesting is the finding that the differences in tempo-adjusted life expectancy did not decrease since Reunification but went on increasing until the end of the 1990s. While the differences in conventional life expectancy between West and East German males decreased to roughly one and a half years in 2000, the difference in tempo-adjusted life expectancy is now even higher with a difference of almost two years. Only in the second half of the 1990s the trend in increasing differences in tempo-adjusted life expectancy lowered its speed and indicates a convergence only in the very last year of the observation period.

The results for West-East-German differences among females are similar to those just described for males. The survival advantage for West German females is considerably lower when tempo-adjusted life expectancy is used instead of conventional life expectancy. Since among females the trends in conventional life expectancy in West and East Germany before Reunification were not as different as among males, the relative trends of increasing West-East-differences in conventional and tempo-adjusted life expectancy are more similar as compared to the differences between West and East German males, i.e. the tempo distortions in the measured trend are less marked. However, this does not hold for the absolute differences in $e_0(t)$ and $e_0^*(t)$. While the differences in conventional life expectancy increased to 2.85 years in 1988, the differences in tempo-adjusted life expectancy did not exceed an extent of 2 years. Similar to the situation among men, the differences in tempo-adjusted life expectancy between West and East German females did not decrease with Reunification parallel to conventional life expectancy but increased until the mid 1990s. The trends in conventional and tempo-adjusted life expectancy crossed over between 1992 and 1993. From then on, the survival advantage of West German females measured with tempo-adjusted life expectancy is considerably higher as compared to the results based on tempo-unadjusted values. Although a decreasing trend in mortality differences between West and East German females can also be stated with tempo-adjusted life expectancy since the mid 1990s, the remaining differences in favour of West German women is still considerably higher. While the disadvantage of East German women decreased to 0.46 years in the year 2000 according to conventional life expectancy, the tempo-adjusted differences do still show an extent of 1.5 years.

Discussion

The results presented in the previous chapter are striking and could be of innermost importance for the general understanding of several phenomenon connected with changing mortality: once life expectancy is adjusted for tempo effects, differences between West and East Germany do not decrease immediately after Reunification and are ten years later considerably higher as compared to differences in conventional life expectancy. This indicates that the discussion about the reasons for the trends in mortality differences between West and East Germany of the last years might have been based on inappropriate measures and thus led to the wrong direction as already supposed by Luy (2004a). The so far discussed reasons for Eastern German excess mortality clearly show that the general idea was and still is to find a factor

making life in Western Germany (or “Western life” in general) healthier and thus of better quality than living conditions (or the way of life) in Eastern Germany. The puzzling aspect was that no factor could be found corresponding to the observed trends in conventional life expectancy at birth. However, according to the trends in West-East German differences in tempo-adjusted life expectancy, the factor we are searching for does obviously not have to decrease the gap in life expectancy by more than 2 years among females respective 1.5 years among males within ten years and does not have to change mortality trends immediately after Reunification from one year to another. We rather have to look for a factor causing an immediate and continuously increasing rise in average age at death that causes these tempo distortions in life expectancy but does not necessarily have to increase the average length of life to the extent indicated by conventional tempo-unadjusted life expectancy. Obviously, the same holds for the stage of increasing differences prior to Reunification under changed conditions with higher tempo distortions in life expectancy for the West German population.

The arguments presented here should not mean that all the factors discussed in numerous papers and research projects have no impact at all on mortality differences between West and East Germany. It is quite sure that mortality differences between West and East Germany are caused by a various number of different factors like every other phenomenon of differential mortality. Thus, we should not “fall into the trap of trying to find an elusive single ‘ultimate cause’”, like Hobcraft (2004: 81) warned in the context of fertility analysis. However, this paper presents a strong argument that the real differences in mortality conditions between West and East Germany differ considerably from what we thought they were. From this point of view it is not surprising that none of the usually stated explanatory variables for the West-East German survival gap fits to the observed mortality trends measured with conventional life expectancy at birth. To catch up the central message sent by Vaupel et al. (2003): it may in fact be never too late to increase the length of life, but it seems to take longer than trends in conventional life expectancy suggest, and the reasons might be of completely different kind than generally expected.

Thus, the results presented in this paper might completely change the view of the causes of mortality differences between West and East Germany and maybe similarly the view of the causes of the general survival gap between Western and Eastern Europe. We can expect that tempo effects distort the analysis in all cases where the compared populations experienced different trends in changing mortality. Another case might be the closing gap in sex mortality

differences. According to the simple illustrating example used in this paper we should not doubt the existence of tempo effects and the distortions they possibly cause. More critical might be the used method proposed in the first Bongaarts and Feeney paper on mortality tempo since it is based on a number of assumptions that are unlikely to be completely satisfied. Accepting the existence of tempo effects, however, the used way of estimating tempo distortions should be preferred against using unadjusted estimates for period life expectancy as long as there are no better solutions. Thus, the main goal of formal demographer's future work should be the development of methods for tempo adjustment based on less restrictive assumptions for populations where detailed cohort data about births, deaths, and migration do not exist, what will be the usual case in most subsequent studies.

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Appendix

(a) Euler's method to solve a differential equation

The following description of the so-called Euler's method is taken from "Keshet's Typed Notes (2004)", chapter 9.13, pp. 16-17.⁵ In cases where it is difficult or impossible to find the desired solution for a differential equation with guesses, integration methods, or from previous experience, it is possible to use approximation methods and numerical computations to do the job. Most of these methods rely on the fact that derivatives can be approximated by finite differences. For example, suppose a differential equation of the form

$$\frac{dy}{dt} = f(y) \tag{4}$$

with initial value $y(0) = y_0$, can be approximated by selecting a set of time points t_1, t_2, \dots , which are spaced apart by time steps of size Δt , and replacing the differential equation by the approximate finite difference equation

$$\frac{y_1 - y_0}{\Delta t} = f(y_0). \tag{5}$$

This relies on the approximation

$$\frac{dy}{dt} \approx \frac{\Delta y}{\Delta t}, \tag{6}$$

which is a relatively good approximation for small step size Δt . Then by rearranging this approximation follows that

$$y_1 = y_0 + f(y_0)\Delta t. \tag{7}$$

Knowing the quantities on the right allows us to compute the value y_1 , i.e. the value of the approximate "solution" at the time point t_1 . It is then possible to continue to generate the value

⁵ Keshet's textbook "Math 102 Course Notes (2004)" is online available and can be downloaded from <http://ugrad.math.ubc.ca/coursedoc/math102/keshet.notes/index.html>

at the next time point in the same way, by approximating the derivative again as a secant slope. This leads to

$$y_2 = y_1 + f(y_1)\Delta t . \quad (8)$$

The approximation generated in this way, leading to y_1, y_2, \dots is called Euler's method. The fact that this procedure is only an approximate solution for a differential equation should not lower the value of the results presented in this paper since the general Bongaarts/Feeney-equation (2) is based on more severe assumptions that are never perfectly satisfied. Thus, the results presented here are anyway expected to provide solely an impression of the extent to which tempo distortions might lead in the wrong direction in the case of analysing mortality differences between West and East Germany using conventional life table techniques. An important goal of future works in formal demography must be the development of new ways for estimating tempo-adjusted life expectancy based on less restrictive assumptions.

(b) Derivation of equation (3)

In order to apply Euler's method to solve equation (2) for $e_0^*(t), f(y)\Delta t$ in equations (7) and (8) has to be substituted by $\{-1/b \cdot [1 - de_0^*(t)/dt]\}$. From equations (1) and (2) and using annual estimates for the Gompertz parameter b follows that the tempo distortion $S(t)$ can be estimated by

$$S(t) = -\frac{1}{b(t)} \cdot \ln \left[1 - \frac{de_0^*(t)}{dt} \right] . \quad (9)$$

Since $b(t)$ varies only slightly over time (see tab. 1 and app. c and d), the annual estimates of $b(t)$ may be substituted by an average value for $b(t) = b$, as Bongaarts and Feeney (2002) proposed in their first paper on mortality tempo. However, since this would imply another additional assumption, I used the annual estimates $b(t)$. Equation (9) can be rearranged to

$$\ln \left[1 - \frac{de_0^*(t)}{dt} \right] = -b(t) \cdot S(t) , \quad (10)$$

what leads to

$$1 - \frac{de_0^*(t)}{dt} = \exp[-b(t) \cdot S(t)]. \quad (11)$$

Since time is measured in units of annual steps and applying Euler's method (assuming that the change is linear), $de_0^*(t)/dt$ can be represented by $e_0^*(t) - e_0^*(t+1)$ and equation (11) becomes to

$$1 - [e_0^*(t) - e_0^*(t+1)] = \exp[-b(t) \cdot S(t)], \quad (12)$$

what yields

$$e_0^*(t) - e_0^*(t+1) = 1 - \exp[-b(t) \cdot S(t)] , \quad (13)$$

and thus

$$e_0^*(t+1) = e_0^*(t) + \{1 - \exp[-b(t) \cdot S(t)]\} . \quad (14)$$

Using equation (1) and substituting $e_0(t)$ by $e_0(t)^S$ leads directly to equation (3). As described in the text, for the first year 1950 I used $S(1950) = 2.00$ as initial condition leading to an estimate of $e_0^*(1951)$ by using equation (3). The same procedure was then repeated for each subsequent calendar year in order to determine the complete series of estimates for $e_0^*(t)$ until the year 2000.

(c) Estimates of $e_0(t)$, $e_0(t)^S$, b , $e_0^*(t)$, and $S(t)$ for single calendar years, males of West and East Germany, 1975-2000 (no mortality under age 30)

Year	West Germany					East Germany				
t	$e_0(t)$	$e_0(t)^S$	b	$e_0^*(t)$	$S(t)$	$e_0(t)$	$e_0(t)^S$	b	$e_0^*(t)$	$S(t)$
1975	71.17	71.41	0.107	70.97	0.200	71.28	71.41	0.114	71.41	-0.132
1976	71.49	71.54	0.106	71.02	0.468	71.46	71.41	0.110	71.41	0.052
1977	71.96	71.70	0.106	71.07	0.888	71.59	71.40	0.110	71.41	0.188
1978	71.85	71.87	0.107	71.14	0.710	71.33	71.39	0.111	71.41	-0.076
1979	72.20	72.05	0.105	71.21	0.987	71.20	71.38	0.112	71.40	-0.208
1980	72.29	72.25	0.104	71.30	0.997	71.07	71.38	0.113	71.40	-0.328
1981	72.39	72.46	0.105	71.39	0.995	71.38	71.38	0.109	71.40	-0.023
1982	72.63	72.67	0.106	71.50	1.133	71.44	71.38	0.109	71.40	0.041
1983	72.78	72.89	0.106	71.62	1.160	71.66	71.38	0.109	71.39	0.270
1984	73.18	73.11	0.107	71.74	1.441	71.70	71.39	0.111	71.39	0.308
1985	73.26	73.32	0.108	71.88	1.378	71.57	71.41	0.112	71.39	0.173
1986	73.54	73.54	0.107	72.02	1.516	71.51	71.44	0.111	71.39	0.118
1987	73.84	73.74	0.110	72.17	1.662	71.70	71.48	0.110	71.40	0.301
1988	74.07	73.93	0.109	72.33	1.736	71.56	71.53	0.109	71.41	0.153
1989	74.13	74.12	0.111	72.49	1.640	71.88	71.61	0.109	71.42	0.456
1990	74.22	74.29	0.110	72.66	1.560	71.14	71.70	0.106	71.44	-0.302
1991	74.35	74.46	0.108	72.82	1.526	71.31	71.83	0.103	71.47	-0.160
1992	74.68	74.62	0.108	72.98	1.692	71.77	71.99	0.107	71.50	0.267
1993	74.70	74.78	0.110	73.15	1.551	72.01	72.19	0.108	71.55	0.457
1994	74.96	74.95	0.111	73.31	1.644	72.40	72.44	0.106	71.62	0.780
1995	75.05	75.13	0.109	73.48	1.569	72.81	72.74	0.111	71.70	1.108
1996	75.27	75.33	0.110	73.64	1.630	73.27	73.11	0.109	71.81	1.459
1997	75.68	75.56	0.111	73.81	1.870	73.89	73.55	0.112	71.94	1.947
1998	75.99	75.85	0.110	73.99	2.004	74.43	74.09	0.112	72.11	2.324
1999	76.28	76.22	0.111	74.17	2.102	74.82	74.72	0.115	72.31	2.513
2000	76.54	76.67	0.109	74.38	2.165	75.03	75.46	0.113	72.55	2.477

(d) Estimates of $e_0(t)$, $e_0(t)^S$, b , $e_0^*(t)$, and $S(t)$ for single calendar years, females of West and East Germany, 1975-2000 (no mortality under age 30)

Year	West Germany					East Germany				
t	$e_0(t)$	$e_0(t)^S$	b	$e_0^*(t)$	$S(t)$	$e_0(t)$	$e_0(t)^S$	b	$e_0^*(t)$	$S(t)$
1975	76.84	77.04	0.118	75.79	1.048	75.91	76.05	0.123	75.47	0.436
1976	77.17	77.23	0.116	75.93	1.242	76.15	76.09	0.121	75.54	0.607
1977	77.74	77.44	0.119	76.07	1.668	76.53	76.13	0.120	75.61	0.927
1978	77.74	77.66	0.117	76.22	1.524	76.34	76.18	0.123	75.67	0.669
1979	78.03	77.89	0.116	76.37	1.657	76.40	76.24	0.123	75.73	0.676
1980	78.27	78.13	0.119	76.54	1.735	76.17	76.30	0.122	75.79	0.384
1981	78.34	78.37	0.118	76.71	1.636	76.37	76.37	0.121	75.85	0.517
1982	78.57	78.62	0.119	76.89	1.684	76.57	76.46	0.121	75.91	0.663
1983	78.76	78.86	0.119	77.07	1.685	76.82	76.56	0.123	75.97	0.840
1984	79.23	79.10	0.119	77.26	1.969	76.85	76.67	0.123	76.04	0.804
1985	79.30	79.32	0.121	77.46	1.844	76.77	76.80	0.124	76.12	0.651
1986	79.47	79.54	0.122	77.66	1.812	76.73	76.95	0.128	76.20	0.527
1987	79.82	79.74	0.124	77.87	1.951	77.14	77.13	0.127	76.29	0.852
1988	80.02	79.93	0.121	78.07	1.947	77.17	77.32	0.124	76.39	0.777
1989	80.07	80.10	0.121	78.27	1.794	77.49	77.54	0.121	76.50	0.987
1990	80.05	80.25	0.122	78.47	1.581	77.44	77.79	0.120	76.62	0.824
1991	80.26	80.39	0.123	78.67	1.588	77.69	78.06	0.118	76.75	0.939
1992	80.59	80.52	0.121	78.86	1.734	78.38	78.36	0.124	76.89	1.486
1993	80.50	80.63	0.122	79.04	1.465	78.86	78.68	0.122	77.06	1.800
1994	80.78	80.75	0.123	79.22	1.560	79.18	79.03	0.135	77.24	1.936
1995	80.89	80.87	0.123	79.39	1.501	79.53	79.41	0.125	77.45	2.080
1996	80.98	81.01	0.122	79.56	1.424	79.86	79.82	0.122	77.67	2.190
1997	81.32	81.18	0.125	79.72	1.606	80.43	80.25	0.131	77.90	2.527
1998	81.55	81.40	0.125	79.88	1.665	80.76	80.70	0.128	78.17	2.590
1999	81.71	81.69	0.125	80.06	1.653	81.18	81.17	0.131	78.44	2.739
2000	81.93	82.08	0.125	80.24	1.687	81.47	81.66	0.130	78.74	2.721

(e) Intercepts and coefficients of the sixth degree polynomial functions for smoothing the trends in $e_0(t)$ from 1950 to 2000 (no mortality under age 30), calculated with the computer program R

	West Germany		East Germany	
	Males	Females	Males	Females
c	71.2812	73.8031	71.6817	74.4168
1	-0.1075	0.0949	0.0317	0.0520
2	0.0280	0.0260	$-4.6860 \cdot 10^{-3}$	$3.8240 \cdot 10^{-3}$
3	$-2.9904 \cdot 10^{-3}$	$-3.1861 \cdot 10^{-3}$	$1.1630 \cdot 10^{-4}$	$-8.6082 \cdot 10^{-5}$
4	$1.3756 \cdot 10^{-4}$	$1.4818 \cdot 10^{-4}$	$4.1943 \cdot 10^{-6}$	$-8.1862 \cdot 10^{-6}$
5	$-2.7039 \cdot 10^{-6}$	$-2.9242 \cdot 10^{-6}$	$-2.3888 \cdot 10^{-7}$	$3.2682 \cdot 10^{-7}$
6	$1.9180 \cdot 10^{-8}$	$2.0767 \cdot 10^{-8}$	$3.0595 \cdot 10^{-9}$	$-2.8878 \cdot 10^{-9}$

Fig.1: Trends in life expectancy at birth for West and East Germany, 1950-2000

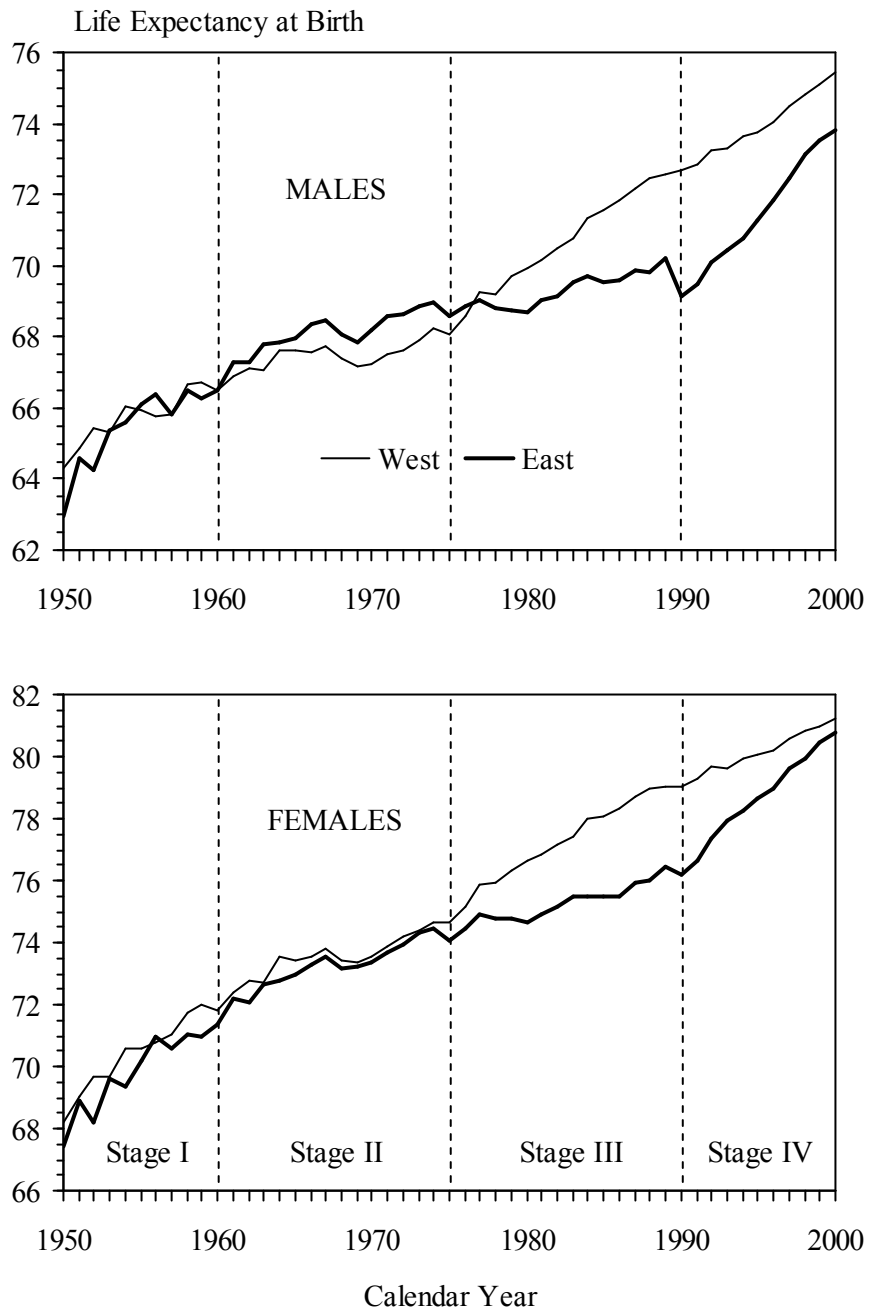


Fig. 2: Mortality tempo effect illustrated in the Lexis diagram

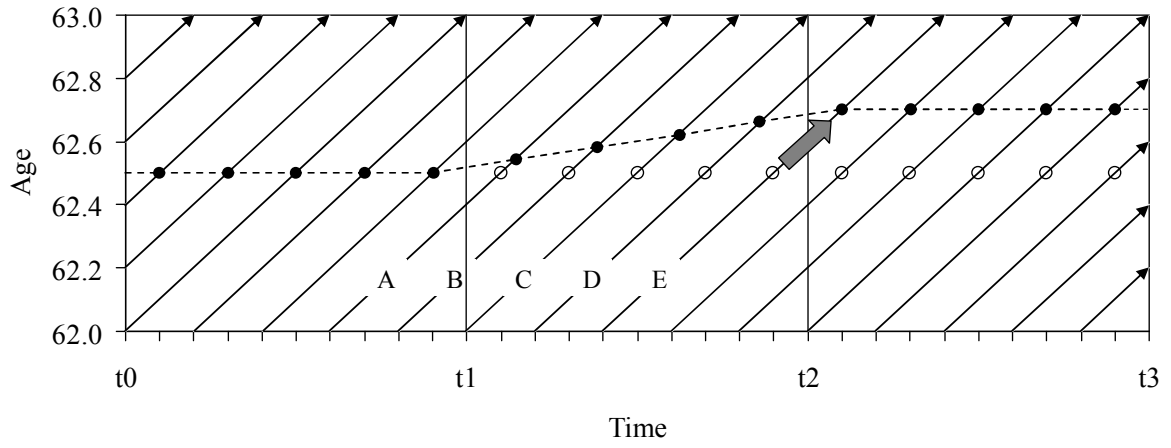


Fig. 3: Observed life expectancy at birth $e_0(t)$ and smoothed estimates $e_0(t)^S$ (sixth degree polynomial), West and East Germany, 1950-2000 (no mortality under age 30)

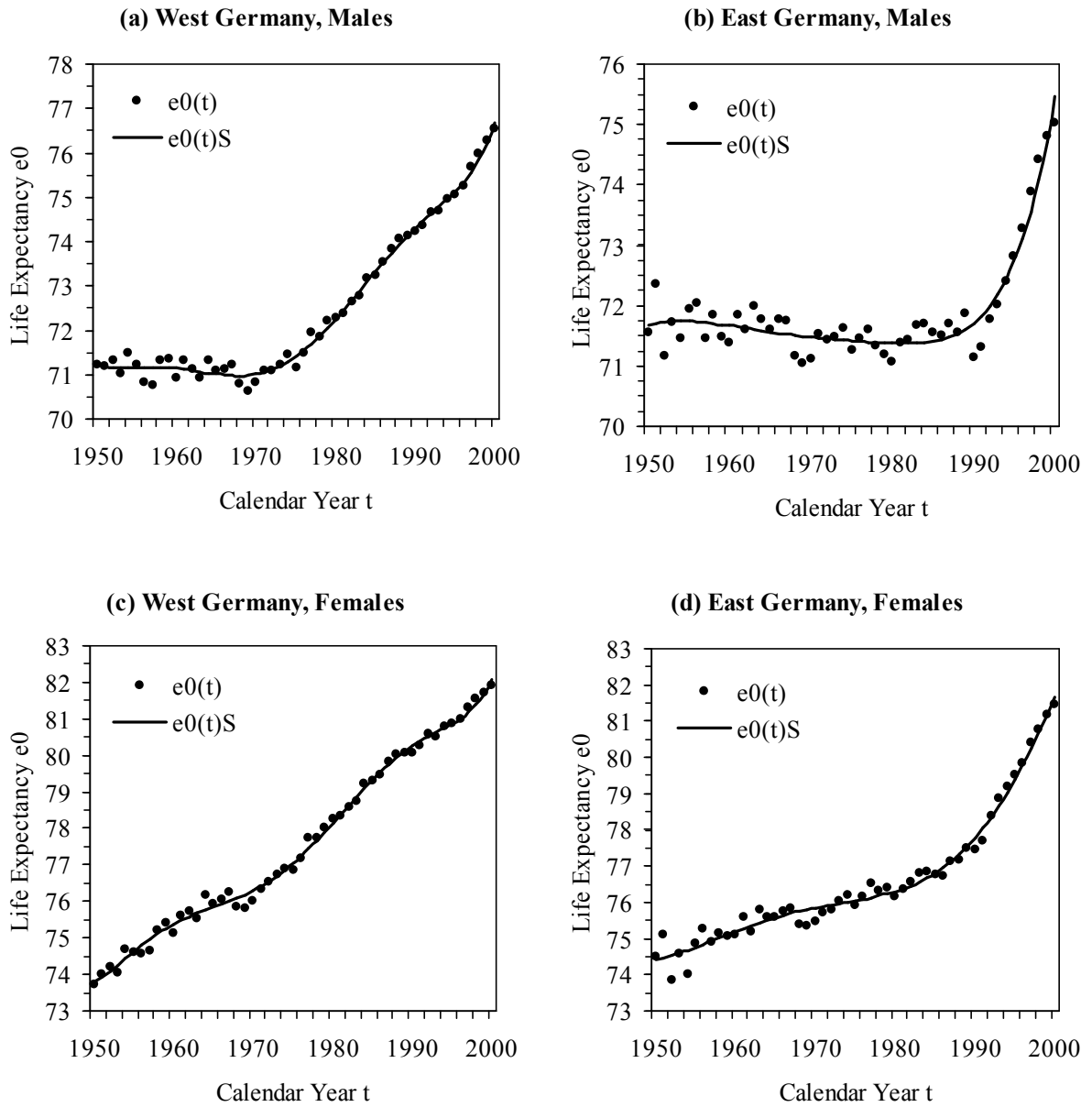


Fig. 4: Observed life expectancy at birth $e_0(t)$ and estimated mean age at death $e_0^*(t)$ (adjusted life expectancy at birth) with tempo distortion $S(t)$, West and East Germany, 1975-2000 (no mortality under age 30)

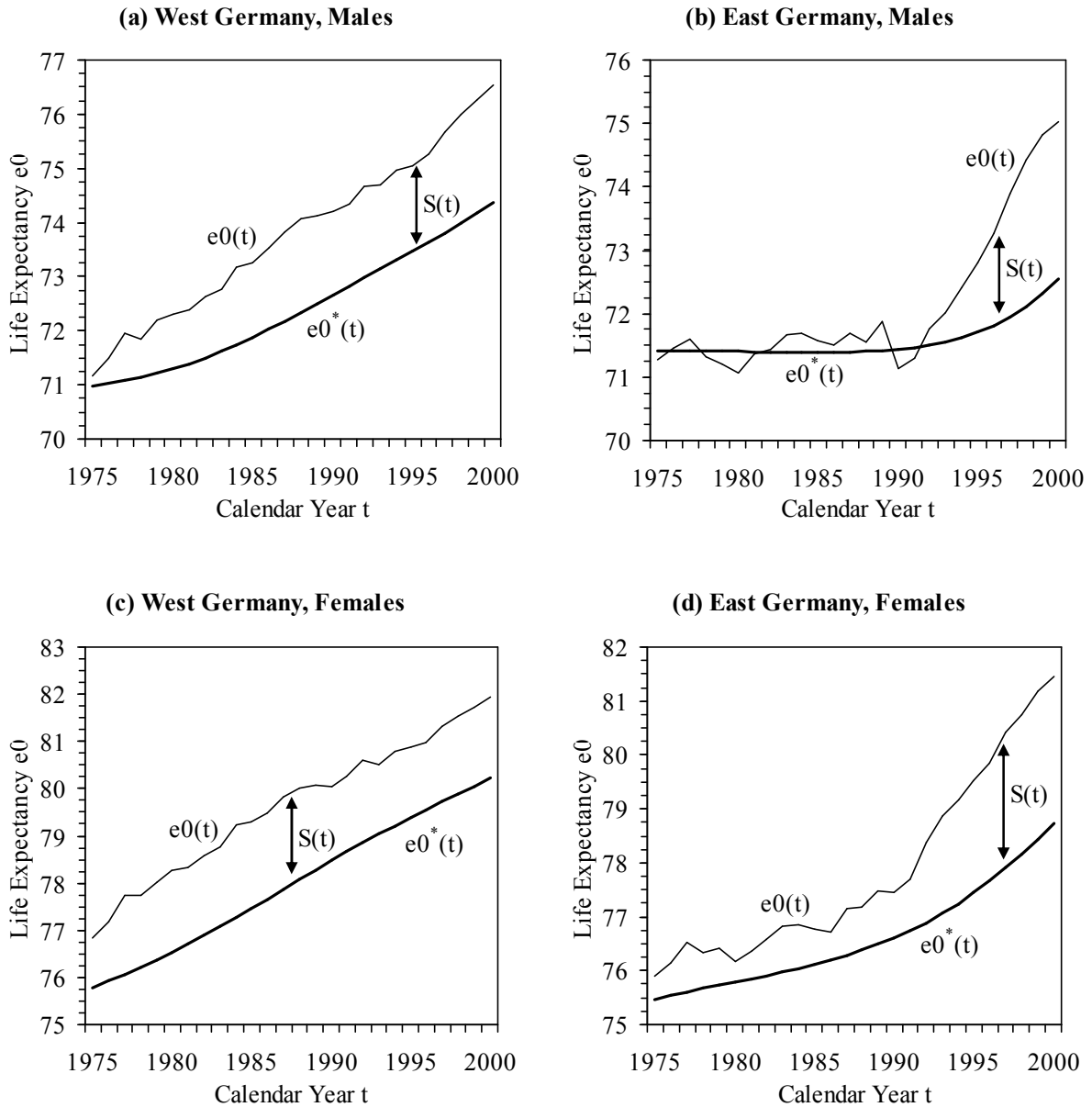


Fig. 5: West-East German difference in life expectancy at birth for conventional life expectancy $e_0(t)$ and tempo-adjusted life expectancy $e_0^*(t)$, Males 1975-2000 (no mortality under age 30)

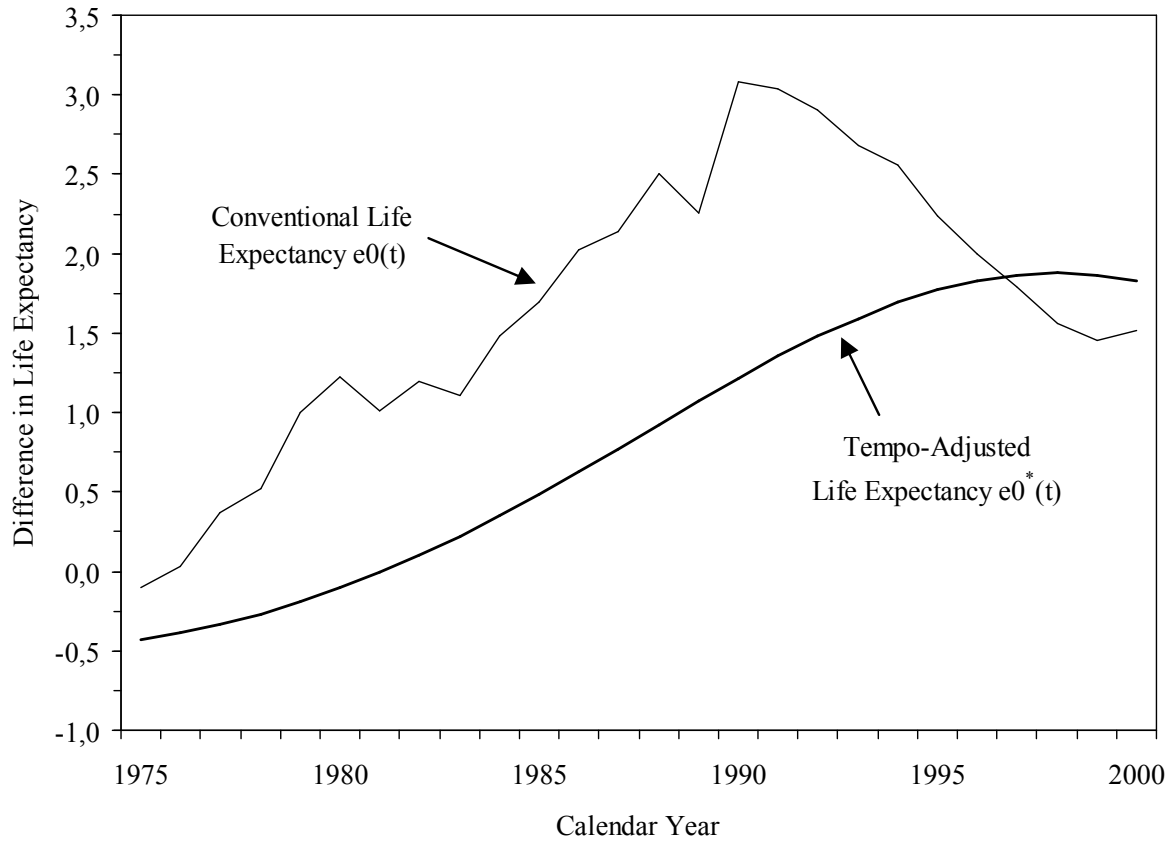
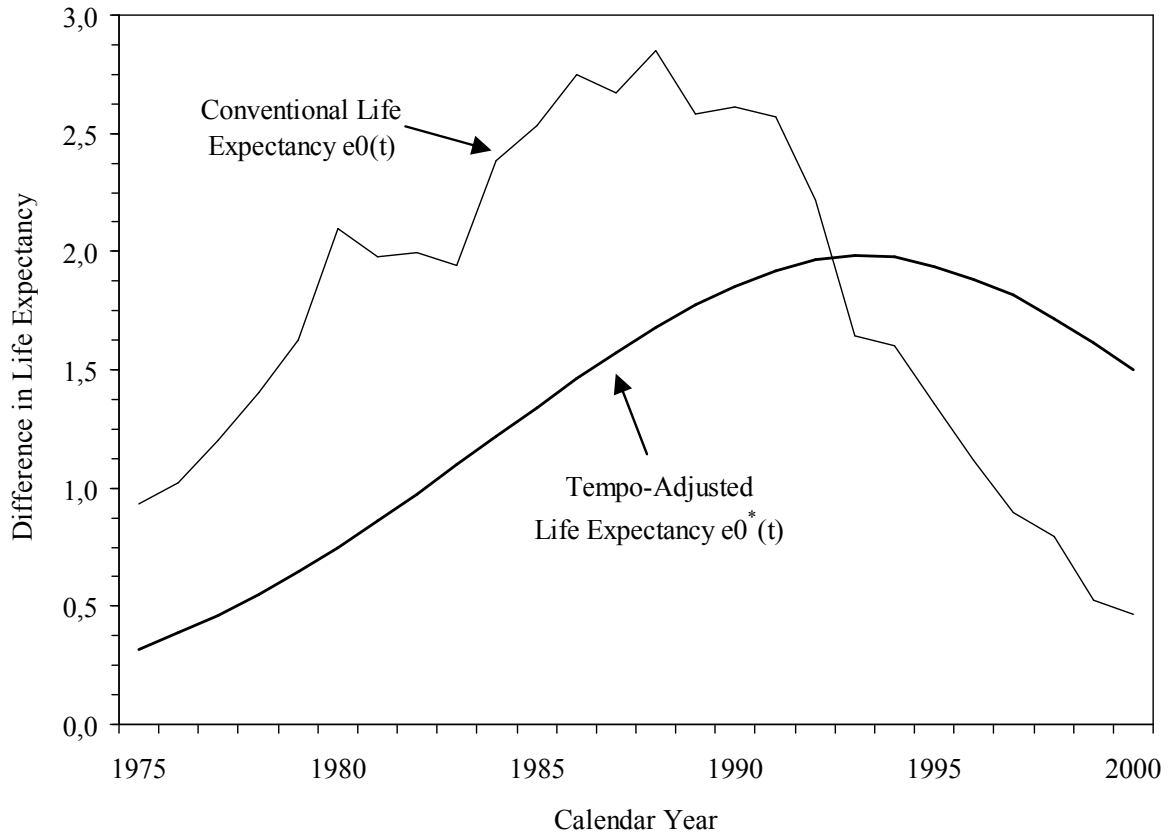


Fig. 6: West-East German difference in life expectancy at birth for conventional life expectancy $e_0(t)$ and tempo-adjusted life expectancy $e_0^*(t)$, Females 1975-2000 (no mortality under age 30)



Tab. 1: Estimates of parameters of the Gompertz mortality change model for males and females in West and East Germany, 1975-2000

	$\mu_0(1975)$	$\mu_0(2000)$	Average 1975-2000		
			b	St. dev. b	R^2
West Germany, Males	6.161 ($\cdot 10^{-5}$)	3.142 ($\cdot 10^{-5}$)	0.108	0.0020	0.991
East Germany, Males	4.737 ($\cdot 10^{-5}$)	3.568 ($\cdot 10^{-5}$)	0.110	0.0026	0.993
West Germany, Females	2.206 ($\cdot 10^{-5}$)	7.644 ($\cdot 10^{-6}$)	0.121	0.0028	0.993
East Germany, Females	1.591 ($\cdot 10^{-5}$)	7.483 ($\cdot 10^{-6}$)	0.124	0.0040	0.995

Tab. 2: West-East German difference in life expectancy at birth according to conventional $e_0(t)$ and tempo-adjusted $e_0^(t)$, 1975-2000 (no mortality under age 30)*

Years Before Reunification					Years After Reunification				
Males		Females			Males		Females		
Year	$e_0(t)$	$e_0^*(t)$	$e_0(t)$	$e_0^*(t)$	Year	$e_0(t)$	$e_0^*(t)$	$e_0(t)$	$e_0^*(t)$
1975	-0.10	-0.43	0.93	0.32	1990	3.08	1.22	2.61	1.85
1976	0.03	-0.39	1.02	0.39	1991	3.04	1.35	2.57	1.92
1977	0.37	-0.33	1.20	0.46	1992	2.90	1.48	2.21	1.97
1978	0.52	-0.27	1.41	0.55	1993	2.69	1.59	1.65	1.98
1979	1.00	-0.19	1.63	0.65	1994	2.55	1.69	1.60	1.98
1980	1.22	-0.10	2.10	0.75	1995	2.23	1.77	1.36	1.93
1981	1.01	-0.01	1.98	0.86	1996	2.00	1.83	1.12	1.88
1982	1.19	0.10	2.00	0.98	1997	1.79	1.87	0.90	1.82
1983	1.11	0.22	1.94	1.10	1998	1.56	1.88	0.79	1.72
1984	1.48	0.35	2.38	1.22	1999	1.46	1.87	0.53	1.61
1985	1.69	0.49	2.53	1.34	2000	1.52	1.83	0.46	1.50
1986	2.03	0.63	2.75	1.46					
1987	2.13	0.77	2.67	1.57					
1988	2.51	0.92	2.85	1.68					
1989	2.25	1.07	2.58	1.77					