Chapter 3
Mortality Differentials Across Germany's Federal States

3.1 Introduction

The literature review in the previous chapter summarized studies that addressed regional mortality differentials in Germany from several perspectives. In this chapter, a more consistent overview of mortality trends in the German regions at different geographical levels is provided. The scene is set by a description of the mortality patterns and trends in East and West Germany and across the 16 German federal states (NUTS-1 level). This is followed by an investigation of small-area mortality trends in the following chapter (Chap. 4).

This chapter opens with a description of the availability and the limitations of the data. Cause-of-death statistics and related coding problems in Germany are also outlined in some detail here (Sect. 3.2). This is followed by a summary of the methods applied (Sect. 3.3). Section 3.4 looks at the long-term trends in life expectancy in East and West Germany and the life expectancy trends of the federal states. The regional dispersion of life expectancy across the federal states is addressed. These life expectancy trends are then picked up and complemented by a measure of lifespan disparity (Sect. 3.5). State-specific mortality trends over time are analyzed by causes of death in Sect. 3.6.

3.2 Data

3.2.1 Population and Death Counts

Population and death counts are generally available for a long time series for the West German states. For the very early 1980s, however, several Federal State Offices of Statistics in East Germany cannot provide detailed data. Population and death

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counts are registered at the person's place of residence. The Federal State Offices of Statistics collect the data for the respective federal state and pass the state-specific data to the Federal Statistical Office in Wiesbaden. In general, the smaller the geographical unit, the less detailed the data provided are.

Vital statistics are of high quality in Germany. Although death counts are considered to be of very high quality (Scholz and Jdanov 2007), the population at very old ages appears to be overestimated (Human Mortality Database 2008a; Jdanov et al. 2005; Kibele et al. 2008; Scholz and Jdanov 2007). Scholz and Jdanov (2007) have related this overestimation to missing de-registrations, mainly in the early 1990s, which resulted in people who were no longer present still being counted (*Karteileichen*). The registration system was altered in 2004 and eliminated this error source in the population statistics but does not correct existing errors. West Germany has been more affected by a population overestimation than East Germany. Fortunately, the influence of population overestimation at very old ages on life expectancy at birth is small.

When comparing East and West Germany, it should be noted that the definition of infant deaths (and stillbirths) differed in the GDR and the FRG from 1958 onward (Thara 1997). For a birth to be classified as live, the FRG required one sign of life, while the GDR required two signs of life. The GDR definition was adjusted to match the FRG definition during the reunification process, and the definitions used in the East and in the West have been the same since 1991. The comparison of mortality between East and West could be biased to some extent by births that took place prior to the adjustment of this definition (Dinkel 1999; Nolte et al. 2000a). A comparison of infant mortality trends in the GDR and the FRG that took into account the differing definitions showed, however, that this difference does not bias the results. It appears likely that, for ethical reasons, GDR physicians treated every newborn with at least one sign of life the same way as their counterparts in the FRG (Thara 1997).

In the comparison of East and West Germany, the period of analysis is 1956–2006. Whenever possible, the following analyses of mortality across federal states include data from 1980 onward (Table A.1 in the appendix gives an overview of the availability of data for the population and death counts by federal state).

3.2.2 Cause-of-Death Statistics

Cause-specific data are available from 1980 onward for all German federal states by 5-year age groups (0, 1–4, 5–9,…, 80–84, 85+). East and West Berlin are separated in the cause-of-death data until 1997. The 9th revision of the International Classification of Diseases (ICD-9) was used for the cause-of-death coding in Germany from 1979 to 1997 and was subsequently replaced by the 10th revision (ICD-10) in 1998. The peculiarities of the cause-of-death statistics are now discussed.

Causes of death (CODs) are coded according to the current ICD revisions. The process of the production of the COD statistics involves four steps, from the recording of individual deaths to the publication of national COD statistics. In Germany, these statistics are monocausal.

First, the physician fills out the death certificate by describing the diseases, health conditions, and damages found in the deceased. Second, a plausibility check of the certificate is performed by the local health authority (e.g., Is there enough information on the death certificate? Does the cause fit the age and sex?). Third, the cause of death is coded according to the ICD. The underlying cause of death is determined using a causal chain by specialized personnel at the State Office of Statistics (Hamburg is an exception—Hamburg's death certificates are coded at the local health authority; Giersiepen and Greiser 1989; Schelhase 2006). The underlying cause of death is thereby defined as "(a) the disease or injury which initiated the train of morbid events leading directly to death, or (b) the circumstances of the accident or violence which produced the fatal injury" (World Health Organization 2004, p. 23). Even when the rules of the ICD coding are adhered to, there is scope for interindividual variation in defining the underlying cause of death. This may yield different regional and temporal coding practices (Schelhase and Rübenach 2006; Schelhase and Weber 2007; T. Schelhase, Federal Statistical Office Germany, on December 2, 2008, personal communication). Fourth, the Federal State Offices of Statistics aggregate their data at the end of an observation year and pass it on to the Federal Office of Statistics in Wiesbaden, where the data are then aggregated for Germany and are subsequently published (Schelhase and Rübenach 2006; Schelhase and Weber 2007).

In 1999, autopsies of 10% of all of the deceased were performed. Autopsies are required for infant deaths and whenever there is a sign of nonnatural death. The share of autopsies is decreasing and is below a desirable value (Schelhase and Weber 2007; Schwarze and Pawlitschko 2003).

3.2.2.1 Differences Between the GDR and the FRG

The coding structure used in the GDR was different from the structure used in the FRG. In the GDR, the physician who confirmed the death also coded its cause(s) according to the ICD. The Eastern part of Germany adopted the coding practice of the FRG on October 1, 1990 (Brückner 1993). Prior that time, the cause-specific mortality structure deviated systematically from the structure that prevailed in West Germany (Brückner 1993; Häussler et al. 1995; Hoffmeister and Wiesner 1993; Modelmog et al. 1992). Brückner (1993) mentions examples of specific causes of death for which not all of the WHO coding rules were applied by the treating and coding physician. Cardiovascular mortality tended to be overreported, and cancer mortality was underreported in the GDR (Dinkel 1999; Luy 2004).

Differing coding practices in the FRG and the GDR therefore represent an obstacle to making a direct comparison of cause-specific mortality levels before the adjustment of the coding practice in October 1990.

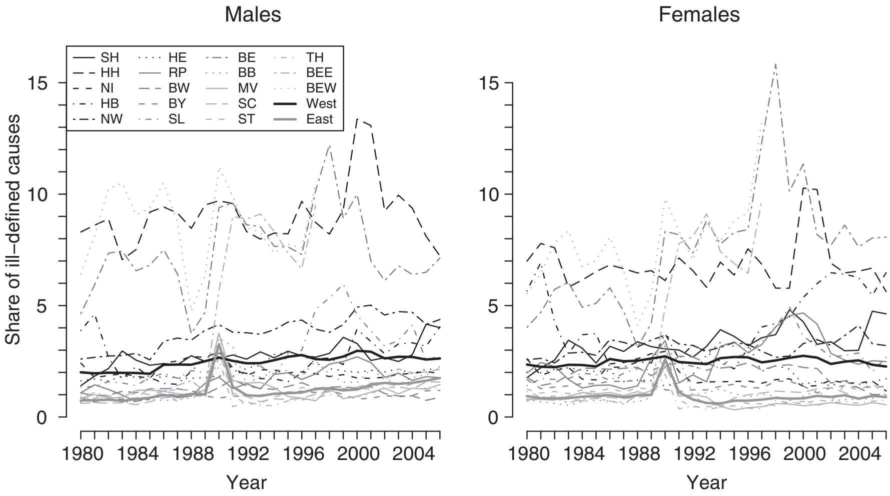

Fig. 3.1 Share of ill-defined causes in all deaths by federal state; 1980–2006. *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western Pomerania, *SN* Saxony, *ST* Saxony-Anhalt, *TH* Thuringia. East and West Germany both excluding Berlin (Data source: Federal State Offices of Statistics, Germany)

3.2.2.2 Ill-Defined Causes

One indicator in particular suggests that coding practices differ across federal states, namely, the share of ill-defined causes in the total number of deaths ("Symptoms, signs, abnormal findings, ill-defined causes"; Chapter XVIII of ICD-10). Hamburg, Berlin, Bremen, and North Rhine-Westphalia have levels that are clearly above the national average. In the East German states that had previously reported levels that were clearly below the West German average, this pattern was disrupted by a sharp jump in 1990, when the change in coding practice introduced discontinuities (Fig. 3.1; Häussler et al. 1995). East Germany followed the Eastern European pattern, in which physicians were advised to indicate a distinct cause of death and not to code into the ICD chapter on ill-defined causes.

In the smaller federal states, such as the city-states, privacy requirements have to be met before publication, that is, deaths must not be traced to individuals. This can lead to a partial recoding into the group of ill-defined causes (T. Schelhase, Federal Statistical Office Germany, on December 2, 2008, personal communication). Given the differing shares of ill-defined causes among all of the causes of death, this category has to be taken into account when causes of death are compared regionally (cf. Schubert 2001).

3.2.2.3 ICD Classifications

Because new diseases are sometimes discovered, and older ICD versions eventually become obsolete, ICD classifications are revised periodically. Since 1998, the ICD in its 10th revision has been used in Germany. From 1979 to 1997, the 9th revision was valid. With the transition from ICD-9 to ICD-10 in 1998, the numeric code was replaced by an alphanumeric code (Schelhase and Rübenach 2006).

Each new revision of the ICD classification leads to marked changes, and these were especially pronounced when ICD-10 was first implemented. For example, HIV/AIDS was undefined in ICD-9 and was first introduced by ICD-10. The changes and the progressive increase in the CODs can lead to complications in the comparability of previous revisions.

To ensure comparability over time, correspondence tables, in which the ICD items of each revision are assigned the codes of the preceding revision, are applied. This method allows for the comparison of broader groups of causes of death over time. Eurostat provides a "European shortlist," in which 65 causes, together with their respective ICD codes in different revisions, are listed (European Communities 2003; Janssen et al. 2004).

3.2.2.4 Selection of Causes for Subsequent Analysis

For the purposes of this study, it is sufficient to deal with the broader groups of the causes of death. The incorporation of ICD-9 and ICD-10 is done by using Eurostat's European shortlist of causes (European Communities 2003). The following groups of causes of death are included: neoplasms, diseases of the circulatory system, diseases of the respiratory system, external causes of injury and poisoning (excluding accidental poisoning by alcohol), and alcohol-related causes of death (comprising chronic liver disease, alcohol abuse, and accidental poisoning by alcohol). All other causes fall into a remainder group. The selected causes and the respective ICD-9 and ICD-10 items are given in Table A.2 in the appendix.

3.3 Methods

This chapter describes the methods used throughout this chapter. In the maps, cut points are based on quantiles (Brewer and Pickle 2002; James et al. 2004).

3.3.1 Life Expectancy

The life tables are based on mortality rates, covering ages zero up to age 90+, with single-year age groups created in the conventional manner (Chiang 1984; Preston et al. 2001). Temporary life expectancy between ages 0 and 75 (or 90) (Arriaga 1984) was calculated from data up to age 75+ (or 90+), with single-year age groups. Temporary life expectancy is available for a longer time period (1983–2006) and complements the analysis with life expectancy at birth in certain places. Unless otherwise indicated, life expectancy refers to life expectancy at birth (e_0).

The age decomposition of differences between two values of life expectancy allows for the calculation of the impact of each age group on this difference (Andreev et al. 2002).

Life expectancy increases follow a linear trend in the West German states and, in the period after reunification, in the East German states as well. The annual life expectancy increase is summarized by means of linear regression

$$e_0(t) \cong a + bt \tag{3.1}$$

with a as the baseline value for life expectancy at birth, e_0 and b as the annual change in life expectancy, and t being time (year), starting either in 1980 or in 1992. Life expectancy was estimated separately for the two sexes and for each federal state.

3.3.2 Lifespan Disparity $e^\dagger$

As a measure of life disparity or life expectancy lost due to death, $e^\dagger$ (e dagger) is applied (Shkolnikov et al. 2011; Vaupel and Canudas Romo 2003). It tells how many years of life are—on average—lost due to death. It weights the average remaining life expectancy at age x by the number of life table deaths at age x.

Expressed in discrete form, $e^\dagger$ is

$$e^\dagger = \sum_{y=0}^{\omega-1} d_y \overline{e}_y \tag{3.2}$$

with ω as the highest age group. The age of 111 is the highest age incorporated for East and West Germany (highest reported age in the Human Mortality Database), and 90 is the highest age for the federal states, for which ${}_{90}e_0^\dagger$ is computed. Average remaining life expectancy $\overline{e}_y$ is approximated by $\overline{e}_y = 1/2[e_y + e_{y+1}]$ (Shkolnikov et al. 2011).

Dividing lifespan disparity $e^\dagger$ by life expectancy e yields Keyfitz's entropy measure H (Keyfitz 1977; Vaupel and Canudas Romo 2003).

In order to reduce lifespan disparity, saving lives must focus on ages at which both the remaining life expectancy and the number of deaths are high. This is expressed by the quantity $d_y\overline{e}_y$ (Shkolnikov et al. 2011; Vaupel et al. 2009).

Differences in the measure $e^\dagger$ can be decomposed by age groups and causes of death, just like a decomposition of life expectancy differences (Shkolnikov et al. 2011; Vaupel and Canudas Romo 2003).

3.3.3 Dispersion Measure of Mortality

For the current purposes, a mortality dispersion measure has to express the diversity among the federal states in respect to time. As the population sizes of the federal states vary considerably, a population weighting is desirable. The dispersion measure of mortality (DMM) is applied. The DMM is equal to the average interregional difference, weighed by population size (Moser et al. 2005).

The dispersion measure of mortality is based on the mortality differences between all pairs of geographical units and weighted by population size. It is calculated as

$$\text{DMM} = \frac{1}{(2Wz)^2} \Sigma_i \Sigma_j (|e_i - e_j| * W_i * W_j) \quad (3.3)$$

with i, j denoting the federal states, z denoting Germany, and W is the weighting with P $\Sigma_i W_i = \Sigma_j W_j = W_z = 1$. The state-specific life expectancy is given by e (Moser et al. 2005). A greater value of DMM reflects higher degrees of inequality in length of life among the federal states. Relative DMM values are obtained by dividing the absolute DMM value by the overall value life expectancy for Germany.

The population-weighted average of life expectancy in the federal states usually does not yield the national life expectancy due to the different population structures in the federal states. Therefore, life expectancy-adjusted population weights W are used (Shkolnikov et al. 2001).

3.3.4 Cause-of-Death Analysis

Mortality trends by causes of death are investigated for the time period 1991–2006 for the German federal states. As direct cause-specific comparisons between eastern and western German federal states are difficult to make for the time before reunification, this is the longest reasonable time period that can be studied. A Poisson regression model (log-linear model) is applied, which links the hazard of death with age, calendar period, and federal state as explanatory variables. A similar approach has been applied by Spijker (2009) and Wolleswinkel-van den Bosch et al. (2001).

The Poisson regression with μ_i defined as occurences$_i$/exposures, the mortality hazard for cause i, can be described as follows:

$$\log(\mu_i) = \beta_0 + \beta_1 A + \beta_2 T + \beta_3 FS \quad (3.4)$$

where β_1 is the age-specific mortality effect, β_2 is the period effect on mortality, and β_3 is the effect of the federal states on mortality. The letters A, T, FS refer to the variables age, time period, and federal state. The Bayesian information criterion (BIC) is taken as a criterion that describes the model selection. It is derived from the log likelihood (LL), and it takes into account the degrees of freedom k and the sample size n ($BIC = -2*LL + k*\ln(n)$). A lower value of BIC hence indicates a better model fit.

Six age groups (0–14, 15–39, 40–54, 55–69, 70–84, 85+) and four time periods (1991–1994, 1995–1998, 1999–2002, 2003–2006) are used. All of the variables enter the models as categorical variables. The reference groups are the age group 0–14, the time period 1991–1994, and the federal state Baden-Württemberg.

Analyses were conducted separately by sex and by broad cause-of-death groups. These groups are neoplasms, cardiovascular diseases, respiratory diseases, external causes of death, alcohol-related causes of death, and a remainder group of other causes of death (see Table A.2 in the appendix for the corresponding ICD codes). Given the broad classes, the transition from ICD-9 to ICD-10 in 1998 should not affect the results.

The regression results are reflected in the mortality rate ratios (MRR), that is, the exponentials of the regression coefficients. The MRR in the reference group is one, and the MRR for the other groups then implies the relative deviation from the reference group. For example, a MRR of 1.4 indicates a 40% higher mortality risk compared to the reference group.

In the initial model, only age (A) and time period (T) are taken as explanatory variables. Additionally, the second model includes the federal state (FS). A comparison between the two models indicates whether the variation in the mortality rates can be explained by regional variation and to what extent.

Three possible interactions between the independent variables age, period, and federal state are introduced. The models therefore appear as follows:

Model 1: A + T
Model 2: A + T + FS
Model 3a: A*FS + T
Model 3b: A*T + FS
Model 3c: A + T*FS

The A*FS interaction enables us to investigate variations in the age patterns of mortality by federal state. The interaction A*T allows us to see differences in temporal mortality changes by age group, and T*FS reveals differences in temporal changes by federal state.

Because the comparison of the 16 federal states in the six cause-of-death groups is not straightforward, a clustering method was applied to classify federal states according to their cause-of-death structures. A hierarchical cluster analysis was applied to the MRR of the federal states in cause-specific results from Model 2 (A + T + FS). Additionally, the cluster analysis was also applied to the federal states' cause-specific performance over time (Model 3c: A + T*FS). In both models, the focus is on the regional mortality effects. In the latter model, the cluster procedure was run for each of the four time periods separately.

The hierarchical clustering (complete linkage method) implemented the Euclidean distance as a similarity measure. The Calinski-Harabasz pseudo-F statistics indicated the optimal number of clusters derived from the federal states. A higher value of these statistics indicated a more distinct clustering. The federal states within the obtained clusters were then found to have relatively similar cause-specific mortality structures, and the clusters were shown to differ from one another (cf. Day et al. 2008; Rabe-Hesketh and Everitt 2004; Vallin et al. 2005).

The regressions and cluster analyses were run in Stata 10.1; all other calculations and maps were done in R.2.6.0.

3.4 Life Expectancy and Its Variation Across Federal States

The following sections investigate life expectancy trends in East and West Germany and in the German federal states (Sects. 3.4.1, 3.4.2, and 3.4.3). The East-West perspective is crucial when analyzing regional mortality differentials in Germany, as many mortality differences at more refined geographical levels can be traced to East-West discrepancies.

3.4.1 Life Expectancy in East and West Germany

An examination of the trends in life expectancy from 1956 to 2006 shows that East-West mortality differences marked a crucial regional divide in Germany over a long period of time. When looking at trends in life expectancy at birth in East and West Germany, three distinct periods can be compared (Fig. 3.2).

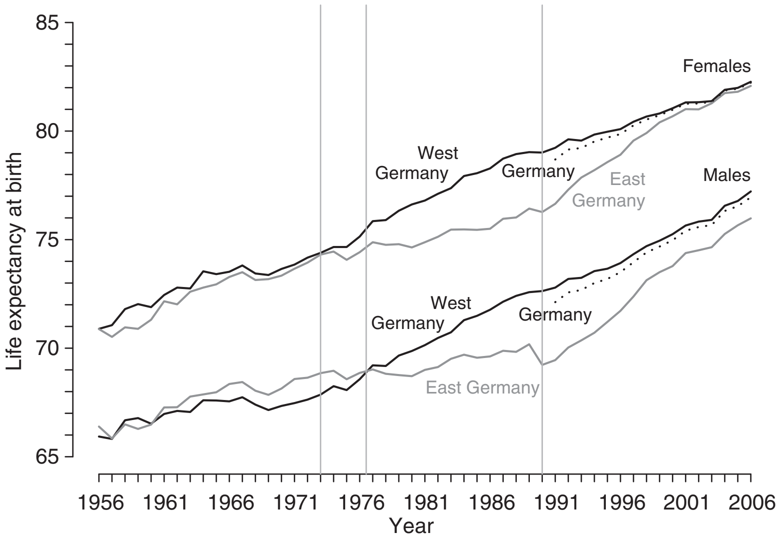

Fig. 3.2 Life expectancy in East and West Germany; 1956–2006. *Vertical lines* distinguish important time periods and indicate when East and West German life expectancies cross and 1990, the year of reunification. 1956–1972 (f) and 1956–1976 (m): life expectancy was higher in East Germany; 1973–1990 (f) and 1977–1990 (m): life expectancy was higher in West Germany and increased more rapidly than in East Germany; after 1990: life expectancy was higher in West Germany but increased more rapidly in East Germany (Data source: Human Mortality Database 2008c)

The first period lasted until the mid-1970s. It was marked by moderate life expectancy improvements. While among women, life expectancy was slightly higher in West Germany, East German men had a slight advantage in most years over West German men.

The second period lasted from the mid-1970s until 1990. In the mid-1970s (1973 for women, 1977 for men; marked by vertical lines), the East-West life expectancy gap opened up. During the entire period, life expectancy was higher in West Germany. The East-West gap widened because West Germany experienced greater life expectancy gains, while the improvements in East Germany were only moderate. In contrast to the general trend in rising life expectancy, East Germany experienced decreasing life expectancy from 1989 to 1990, and, among men, the decrease amounted to almost 1 year. The female gap was greatest in 1985–1991 (2.6–2.9 years difference), and the male gap peaked in 1990 at 3.4 years (72.6 years in the West compared with 69.2 years in East Germany).

The third period refers to the time after the reunification of Germany. Reunification represents a turning point at which the East-West life expectancy gap started to close. Increases in life expectancy in East Germany were greater during this period than before, which leads to a convergence of life expectancy levels in East and West Germany. By the early 2000s, the female gap had almost closed. In 2006, female life expectancy was 82.3 years in western Germany and 82.1 years in eastern Germany. In men, the gap was still larger than 1 year: in 2006, male life expectancy was 77.2 years in the West and 76 years in the East.

3.4.1.1 Age-Specific Differences in Life Expectancy

Differing age-specific mortality patterns in East and West Germany are responsible for the life expectancy gap. Before the 1990s, the mortality decline tended to be steeper at younger ages. Only women in West Germany achieved significant mortality declines at older ages as well. East German males at young adult ages saw mortality increases in the early 1990s. Afterward, mortality declines were achieved in all age groups, including at old ages (Nolte et al. 2000a).

In order to assess the contributions of age-specific mortality differences to the total East-West life expectancy difference, this gap is decomposed by age groups. The results are illustrated in Fig. 3.3. Positive deviations reflect the contributions of the age-specific mortality advantages of West Germany relative to East Germany, while negative deviations reflect the contributions of the East German mortality advantages.

In the first period, when East-West differences were small, West Germany initially had an advantage in infant and child mortality. However, from the mid-1960s until the late 1970s, the GDR had lower mortality rates at these ages and among men, as well as in most other age groups. The small differences in female life expectancy resulted from low mortality in young age groups in the GDR being offset by low mortality at ages 65+ in West Germany.

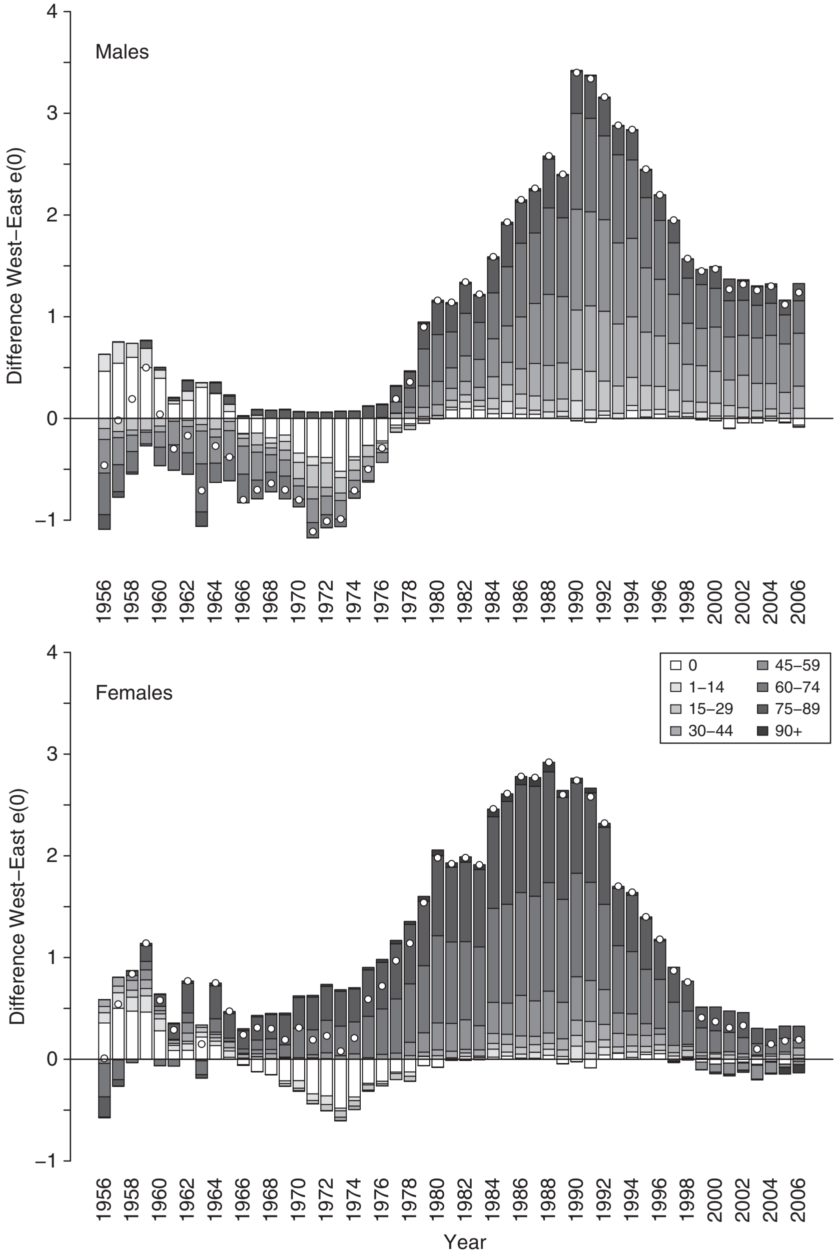

Fig. 3.3 Contribution of age-specific mortality to differences in life expectancy between West and East Germany; 1956–2006. *Circle* indicates total life expectancy difference (Data source: Human Mortality Database 2008c)

In the second period, the life expectancy gap increased as the West German mortality advantage was extended to almost all age groups. The widening of the gap over time was largely attributable to men at ages 45–74. Among women, the higher West German life expectancy was largely due to lower death rates at ages 60–89.

In the third period, after reunification, the gap closed. The reduction in the East-West difference was particularly rapid during the 1990s. The male life expectancy gap was still attributable to eastern German excess mortality at ages 45–74 but also to excess mortality at ages 15–44. For women, higher eastern German death rates at older ages continued to explain most of the life expectancy gap after reunification.

3.4.2 Life Expectancy by Federal State

In this section, the spatial distribution of life expectancy in the 16 German federal states, which refines the established East-West difference, is investigated. The spatial distribution at the latest studied time point is described. This is followed by a description of the life expectancy trends in the federal states.

3.4.2.1 Regional Pattern of Life Expectancy

Figure 3.4 presents the regional pattern of life expectancy, showing maps with the life expectancies in the federal states for males and females in 2004–2006. Male life expectancy was highest in Baden-Württemberg and was lowest in Saxony-Anhalt. The difference between these extremes is 3.5 years. In addition to Baden-Württemberg, Hesse and Bavaria are federal states with very high life expectancies. The eastern German states, as well as Saarland and Bremen in the West, perform poorly and have the lowest life expectancy levels. Among the eastern German states, Berlin and Saxony perform best, having life expectancies that are close to the German average.

For women, the regional life expectancy pattern is similar to the male pattern, with a few exceptions. Again, Baden-Württemberg and Saxony-Anhalt are at the extremes of the life expectancy distribution. The difference in female life expectancy between these two federal states constitutes 2.4 years. The best performers among women are again Baden-Württemberg, Hesse, and Bavaria, but also Hamburg and Saxony. While Saxony, an eastern German federal state, holds an average position in terms of life expectancy among men, it belongs to the top third among women. Life expectancy is lowest in the eastern German states of Mecklenburg-Western Pomerania, Brandenburg, Saxony-Anhalt, and Thuringia and in the West German states of North Rhine-Westphalia and Saarland.

The spatial pattern for life expectancy at age 65 is similar to the spatial pattern of life expectancy at birth (Fig. A.1 in the appendix; time trends in Fig. A.2). City-states are an exception. In life expectancy at age 65, the city-states perform well, with all of them belonging to the upper third.

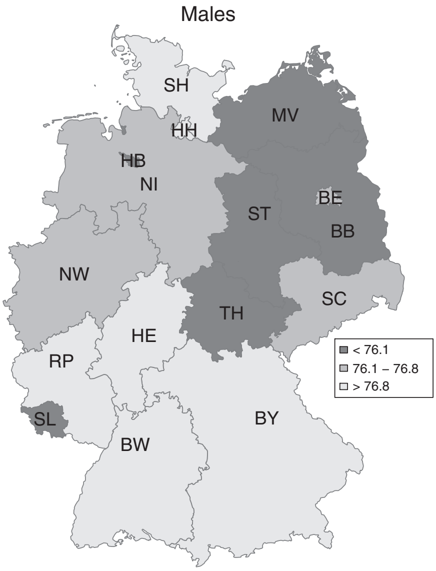

Fig. 3.4 Life expectancy by federal state; 2004–2006. *SH* Schleswig-Holstein (e_0 males 76.83 years, females 81.30 years), *HH* Hamburg (76.98, 81.35), *NI* Lower Saxony (76.64, 81.35), *HB* Bremen (76.09, 81.21), *NW* North Rhine-Westphalia (76.46, 81.18), *HE* Hesse (77.61, 81.95), *RP* Rhineland-Palatinate (76.99, 81.37), *BW* Baden-Württemberg (78.27, 82.82), *BY* Bavaria (77.30, 81.82), *SL* Saarland (75.69, 80.53), *BE* Berlin (76.65, 81.69), *BB* Brandenburg (75.53, 80.90), *MV* Mecklenburg-Western Pomerania (74.81, 80.60), *SN* Saxony (76.18, 81.83), *ST* Saxony-Anhalt (74.74, 80.41), *TH* Thuringia (75.56, 80.99) (Data source: Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy 2007)

3.4.2.2 Trends in Life Expectancy

Life expectancy trends from 1979–1981 to 2004–2006 in the federal states exhibited several distinct patterns (Fig. 3.5). Life expectancy in the German federal states increased over the study period. There was a decrease or stagnation in the eastern German states during the reunification period. Before this time, the western German states reported higher life expectancy levels and greater gains than the eastern German states. This led to a widening of the life expectancy gap. After reunification, the eastern German states experienced greater gains than the western German states, causing a reduction in the East-West gap. The spatial distribution of high and low life expectancy remained very stable over time. Absolute regional differences in life expectancy were smaller for women.

Baden-Württemberg was the vanguard state, with the highest life expectancy at all of the time points considered. While the East German states before reunification were clearly the laggard states, strong life expectancy gains in these states after reunification changed the picture. As can be seen in Fig. 3.4 for the time period 2004–2006, the laggard group became more diverse.

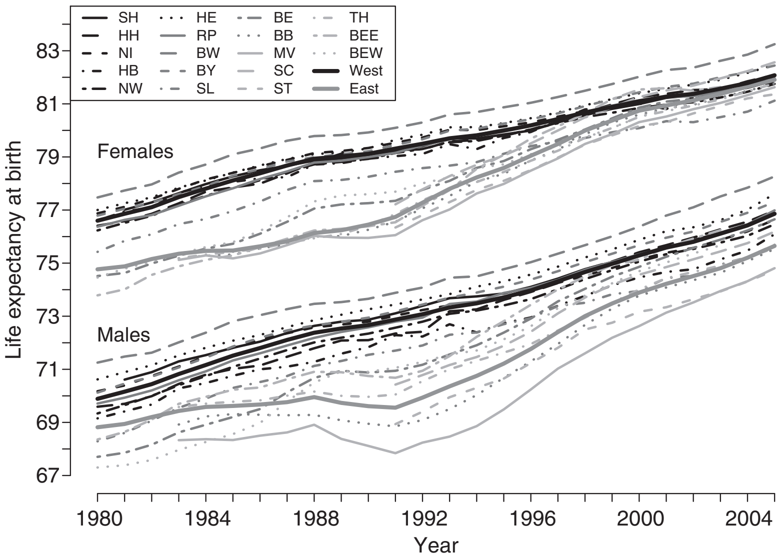

Fig. 3.5 Life expectancy by federal state; 1979–1981 to 2004–2006. *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western Pomerania, *SN* Saxony, *ST* Saxony-Anhalt, *TH* Thuringia (Data source: Federal states: State Offices of Statistics, Germany; Human Mortality Database 2008c)

A brief international comparison shows that, while men in Baden-Württemberg reached a life expectancy of 78.3 years in 2004–2006, Swedish men reached this value in the year 2004 and Japanese men in the year 2002. Among women, for whom Baden-Württemberg is the forerunner state, life expectancy in 2004–2006 amounted to 82.8 years. This value was reached by Japanese women (who are the global best performers) in 1995, by Swedish women in 2005–2006, and by Spanish and French women in 2003 (Human Mortality Database 2008b). The German forerunner is therefore close to the global forerunners in terms of low mortality.

In order to summarize annual life expectancy improvements, a linear regression analysis was performed for the years 1980–2006. Life expectancy was expressed as a linear function of time. The regression was applied to West German states over the period 1980–2006. All of the federal states were compared for the period 1992–2006. Table 3.1 shows the estimated annual increases in life expectancy at birth by federal state.

Over the entire 27-year observation period of 1980–2006 in West Germany, Hamburg and Rhineland-Palatinate reported the largest life expectancy gains. Hamburg, which initially had a life expectancy in the lower half, experienced average annual increases of 0.3 years for men and 0.22 years for women. The northern West German states of Lower Saxony, Schleswig-Holstein, and Bremen exhibited

Table 3.1 Linear regression estimates of annual life expectancy increase in years (slope) and baseline life expectancy (B) by federal state; 1980–2006 and 1992–2006

	1980–2006				1992–2006			
	Males		Females		Males		Females	
Federal state	B	Slope	B	Slope	B	Slope	B	Slope
Schleswig-Holstein	70.5	0.247	77.1	0.193	73.2	0.268	79.4	0.193
Hamburg	69.4	0.297	76.7	0.220	72.6	0.335	79.3	0.219
Lower Saxony	70.4	0.241	77.3	0.190	73.0	0.268	79.7	0.173
Bremen	69.2	0.259	76.9	0.199	72.0	0.296	79.2	0.208
North Rhine-Westphalia	69.6	0.272	76.7	0.206	72.7	0.287	79.3	0.183
Hesse	70.6	0.265	77.3	0.207	73.4	0.309	79.8	0.203
Rhineland-Palatinate	69.7	0.281	76.7	0.215	72.9	0.301	79.5	0.187
Baden-Württemberg	71.1	0.268	77.8	0.213	73.9	0.329	80.2	0.223
Bavaria	70.3	0.271	77.0	0.217	73.3	0.299	79.7	0.211
Saarland	68.6	0.276	75.9	0.208	71.9	0.281	78.5	0.192
Berlin	67.4	0.365	74.3	0.311	71.3	0.423	78.0	0.312
Berlin West*	66.9	0.377	74.5	0.295	71.1	0.426	78.0	0.306
Berlin East*	68.1	0.335	73.4	0.376	71.4	0.467	77.9	0.396
Brandenburg**	–	–	–	–	69.3	0.501	77.5	0.348
Mecklenburg-Western Pomerania**	–	–	–	–	68.2	0.525	77.0	0.376
Saxony**	–	–	–	–	70.9	0.420	78.1	0.354
Saxony-Anhalt**	–	–	–	–	69.7	0.398	77.2	0.338
Thuringia**	–	–	–	–	70.6	0.391	77.5	0.337

Data source: Federal State Offices of Statistics, Germany
Data availability: *1980–2004; **incomplete for 1980–2006

the lowest life expectancy increases. Men in these three states had annual increases of 0.24–0.26 years, while women had increases of less than 0.2 years. Annual increases for the other western German states were rather similar at about 0.26–0.28 years among men and 0.21–0.22 years among women.

West Berlin is an exception to the western German pattern. The city had very low levels of life expectancy in the early 1980s, almost comparable to life expectancy in the GDR at that time. However, West Berlin experienced very large improvements, and Berlin held an average position in Germany with regard to life expectancy during this period (see Figs. 3.4 and 3.5).

The period from 1992 to 2006 was characterized by steep life expectancy improvements in the eastern German states, but men in western Germany also experienced larger increases relative to the increases seen over the entire period.

When looking first at the western German federal states between 1992 and 2006, it is apparent that Lower Saxony, Saarland, and North Rhine-Westphalia (and women in Rhineland-Palatinate and men in Schleswig-Holstein) saw the lowest life expectancy gains. Hamburg and Baden-Württemberg experienced considerable life expectancy improvements for both sexes in 1992–2006. Gains over this period were also seen among men in Hesse and among women in Bavaria. In Rhineland-Palatinate, men, but not women, experienced high annual gains.

In eastern Germany, the life expectancy increases between 1992 and 2006 were much larger than in western Germany. Brandenburg and Mecklenburg-Western Pomerania had the lowest base level of life expectancy among the eastern German federal states but experienced sizeable increases in the period from 1992 to 2006. Saxony-Anhalt and Thuringia saw the smallest improvements. Saxony had a high initial life expectancy and experienced medium improvements among men and large improvements among women.

In both East and West Berlin, the average annual life expectancy gains were greater in 1992–2004 than in 1980–2004. Over the entire study period, as well as after reunification, the average annual gains in life expectancy in the federal states were larger for men than for women.

The correlation between constant and slope was negative in both of the time periods considered, that is, federal states with initially lower life expectancy tended to experience greater gains. This was also true within West Germany and within East Germany. However, women in eastern Germany constituted an exception: in 1992–2006, the correlation coefficient was positive.

When all of these trends are considered together, it becomes clear that the initial regional divergence was followed by regional convergence after reunification. Increases in life expectancy were larger in many federal states, especially in the East German states, than in the global forerunner countries (Oeppen and Vaupel 2002). Baden-Württemberg has consistently been the federal state with the highest life expectancy. The West German federal states which saw declines in relative terms were Schleswig-Holstein and Niedersachsen. Saarland, which had a low level of life expectancy in 1980, and which experienced low life expectancy gains throughout the entire study period, continues to hold an unfavorable position today. On the other hand, West Berlin, which occupied an unfavorable position in 1980, is now in a medium position. Apart from East Berlin, Saxony has had the highest life expectancy among the East German states. Saxony has also continued to report large annual gains in life expectancy.

3.4.3 Dispersion of Life Expectancy Across Federal States

This section deals with the measurement of mortality dispersion across federal states and its time trends. Question have arisen as to whether interstate differences in life expectancy have increased or decreased over time and how the trends in West and East Germany have contributed to the overall trend.

3.4.3.1 Dispersion Measures

Mackenbach and Kunst (1997) advocated using two steps of analysis when studying inequalities between groups: the first step is to describe the differences between the groups, and the second step is to summarize the variation in a single figure.

A great variety of inequality measures exist. Many of them were developed and used to describe differences within a population, such as socioeconomic inequality in mortality in a country. The translation of such measures to regional inequality is often feasible. The selection of an adequate measure is important and of course depends on the research question as well as on the data availability and the degree of sophistication desired (Mackenbach and Kunst 1997).

Commonly used dispersion measures include the range between the minimum and maximum values, the interquartile range, the coefficient of variation, the Gini coefficient, the Lorenz curve, the slope index of inequality, the concentration index, the standard deviation, and the dispersion measure of mortality (Ezzati et al. 2008; Low and Low 2004; Mackenbach and Kunst 1997; Moser et al. 2005; Shkolnikov et al. 2003; Wagstaff et al. 1991; WHO Commission on Social Determinants of Health 2008).

It is important to consider whether the absolute or relative scale is appropriate and whether population weighting should be applied (Harper et al. 2008). Mackenbach and Kunst (1997) asserted that it is always necessary to look at the absolute and relative scales.

For Germany, the evidence of regional mortality convergence or divergence based on summary measures is almost nonexistent. Trends in mortality inequality across regions are mainly described by the minimum and maximum values. For example, Luy (2006), Luy and Caselli (2007), and Valkonen (2001) used the minimum and maximum values and the range between the two to describe disparities in life expectancy within Germany's federal states in several time periods.

The use of the range as a mortality dispersion measure has been criticized because it does not consider the intermediate groups or the group size and may reflect outliers (see, e.g., Mackenbach and Kunst 1997; Wagstaff et al. 1991).

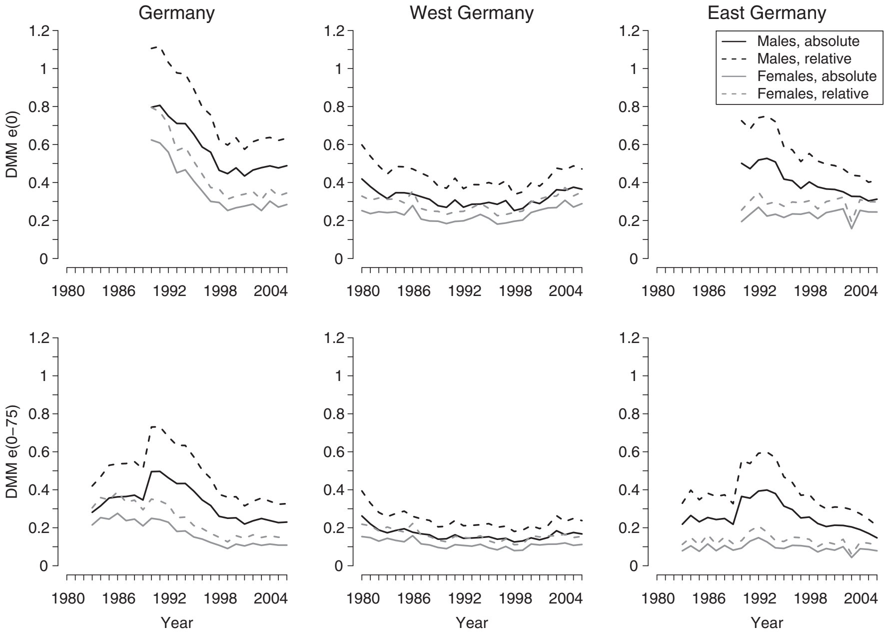

Fig. 3.6 DMM across federal states for life expectancy at birth (e_0) and temporary life expectancy ($_{75}e_0$); 1980–2006. Absolute DMM in years, relative DMM in years relative to life expectancy. East and West Germany both excluding Berlin (Data source: Federal State Offices of Statistics, Germany)

To overcome this problem, the population-weighed summary measure DMM is applied in all of the years in which data availability allows for its calculation. DMM of 1 year means that the average population-weighed difference across all pairs of federal states equals 1 year. It is also given relative to life expectancy in the respective year. The dispersion measure is applied to trends in e_0 as well as to temporary life expectancy between ages 0 and 75, $_{75}e_0$, from 1983 to 2006.[1]

3.4.3.2 Results

The previous subchapter illustrated the convergence of life expectancy across the federal states after reunification. The DMM provides a quantitative description of this tendency (Fig. 3.6). Across all German states from 1990 to 2006 (upper left panel in Fig. 3.6), the change is twofold. The highest dispersion levels were observed in 1990 and 1991, and DMM decreased until 1999. Convergence stopped at this point.

[1] Without these data, a nationwide comparison is only possible from 1990 onward. Longer time series for all East German federal states allow for a comparison of dispersion in East Germany in the crucial periods before and after reunification.

After 1999, the dispersion increased slightly. The directions of male and female trends were similar, but males exhibited higher levels of regional life expectancy dispersion.

Looking at DMM within western and within eastern Germany (upper middle and upper right plot in Fig. 3.6) provides greater insight into the patterns behind the German trend. West Germany exhibited slowly decreasing dispersion throughout the 1980s and until the late 1990s. From the end of the 1990s until the end of the study period, regional dispersion increased slightly. In general, it is remarkable how steady the levels in West Germany were. Dispersion across East German federal states presents itself differently. Dispersion among women was at a low and stable level throughout the study period 1990–2006. Among men, dispersion steadily decreased. Dispersion across East German federal states was highest in 1992–1994.

Investigating temporary life expectancy between ages 0 and 75 allows for the inclusion of a longer time period for the German federal states, as the data for East Germany reaches farther back in time. For the common time periods, the patterns of DMM in life expectancy at birth and temporary life expectancy were very similar (Fig. 3.6). For the temporary life expectancy between ages 0 and 75, dispersion across all of the German federal states was highest in 1990–1991 for males (lower left plot in Fig. 3.6). For both males and females, dispersion decreased throughout the 1990s and then leveled off. Dispersion in female ${}_{75}e_0$ was mainly stable from 1983 to 1992 and then began to decrease.

The trends in regional dispersion in temporary life expectancy ${}_{75}e_0$ across West German federal states were similar to trends in life expectancy at birth. However, DMM increases were less pronounced than those in life expectancy at birth, which suggests that old-age mortality is important.

3.5 Lifespan Disparity and Its Variation Across Federal States

In addition to the average lifespan, population health can also be examined from the perspective of lifespan inequality. The health equality agenda seeks to achieve both high life expectancy and low lifespan disparity. This will ensure a longer and more predictable length of life for everyone. While mortality reductions in any age group lead to increasing life expectancy, the reduction of deaths at early ages reduces lifespan disparity (mortality compression), while a reduction in late deaths leads to a rise in lifespan disparity (mortality expansion). A threshold age divides early and late deaths. This age usually lies slightly below life expectancy (Shkolnikov et al. 2011; Vaupel et al. 2009; Zhang and Vaupel 2009). The compression of mortality is a synonym for the rectangularization of the survival curve (Wilmoth and Horiuchi 1999).

International evidence shows that the countries with the highest life expectancy globally (Sweden, Norway, France, Japan, Switzerland) were able to reduce mortality in an “effective” way, that is, by increasing average life expectancy, while at the same time reducing early deaths (Oeppen 2008; Vaupel et al. 2009). On the other hand, Smits and Monden (2009) showed that, generally, those forerunner countries that reached the highest levels of life expectancy first achieved this at higher levels of lifespan disparity than the countries that followed soon after. Laggard countries that reached a certain level of life expectancy much later again exhibited higher levels of lifespan disparity.

Several measures for capturing the degree of inequality in age at death exist, and all have been shown to be highly correlated (Cheung et al. 2005; Keyfitz 1977; Shkolnikov et al. 2003; van Raalte 2008; Vaupel and Canudas Romo 2003; Vaupel et al. 2009; Wilmoth and Horiuchi 1999). However, these inequality measures differ with respect to their mathematical properties and in their degrees of sensitivity to changes in different parts of the age-at-death distribution (Shkolnikov et al. 2003; van Raalte 2008).

In country comparisons, it has been shown that similar levels of life expectancy can correspond to different levels of lifespan inequality (Edwards and Tuljapurkar 2005; Shkolnikov et al. 2011; Smits and Monden 2009).

Although these comparisons were made at the national level, it may be assumed that differences also exist at regional levels. Given the specific life expectancy patterns of the German federal states, there is good reason to suspect that the pathways to high life expectancy have not been the same for all federal states. The life expectancy differences between the eastern and the western German states, in particular, may also be reflected in lifespan disparity.

In the following discussion, the long-term structures in East and West Germany will be identified, and then, the regional structures in the federal states will be analyzed.

3.5.1 Lifespan Disparity in East and West Germany

The comparison of the life expectancy and lifespan trajectory between East and West Germany has revealed the existence of five distinct stages. These are described in the following section. For three of these stages, life expectancy and lifespan disparity differences between East and West Germany are decomposed by age.

3.5.1.1 Five Periods of Lifespan Disparity Changes

Lifespan disparity $e^{\dagger}$ and life expectancy show a very strong negative correlation.[2] However, as life expectancy is higher in West Germany most of the time, it may be expected that lifespan disparity would also be temporally shifted.[3] Instead of analyzing

[2] Pearson's correlation coefficients between $e^{\dagger}$ and e_0, 1956–2006: West German males –0.97, West German females –0.99, East German males –0.79, and East German females –0.88.

[3] The appendix shows absolute and relative lifespan disparity in East and West Germany (Figs. A.3 and A.4) and the age-specific decomposition of differences in absolute lifespan disparity between East and West Germany from 1956 to 2006 (Fig. A.5).

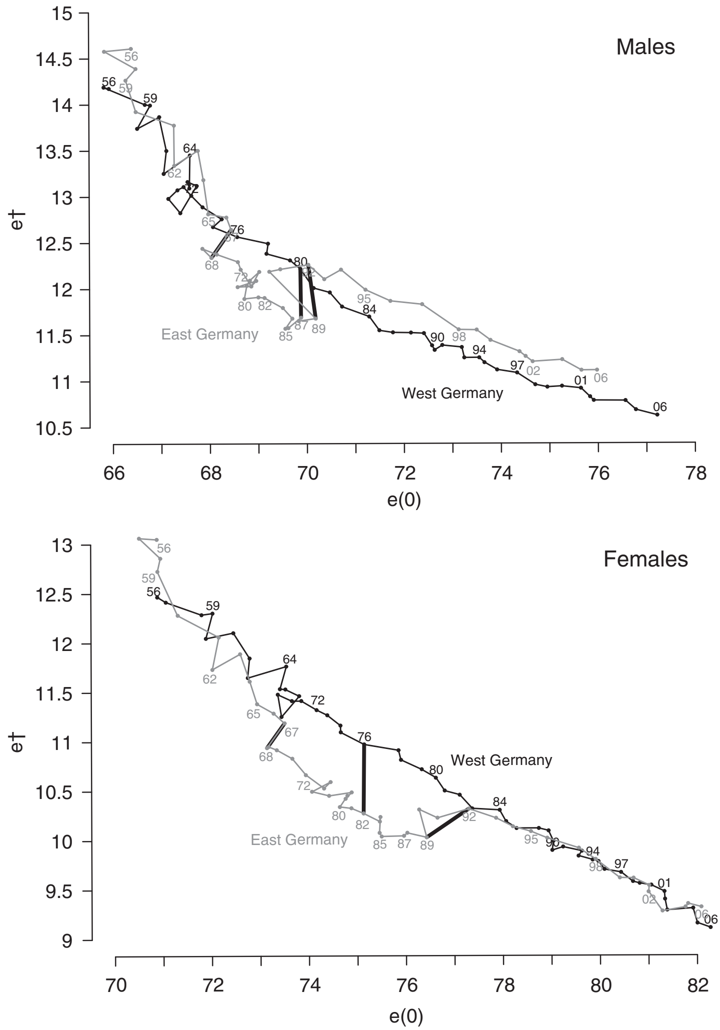

Fig. 3.7 Lifespan disparity $e^{\dagger}$ versus life expectancy e_0 in East and West Germany; 1956–2006. *Bold lines* indicate comparisons described in the text (Data source: Human Mortality Database 2008c)

annual differences in $e^{\dagger}$ (as was done for life expectancy), the focus here lies on the comparison of $e^{\dagger}$ in East and West Germany at the same levels of life expectancy.

Figure 3.7 shows the $e^{\dagger}$ versus e_0 trajectories in East and West Germany of $e^{\dagger}$ given the same level of e_0. As life expectancy increased, lifespan disparity decreased. There are, however, exceptions to this trend. Five time periods can be distinguished (Fig. 3.7 and Table 3.2).

Table 3.2 Expected relationship between changes in e_0 and changes in $e^\dagger$ and observed trends in East Germany; 1956–2006

	Change in e_0	Change in $e^\dagger$
Expected	+	–
Observed		
–late 1960s	+	–
1967–1968	–	–
1970s–1980s	+	–
1989–1992	–(m)/+(f)	+
1992+	+	–

1. Late 1960s: At same levels of life expectancy in East and West Germany (until male e_0 is about 68 years and female e_0 is between 73 and 74 years), the lifespan disparity was similar.
2. Late 1960s (mainly 1967–1968): Transition toward lower lifespan disparity in East Germany.
3. 1970s–1980s: At same levels of life expectancy, lifespan disparity was lower in East Germany (parallel shift to West Germany).
4. 1989–1992 (reunification period): Lifespan disparity increased strongly in East Germany (short convergence period).
5. 1992+: Men—At same levels of life expectancy, lifespan disparity was higher in East Germany. Women—At same levels of life expectancy, lifespan disparity was equal in East and West Germany.

In order to find out which age-specific mortality patterns underlie these differences, Periods 2–4 were analyzed in greater detail by decomposing the East-West differences. As was done for life expectancy, the decomposition analysis can determine the age contributions to $e^\dagger$ changes or differences (men: Fig. 4.8; women: Fig. A.6 in the appendix).

While a male death causes on average 14.2 years of lifespan lost in West Germany (females: 12.5) and 14.6 years in East Germany (females: 13.0), the average number of years of lifetime lost due to death declines to 10.6 and 11.1 years (9.1 and 9.3) in 2006.

3.5.1.2 Transition to Lower Disparity in East Germany (Period 2): 1967–1968

In this period, lifespan disparity $e^\dagger$ in East Germany departed from the common trajectory, with West Germany moving toward lower disparity. East Germany simultaneously experienced a temporary decrease in life expectancy e_0. Figure 3.8 shows which age groups determine the e_0 and $e^\dagger$ declines among men (Fig. A.6 in the appendix shows the results for women).

Infant and child mortality decreased between 1967 and 1968. In contrast to the overall trend of falling death rates over time, old-age mortality (ages 60+) increased. The negative impact of old-age mortality prevailed, and hence, life expectancy

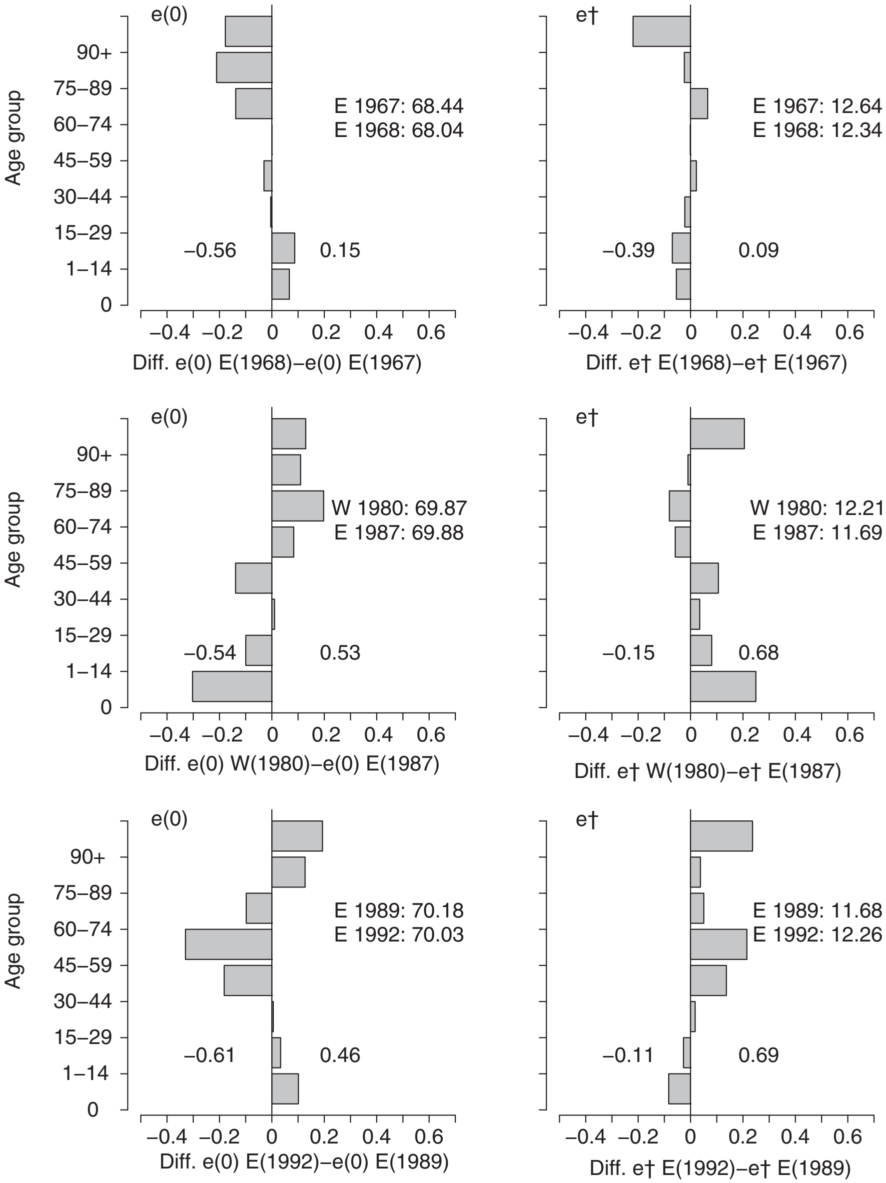

Fig. 3.8 Contribution of age-specific mortality to differences in e_0 (*left panel*) and $e^{\dagger}$ (*right panel*), males: comparison 1967–1968 in East Germany (Period 2, *upper panel*); comparison West Germany 1980 and East Germany 1987 (Period 3, *middle panel*); comparison 1989 and 1992 in East Germany (Period 4, *lower panel*) (Data source: Human Mortality Database 2008c)

decreased by 0.4 years among men. Lifespan disparity decreased mainly because of declining mortality in childhood and increasing mortality at very high ages (90+), which compresses the age-at-death distribution. This shows that decreases in lifespan disparity are not always related to improvements in life expectancy.

3.5.1.3 Lower Lifespan Disparity in East Germany (Period 3): 1970s–1980s

After the transition in 1967–1968 toward lower lifespan disparity levels in East Germany, East Germany remained at a lower disparity level during the 1970s and 1980s. For example, male life expectancy was 69.9 years in 1980 in West Germany and in 1987 in East Germany. Lifespan disparity at these time points was 12.2 years in West Germany and half a year lower in East Germany, respectively. Different underlying age-specific mortality patterns produced this result (Fig. 3.8, middle panels). Although e_0 and $e^\dagger$ for men at these particular time points are compared, the results are roughly transferable to other years for which life expectancy in East and West Germany was the same. The results also apply to women with a slightly shifted age pattern (an example for women is shown in the appendix in Fig. A.6, middle panels).

Below the age of 60, mortality was lower for East German men in 1987. Low infant mortality had an important impact on life expectancy. If infant mortality had been at the West German level, life expectancy in East Germany would have been 0.3 years lower. West Germany, on the other hand, had lower mortality above age 60. This age-specific mortality pattern resulted in a lower lifespan disparity in West Germany in the age group 45–89 (0.15 years). The mortality structure in the other age groups led to a higher level of lifespan disparity in West Germany (Fig. 3.8, middle panels).

The effect of lower lifespan disparity was more pronounced among women, as East-West differences in old-age mortality are more important for women than for men (women: middle plots in Fig. A.6). Furthermore, lower infant mortality in particular, and also, to a minor extent, mortality just under the age of 75, counterbalanced excess mortality at old ages in East Germany. Both effects led to an increased lifespan disparity among West German women.

3.5.1.4 Transition to Higher Disparity in East Germany (Period 4): 1989–1992

The third point of interest refers to the converging e_0 versus $e^\dagger$ pattern in East Germany just after German reunification. The results for men are displayed in the lower panels of Fig. 3.8 (for women, they are shown in Fig. A.6 in the appendix). Alongside male life expectancy decreases, lifespan disparity increased between 1989 and 1992. East Germany adjusted to the West German $e^\dagger - e_0$ trajectory with a higher lifespan disparity level at a given life expectancy level (Fig. 3.7). Interestingly, tendencies toward higher levels of $e^\dagger$ had already been established in the mid-1980s, but the convergence among women and the crossover among men with West Germany did not occur until the reunification period.

The life expectancy decline among East German men of 0.15 years between 1989 and 1992 can be explained by increasing mortality rates in the age group 30–74. Infant and child mortality and mortality above age 75 declined. These improvements offset some of the deterioration at middle ages and their impact on life expectancy.

Without these improvements at infancy and old ages, male life expectancy would have decreased by 0.61 years, instead of by 0.15 years. Increasing mortality at middle ages and decreasing mortality at old ages both contributed to the increase in lifespan disparity. Declining mortality in childhood worked in the opposite direction. Since the impact of infant mortality on $e^{\dagger}$ was small compared to all other age groups, the total increase in $e^{\dagger}$ amounts to almost 0.6 years.

Women experienced increases in both life expectancy and lifespan disparity between 1989 and 1992. Mortality decreased slightly in the age group 15–29 and significantly above age 60. Life expectancy increased by 0.9 years. Lifespan disparity increased by 0.3 years. Mortality improvements in the age group 60–89 contributed negatively to lifespan disparity, while mortality changes at other ages contributed positively to lifespan disparity. As the positive contributions prevailed, lifespan disparity for East German women was higher in 1992 than in 1989 (Fig. A.6 in the appendix).

After 1992, lifespan disparity among East German men was somewhat higher than among West German men at the same levels of life expectancy (Period 5). This is mainly because of excess mortality of East German men at ages 15–49 after reunification (figures not shown here).

3.5.2 *Lifespan Disparity by Federal State*

The comparison is now extended to federal states. First, lifespan disparity ${}_{90}e_0$ at the same ${}_{90}e_0$ levels is compared.[4] Second, this comparison is extended to a longitudinal perspective, and the underlying age structure is analyzed for a selected example. The values are based on 3-year averages.

3.5.2.1 Spatial Pattern of Lifespan Disparity at Equal Level of Life Expectancy

Figure 3.9 shows a regional comparison of ${}_{90}e_0^{\dagger}$ when male temporary life expectancy is assumed to be 74 years (left panel) and female temporary life expectancy is assumed to be 80 years (right panel). The values were interpolated, with a linear trend assumed in both measures. At the same level of ${}_{90}e_0$, men in North Rhine-Westphalia, Thuringia, and Rhineland-Palatinate experienced the lowest number of

[4] Data restriction: In the comparison of life disparity across federal states, the age groups were restricted to ages [0–90) years. Knowing that the population size is overestimated at high ages (to different extents across the federal states), the ages 90+ were left out because $e^{\dagger}$, the measure of lifespan disparity, is very sensitive to mortality at high ages. This is less the case for life expectancy. The measures ${}_{90}e_0^{\dagger}$, e_0 and ${}_{90}e_0$ showed a strong negative correlation, and this led to the conclusion that dealing with ${}_{90}e_0^{\dagger}$ instead of $e_0^{\dagger}$ is unlikely to affect principal findings.

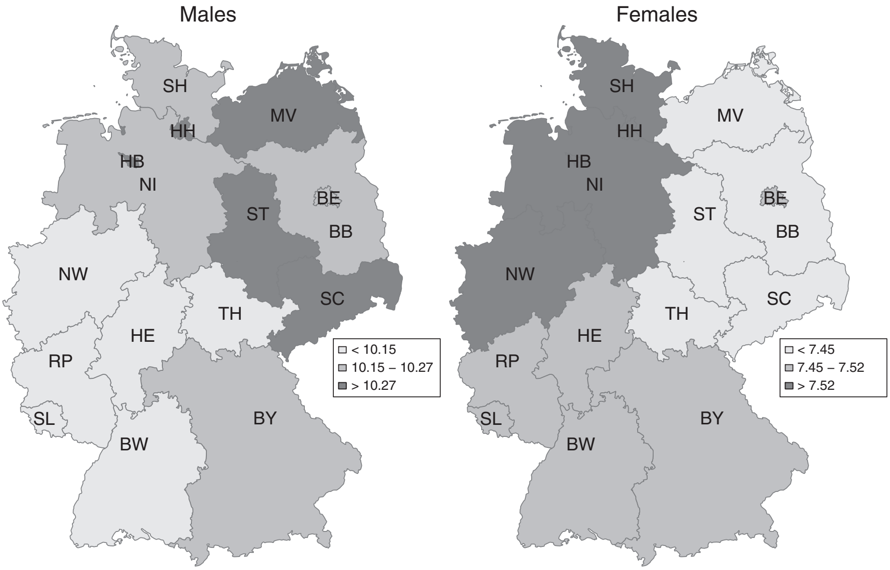

Fig. 3.9 Temporary lifespan disparity ${}_{90}e_0^\dagger$ at male temporary life expectancy ${}_{90}e_0$ of 74 years and female temporary life expectancy ${}_{90}e_0$ of 80 years; interpolated values of 3-year averages of ${}_{90}e_0^\dagger$ and ${}_{90}e_0$. *SH* Schleswig-Holstein (${}_{90}e_0^\dagger$ males 10.17 years, females 7.54), *HH* Hamburg (10.35, 7.64), *NI* Lower Saxony (10.19, 7.55), *HB* Bremen (10.57, 7.71), *NW* North Rhine-Westphalia (10.04, 7.52), *HE* Hesse (10.13, 7.48), *RP* Rhineland-Palatinate (10.08, 7.46), *BW* Baden-Württemberg (10.15, 7.46), *BY* Bavaria (10.19, 7.45), *SL* Saarland (10.12, 7.48), *BE* Berlin (10.27, 7.52), *BB* Brandenburg (10.19, 7.37), *MV* Mecklenburg-Western Pomerania (10.44, 7.42), *SN* Saxony (10.28, 7.42), *ST* Saxony-Anhalt (10.32, 7.43), *TH* Thuringia (10.11, 7.37) (Data source: Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy 2007)

life years lost. Bremen, Mecklenburg-Western Pomerania, and Hamburg experienced the highest number of life years lost. Women in Bremen, Hamburg, and Lower Saxony also had the highest life years lost, while women in the eastern federal states had a relatively small number of life years lost (except for Berlin).

Those federal states that reached a lower level of ${}_{90}e_0$ can be considered the forerunner states; others will reach this point later in time. For example, among men, Bremen and North Rhine-Westphalia represented the extremes. North Rhine-Westphalia reached 74 years of ${}_{90}e_0$ in the period 1997–1999, and ${}_{90}e_0^\dagger$ equals 10 years. Bremen reached the same life expectancy 4 years later, in 2001–2003, and at 10.5 years of lifetime lost (Fig. 3.10). Instead of 10.5 years of life lost, Bremen could gain 0.5 years on average if it had the same, more favorable, age-specific mortality structure of North Rhine-Westphalia.

Interestingly, the federal states with the highest life expectancy levels are not necessarily the states with the lowest levels of lifespan disparity, and the East-West division observed in temporary life expectancy ${}_{90}e_0$ is found to be less prevalent.

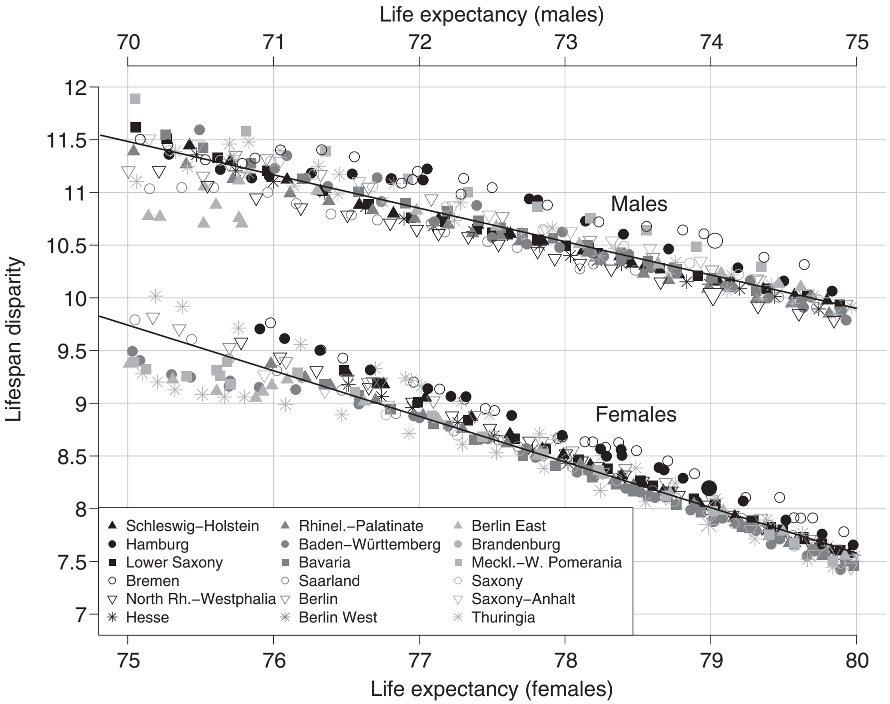

Fig. 3.10 Temporary lifespan disparity ${}_{90}e_0^\dagger$ versus temporary life expectancy ${}_{90}e_0^\dagger$ for ${}_{90}e_0$ between 70 and 75 years (m) and between 80 and 85 years (f); 1979–1981 to 2004–2006 ${}_{90}e_0^\dagger$ (m) = 33.7299 – 0.3177* ${}_{90}e_0$ (m), ${}_{90}e_0^\dagger$ (f) = 42.162 – 0.4322* ${}_{90}e_0$ (f). Examples: North Rhine-Westphalia 1997–1999 and Bremen 2001–2003 (m) and Thuringia 1997–1999 and Hamburg 1995–1997 (f) are printed enlarged (Data source: Federal State Offices of Statistics, Germany)

3.5.2.2 Changes Over Time

The tight relationship between life expectancy and lifespan disparity, as observed in the East-West comparison, is demonstrated again for the federal states. As seen in the comparison between the East and the West German ${}_{90}e_0^\dagger$ versus ${}_{90}e_0$ trajectory and also among the federal states, differences can be seen in the age-mortality profiles that result in the same level of life expectancy but a different degree of lifespan disparity. For both men and women, the federal states mainly kept their positions, with either a high, middle, or low lifespan disparity level at a given life expectancy level.

Among men, North Rhine-Westphalia reached the lowest lifespan disparity level. At lower levels of life expectancy, men in Saarland also had one of the lowest lifespan disparity levels. Bremen, Hamburg, and Mecklenburg-Western Pomerania exhibited some of the highest disparity levels. At a given ${}_{90}e_0$ level, ${}_{90}e_0^\dagger$ of most federal states varied within a range of half a year.

Women in the city-states of Bremen, Hamburg, and West Berlin experienced the highest inequality in length of life. The lowest level of lifespan disparity was experienced by women in Thuringia at all of the time points considered. They converged to a lesser extent with the West German pattern of elevated ${}_{90}e_0^{\dagger}$ at a given life expectancy level after reunification. Although the majority of federal states are closer to each other in terms of lifespan disparity for women than for men, the extremes again show a range of about half a year of lifetime lost.

At low life expectancy levels, regional variations in lifespan disparity were greater, and the East German federal states are farther below the regression line than at higher life expectancy levels. As mentioned above, East Germany had lower lifespan disparity before reunification. This is shown here for particular federal states (e.g., Berlin East and Thuringia) and refers to values of male life expectancy below 71 years and of female life expectancy below 76 years.

3.5.2.3 Lifespan Disparity and Age-Specific Mortality Profiles

In the next part, an age-specific decomposition of temporary life expectancy ${}_{90}e_0$ and temporary lifespan disparity ${}_{90}e_0^{\dagger}$ is applied to federal states with lifespan disparity at the extremes. As an example, the different mortality patterns of men in North Rhine-Westphalia (1997–1999) and Bremen (2001–2003), both of which have a life expectancy level of 74 years, are examined. For women, Thuringia (1997–1999) and Hamburg (1995–1997), both of which have a life expectancy of 79 years, ${}_{90}e_0$ are compared. The results are displayed in Fig. 3.11.

In the comparison between men in North Rhine-Westphalia and Bremen, the mortality differences at young ages are found to produce small contributions to the ${}_{90}e_0$ difference. Excess mortality in Bremen at ages 30–59 years was found to be offset by mortality that is lower than in North Rhine-Westphalia at ages 60+. Life expectancy therefore equals 74 years in both federal states, though at different time points. However, the different age-specific mortality profiles are shown to have had different effects on lifespan disparity. Excess mortality among men in Bremen at ages 30–59 years was found to be the main contributor to elevated lifespan disparity in this federal state. The lower mortality in Bremen at ages 75–89 further contributed to the higher lifespan disparity here (Fig. 3.11).

The performance of women in Thuringia and Hamburg is now compared for the time points at which life expectancy was 79 years. Excess mortality is found among women in Hamburg in the age group 30–59. In the age group 75–89, mortality in Thuringia was shown to be higher than in Hamburg. The age separating early from late deaths was found to lie in the age group 75–89. Excess mortality at the middle ages, 30–59, and, to a minor extent, in the age group 85–89, was shown to cause greater lifespan disparity in Hamburg (disaggregated figures for the age group 85–89 not shown here).

For men in North Rhine-Westphalia and for women in Thuringia, the deaths were centered more around the mean age at death, leading to a lower degree of inequality in age at death. A high number of early deaths—and, to a minor extent,

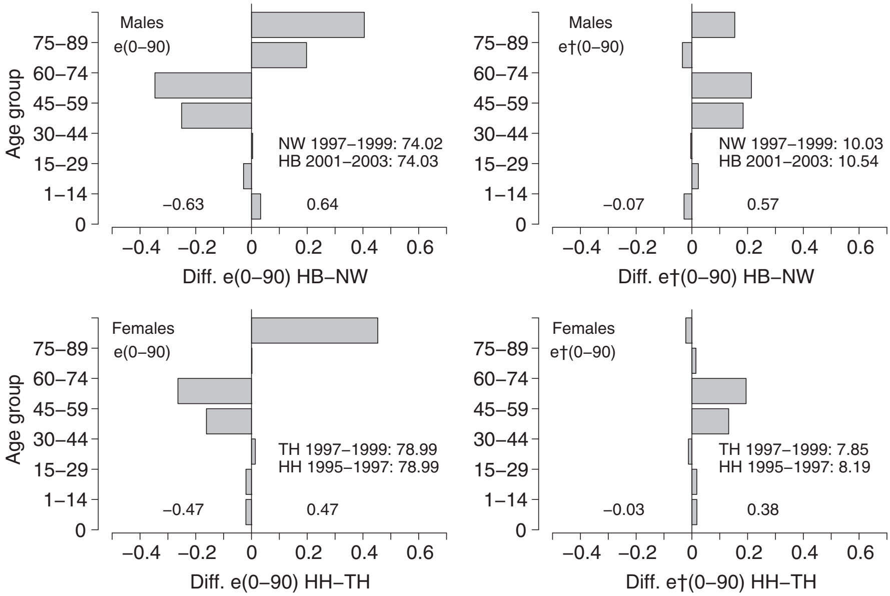

Fig. 3.11 Contribution of age-specific mortality to differences in temporary life expectancy ${}_{90}e_0$ and temporary lifespan disparity ${}_{90}e_0^{\dagger}$ in selected federal states when ${}_{90}e_0$ is equal; comparison between federal state with higher to federal state with lower ${}_{90}e_0^{\dagger}$. *NW* North Rhine-Westphalia, *HB* Bremen, *TH* Thuringia, *HH* Hamburg (Data source: Federal State Offices of Statistics, Germany)

low old-age mortality in Bremen (men) and in Hamburg (women)—led to a greater dispersion of age at death.

3.6 Cause-of-Death Patterns Across Federal States

The developments in life expectancy across regions are the result of differential age- and cause-specific mortality trajectories. Therefore, the analysis in this section seeks to identify cause-of-death structures across federal states. The structures underlying the life expectancy increase over time shall be explored. How these cause-of-death patterns change over time, and how they influence trends in all-cause mortality, will be investigated. The analysis will also seek to determine which causes of death exhibit the greatest spatial variation and how spatial variation changes over time.

Although studies on cause-specific mortality differences between East and West Germany exist (Häussler et al. 1995; Kibele and Scholz 2008; Klenk et al. 2007; Luy 2004; Nolte et al. 2000b; Resch 2001; Wiesner and Bittner 2004), a cause-specific comparison of all of the German federal states has not yet been attempted for the period after reunification. Differing coding practices in the GDR and the FRG make it difficult to undertake a cause-specific comparison in the time period before reunification.

Table 3.3 Distribution of death counts by cause-of-death group; 1991–2006 (pooled)

	Share in %	
Cause of death	Males	Females
All causes	100	100
Neoplasms	28	23
Cardiovascular diseases	42	52
Respiratory diseases	7	5
External causes of injury and poisoning	6	3
Alcohol-related causes	4	2
Other causes	13	15

Data source: Federal State Offices of Statistics, Germany

For a few causes of death, mortality comparisons between federal states after reunification are available. They reveal a north-east to south-west high-to-low gradient in cardiovascular mortality. The city-states are shown to have low cardiovascular mortality rates, while the rates in Saarland are found to be as high as in the eastern German states (Müller-Nordhorn et al. 2004; Willich et al. 1999). Cancer mortality shows diverse regional patterns, such as high stomach cancer mortality in Bavaria or high lung cancer mortality in the Wismut region in Saxony, regions of North Rhine-Westphalia, Saarland, and the city-states (Abel and Becker 1987; Becker and Wahrendorf 1998; European Communities 2009; Held et al. 2005).

A comparative analysis of the cause-of-death structures over time in the German federal states does not yet exist. The present analysis fills this gap. It combines the regional and age-specific mortality structures with the dimensions of time and causes of death and allows for a direct comparison of one federal state with another for the time after reunification.

3.6.1 Model Comparison

Prior to the interpretation of the results, the cause-of-death distribution will be discussed. Different models of mortality variation are then compared with regard to their goodness of fit. Next, the mortality effects of the incorporated variables (age, time period, federal state), and the reasonable interactions between them, are considered by the cause-of-death group. After the analysis of mortality by age and the temporal patterns of cause-specific mortality, the focus will be on the mortality differences between federal states.

The distribution of death counts by causes (Table 3.3) reveals that, among men, 42% were deaths from cardiovascular diseases (women: 52%), 28% died of cancer (23%), 7% were deaths from respiratory diseases (5%), 6% were deaths from external causes (3%), and 4% were deaths from alcohol-related diseases (2%). Over time, the share of neoplasms in all deaths was increasing, while the share of deaths from cardiovascular diseases was decreasing (figures not shown).

Table 3.4 Bayesian information criterion (BIC) of Poisson models by cause-of-death group; 1991–2006

	Model 1	Model 2	Model 3a	Model 3b	Model 3c
	A+T	A+FS+T	A*FS+T	A*T+FS	A+T*FS
df	10	25	115	43	70
Males					
All causes	65,144	29,047	**14,528**	24,814	26,572
Neoplasms	12,697	7,679	**6,685**	7,164	7,309
CVD	51,785	17,767	14,829	**11,857**	15,274
Respiratory	12,268	8,631	7,431	8,200	**6,513**
External	31,532	11,035	**7,848**	10,175	9,526
Alcohol	32,680	10,935	**5,213**	10,588	10,243
Other	33,439	20,266	**10,989**	18,074	18,516
Females					
All causes	59,985	42,110	32,488	**21,654**	37,346
Neoplasms	9,837	8,161	**6,212**	7,836	7,968
CVD	90,105	41,313	36,808	**14,700**	36,637
Respiratory	18,158	12,197	10,166	11,241	**7,880**
External	25,024	11,095	**8,097**	10,588	9,007
Alcohol	9,726	6,179	**4,304**	6,024	6,091
Other	42,189	26,196	**16,423**	20,465	22,409

Data source: Federal State Offices of Statistics, Germany
Bold figures indicate the lowest BIC of the respective sex- and cause-specific combination
A Age group, *T* Time period, *FS* Federal state, *df* Degrees of freedom

Next, the goodness of fit between different Poisson regression model specifications is compared. Because the regional mortality differences vary by cause of death, several models were set up to analyze the extent of regional variation by cause-of-death group. The first model contains age and time period as explanatory variables (Table 3.4). Model 2 further includes the federal state as an explanatory variable.

The reference categories are the age group 0–14, the time period 1991–1994, and the federal state Baden-Württemberg. In those models, which include an interaction between any of these variables, the respective combination is taken as a reference category. Constants for all models are displayed in Table A.3 in the appendix.

The goodness of fit for all of the estimated models, expressed by the Bayesian information criterion (BIC), is shown in Table 3.4. A comparison of the BIC values between the main effects models (Models 1 and 2) reveals which causes of death display greater mortality differences in the various federal states. A substantial BIC reduction from Model 1 to Model 2, in which the federal state is included as an explanatory variable, provides some initial insight into where the large regional mortality variations can be found. This is the case for deaths from cardiovascular diseases and from external causes, as well as for alcohol-related causes and for all causes of death among men. For these causes of death, the reduction in BIC amounts to more than 50% from Model 1 to Model 2.

The introduction of interaction effects (Models 3a–c) improves the goodness of fit for each model compared to Model 2, which contains only additive effects.

In most causes of death, the inclusion of the interaction A*FS between age groups and federal states yields the best goodness of fit, meaning that the age-specific mortality patterns by cause vary across federal states. Respiratory causes and cardiovascular diseases are exceptions. For respiratory diseases, the inclusion of the T*FS interaction yields the greatest improvement in the model fit. This indicates that temporal mortality improvements in respiratory mortality do not take place in a uniform manner but rather vary by federal state. As for cardiovascular diseases, the interaction term A*T between age groups and time periods most improves the additive model. Given the especially large share of cardiovascular mortality in all-cause mortality among women, the inclusion of the A*T interaction also yields the best goodness of fit for female all-cause mortality. Among all causes of death, the variation in cancer and respiratory mortality is the least dependent on the inclusion of interaction effects.

3.6.2 Cause-Specific Mortality by Age and Over Time

Age-specific mortality patterns differ by causes of death, as seen in Fig. 3.12. All-cause mortality steadily increased among men over all age groups, while among women, mortality was lowest in the age group 15–29. This pattern was similar for cardiovascular and respiratory diseases. Mortality of neoplasms increased at a slower pace beyond the age of 60. Alcohol-related mortality increased until the age group 45–59 and then remained at about the same level over the higher age groups. External mortality showed a first peak in the age group 15–29 (mainly due to traffic accidents) and then strongly increased after age 60 (related to accidental falls). Mortality from other causes of death roughly followed the age pattern of all-cause mortality, but mortality in the age group 15–44 was below mortality in the age group 0–14. This is because most infant deaths fell into the group of other causes.

Over time, all-cause mortality decreased (Fig. 3.13). The general mortality decrease over the four time periods leveled off in the last interval, from 1999–2002 to 2003–2006, but the decrease remained strong in cancer and alcohol-related mortality. All-cause mortality declined by 20% among women and by 27% among men. The greatest mortality decline took place in cardiovascular mortality among men and in external mortality among women. In the remainder group of other causes of death, the mortality decline over the four time periods was the slowest or even negative (women).

Temporal mortality changes differed by age group, especially in all-cause and cardiovascular mortality. Generally speaking, mortality improvements tended to be steeper at younger than at older ages. For these two groups of causes, the inclusion of the A*T interaction effect yielded a significant improvement in the model fit (Table 3.4). Mortality declines for each age group between the first and the last time period are given in Table A.4 in the appendix.

In all-cause mortality, the age-specific mortality risk decreased most in the age group 0–29 over time, and small improvements were seen in the highest age group of 85+. Cardiovascular mortality showed one of the largest improvements over time, and

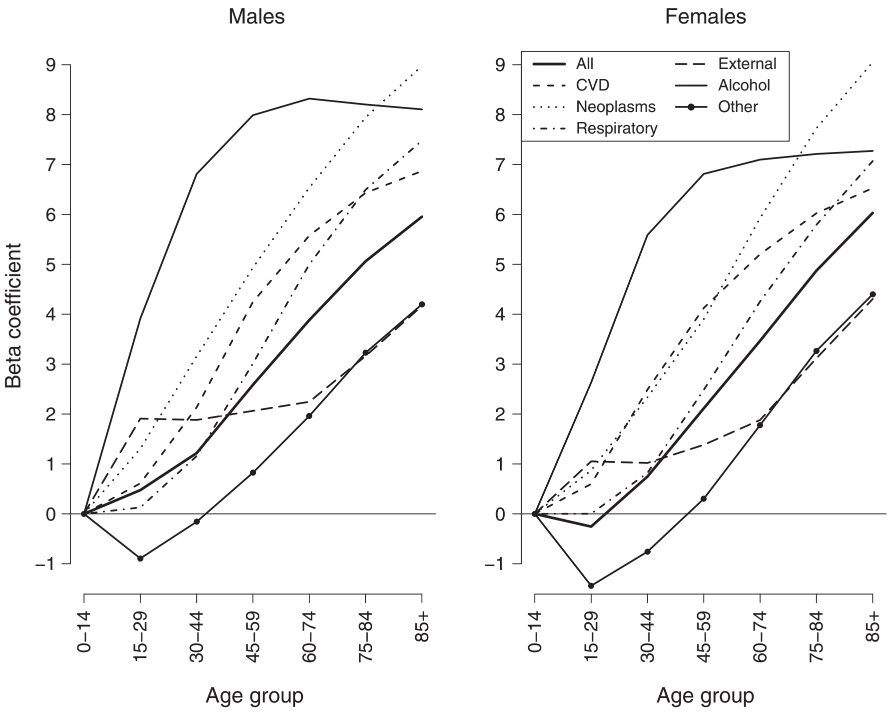

Fig. 3.12 Beta coefficients of cause-specific mortality by age group; 1991–2006 (age effect in Model 2: A + FS + T; reference age group 0–14) (Data source: Federal State Offices of Statistics, Germany)

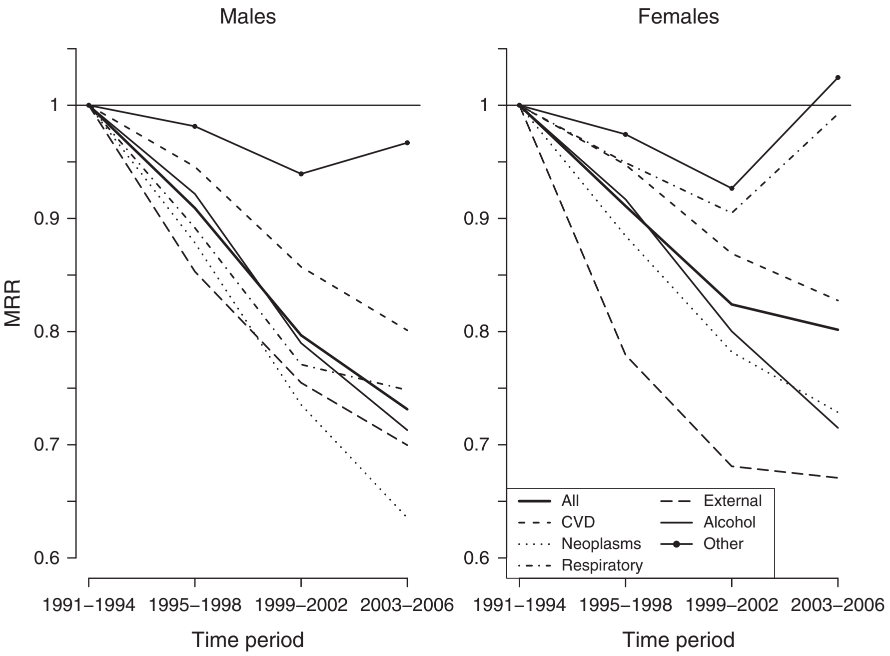

Fig. 3.13 MRR of cause-specific mortality by time period; 1991–2006 (time effect in Model 2: A + FS + T, reference time period 1991–1994) (Data source: Federal State Offices of Statistics, Germany)

these were achieved in almost all age groups. Only the youngest and the oldest age groups experienced smaller improvements.

In external and alcohol-related mortality, the temporal mortality improvements appeared to be similar across all age groups but a little more pronounced at ages under 30. In neoplasms, respiratory diseases, and other diseases, mortality improvements leveled off after ages 45 and above. Other-cause mortality and female respiratory mortality in age group 85+ increased from 1991–1994 to 2003–2006 (Table A.4 in the appendix). Among women, the negative mortality change from 1999–2002 to 2003–2006 in respiratory mortality at ages 85+ affected the overall time trend of respiratory mortality: it was higher in 2003–2006 than in all of the previous time periods (Fig. 3.13; Table A.4 in the appendix).

3.6.3 Cause-Specific Mortality by Federal States

Considerable differences in cause-specific mortality across federal states were found to exist. Table 3.5 (first row, MRR ratio for federal states) displays the mortality ratio between the federal states with the highest and the lowest mortality levels, which provides a rough overview of the existing disparities. These relative ranges of variation were shown to be the smallest for mortality from neoplasms and all-cause mortality. For men, they were also found to be small for respiratory diseases. Across the federal states, mortality differences were found to be the greatest for external, alcohol-related, and other-cause mortality. Absolute differences can differ substantially from the relative differences. For example, the number of deaths for men in 1991–1994 in the age group 85+ ranges from 102 to 175 deaths (per 1,000) from cardiovascular deaths but only from four to eight deaths from external causes.

Patterns of relative regional mortality variation also translate into the age- and state-specific mortality patterns. In all-cause mortality, the regional differences in mortality were the greatest in the age groups 15–29 and 30–44. This feature was especially pronounced for men. Regional variability decreased over age in respiratory mortality. In cardiovascular, external, and all-cause mortality, regional differences persisted into old age (Table 3.5, ratio for federal states in the A*FS interaction).

But what exactly do the regional cause-specific differences look like? A description of the cause-specific mortality patterns of each federal state would be confusing, given the number of cause-state combinations. As described in the methods chapter, a cluster analysis can help to overcome this problem. Federal states are therefore clustered based on their cause-specific MRR, excluding the all-cause category.[5]

Figure 3.14 (left panel, highlighted in gray) shows the results of the clustering of federal states according to cause-of-death structures. Within each cluster, the federal states are ranked according to all-cause mortality MRRs. Among men, there

[5] The underlying cause-specific mortality patterns for the federal states are shown in Figs. A.10 and A.11 in the appendix.

Table 3.5 MRR ratios of federal state with highest MRR and federal state with lowest MMR and constants in different Poisson models by cause-of-death group; 1991–2006

		All	Neoplasms	CVD	Respiratory	External	Alcohol	Other
Males								
FS		1.37	1.25	1.63	1.33	2.51	2.87	1.83
(Model 2: A+T+FS)	Constant	−7.55	−10.30	−11.11	−11.41	−9.29	−15.15	−7.91
Age	0–14	1.37	1.35	2.53	3.03	2.43	na	1.69
(Model 3a: A*FS+T)	15–29	1.89	1.49	1.77	1.87	2.84	8.31	3.29
	30–44	2.24	1.55	1.79	2.28	2.61	5.84	2.39
	45–59	1.67	1.36	1.73	1.83	2.87	3.16	2.67
	60–74	1.35	1.30	1.60	1.56	2.05	2.17	2.08
	75–84	1.24	1.19	1.58	1.39	2.23	1.51	1.94
	85+	1.33	1.26	1.72	1.58	2.78	1.77	2.12
	Constant	−7.54	−10.27	−10.95	−11.21	−9.44	−14.52	−7.98
Time	1991–1994	1.50	1.20	1.67	1.48	2.94	3.53	1.80
(Model 3b: A+T*FS)	1995–1998	1.37	1.23	1.66	1.42	2.72	3.43	1.97
	1999–2002	1.31	1.28	1.62	1.46	2.48	2.70	2.05
	2003–2006	1.32	1.31	1.55	1.93	1.84	2.40	1.72
	Constant	−7.45	−10.22	−11.16	−11.17	−9.14	−15.08	−7.70
Females								
FS		1.22	1.14	1.60	1.67	2.23	1.82	1.80
(Model 2: A+T+FS)	Constant	−7.78	−10.46	−11.27	−11.64	−9.59	−14.97	−8.03

(continued)

Table 3.5 (continued)

		All	Neoplasms	CVD	Respiratory	External	Alcohol	Other
Age	0–14	1.50	1.60	3.28	4.06	2.47	na	1.86
(Model 3a: A*FS+T)	15–29	1.47	1.38	1.80	2.34	2.43	4.18	2.27
	30–44	1.51	1.28	1.73	2.03	1.90	3.43	2.19
	45–59	1.36	1.25	1.63	1.96	2.02	2.24	2.14
	60–74	1.37	1.20	1.75	1.78	2.14	2.11	1.62
	75–84	1.27	1.12	1.69	1.65	2.73	1.70	1.73
	85+	1.21	1.30	1.51	2.00	4.36	2.14	2.22
	Constant	−7.78	−10.42	−11.16	−11.65	−9.79	−14.87	−8.16
Time	1991–1994	1.33	1.15	1.84	1.64	2.84	2.29	1.66
(Model 3b: A+T*FS)	1995–1998	1.22	1.15	1.66	1.97	2.70	1.99	2.19
	1999–2002	1.17	1.14	1.52	1.77	2.65	1.74	1.90
	2003–2006	1.19	1.20	1.42	2.43	2.19	1.59	1.94
	Constant	−7.67	−10.34	−11.33	−11.33	−9.48	−14.41	−7.82

Data source: Federal State Offices of Statistics, Germany
A Age group, *T* Time period, *FS* Federal state

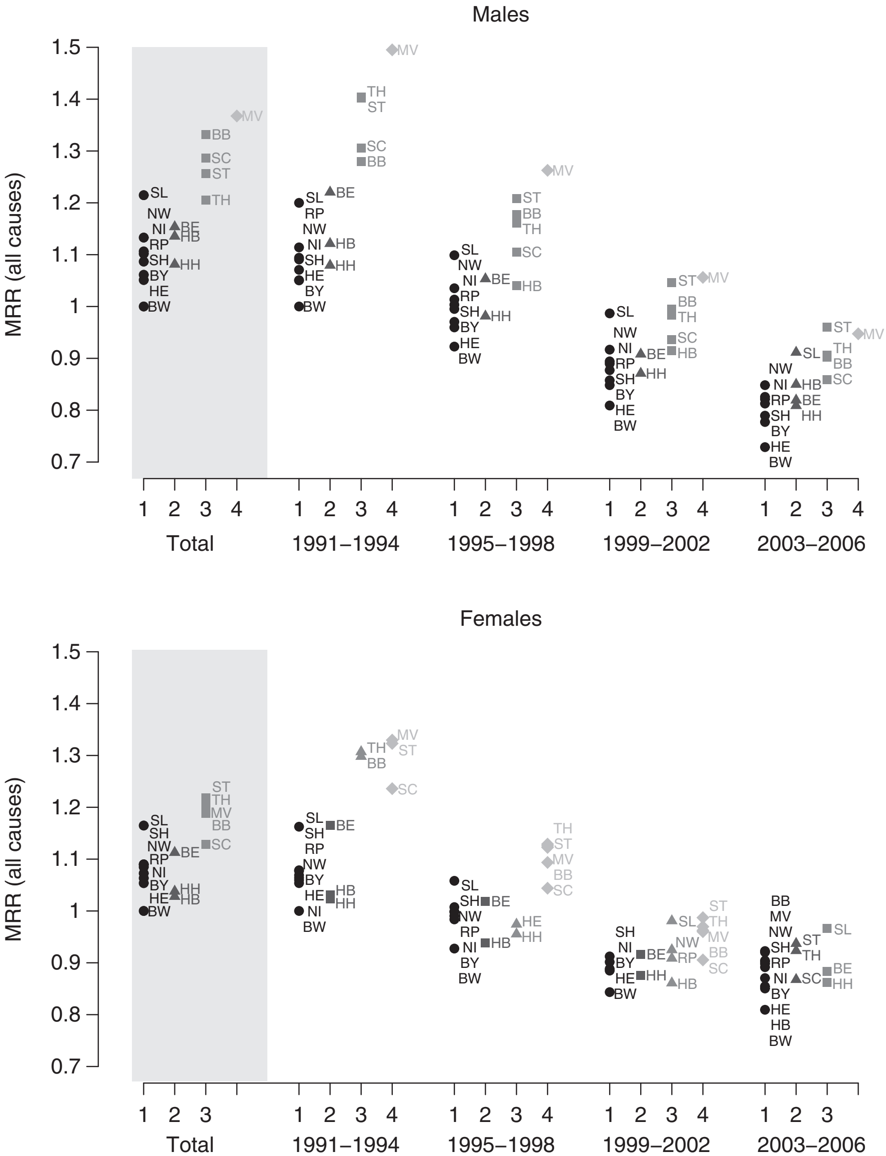

Fig. 3.14 Federal states clustered according to their cause-of-death structures by time period; plotted according to MRR in all-cause mortality; 1991–2006. Total (*highlighted in gray*): space effect from Model 2 clustered; time periods: time-space effect from Model 3c clustered. *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western Pomerania, *SN* Saxony, *ST* Saxony-Anhalt, *TH* Thuringia (Data source: Federal State Offices of Statistics, Germany)

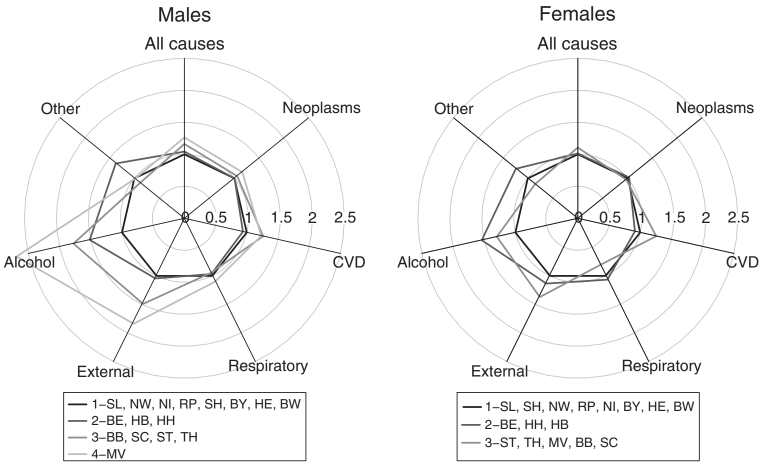

Fig. 3.15 MRR of federal state clusters by cause-of-death groups; 1991–2006 (model with A + T + cluster). *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western Pomerania, *SN* Saxony, *ST* Saxony-Anhalt, *TH* Thuringia (Data source: Federal State Offices of Statistics, Germany)

are four distinct clusters, whereby Mecklenburg-Western Pomerania constitutes its own cluster. Among women, there are three clusters. With the exception of Mecklenburg-Western Pomerania, the clusters are the same for both sexes.

Given the similarities in mortality levels and cause-of-death structures, all of the eastern German states fall into the same cluster, except for men in Mecklenburg-Western Pomerania. The three city-states—Berlin, Hamburg, and Bremen—constitute another cluster. The largest cluster consists of the remaining western German area-states.

Figure 3.15 shows the relative mortality performance for all causes and the cause-of-death groups compared to cluster 1, with the lowest all-cause mortality and consisting of the West German area-states (Figs. A.10 and A.11 in the appendix show the cause-specific results for all federal states).

The eastern German cluster is marked by high mortality in most causes of death. The exceptions are respiratory and other causes, where mixed evidence of low and medium mortality exists. Mecklenburg-Western Pomerania further stands out from this pattern among men, as it has by far the highest male mortality from both alcohol-related diseases and external causes.

The federal states in the city-state cluster generally have average and low mortality levels. While external mortality is low, the level of alcohol-related mortality and mortality from the residual causes is high. While it is at a medium level among men, respiratory mortality among women is high in the city-states. Among all of the federal states, Hamburg has the lowest cardiovascular mortality.

The western German area-states are marked by low to medium mortality. Due to low cardiovascular, cancer, and respiratory mortality, Baden-Württemberg holds the most favorable position in all-cause mortality. Saarland performs poorly, with high levels of cancer, cardiovascular, male respiratory, and other-cause mortality. Although all-cause mortality in this federal state is as high as in the eastern German cluster, the cause-of-death structure differs.

It was shown previously that life expectancy across federal states converged over time, even though the state ranking hardly changed. In the following, the spatial inequalities in cause-specific mortality are investigated, and the question of how the clustering of states according to their cause-of-death structures changes with time is explored.

For most causes of death, the ratio of mortality extremes (minimum and maximum) converges over time (Table 3.5). Decreasing regional variation is seen in all-cause mortality, while there are qualitatively similar inequalities in 1999–2002 and 2003–2006. This is determined by regional convergence in cardiovascular mortality and in external and alcohol-related mortality, and it is counteracted by the increasing regional inequality in neoplasms. Trends in respiratory and other causes of death are inconsistent. Stable regional inequalities from the late 1990s through the 2000s in all-cause mortality are consistent with the previous finding on the spatial inequality in life expectancy, as measured by the DMM (cf. Sect. 3.4.3).

In most federal states, mortality from most causes declines approximately proportionally to the overall cause-specific trends, as expressed by the time effect in Fig. 3.13. Respiratory causes are, however, an exception. The interaction between the federal state and the time period substantially improves the model fit for respiratory diseases (Model 3c in Table 3.4). It suggests that mortality dynamics strongly vary across federal states for this cause of death. Women were even found to have experienced increasing respiratory mortality from 1999–2002 to 2003–2006 (Fig. A.13 in the appendix).

In the next step, the clustering of federal states according to their cause-of-death structures was repeated for each of the four time periods. Figure 3.14 illustrates the clusters and changes in the cluster composition. Compared to the state clustering based on the overall trend, patterns remained stable among men but changed markedly among women.

Among men, the fourfold division into an eastern German cluster, a cluster of city-states, a cluster of western German area-states, and Mecklenburg-Western Pomerania as a separate cluster, is consistent over time. The only exceptions are in 1995–1998 and in 1999–2002, when Bremen falls out of the city-state cluster and falls into the eastern German cluster, and in 2003–2006, when Saarland falls into the city-state cluster. There is remarkably little change in the patterns of causes of death over time in spite of converging mortality levels, which lead to decreased spatial inequality. The description of cause-specific patterns can therefore be taken from the description of the clusters based on the overall mortality patterns (Fig. A.12 in the appendix).

Among women, marked differences in the cluster composition can be observed over time. Mortality levels across the federal states converged, but cause-specific mortality structures changed. This influences the clustering for each time period. Roughly, there is a cluster of West German area-states, a cluster containing the city-states, and a cluster of the eastern German federal states, with each remaining separate for each time period. However, there are exceptions. From 1991–1994 to 1999–2002, there are four clusters, and in 2003–2006, there are three clusters.

For 1991–1994, the eastern German federal states are split up into two clusters. One cluster is composed of Mecklenburg-Western Pomerania, Saxony-Anhalt, and Saxony, while the other cluster consists of Thuringia and Brandenburg. The latter cluster differs from the former in that it has higher respiratory mortality and lower external mortality. For 1995–1998, the cluster of city-states is separated into a cluster made up of Bremen and Berlin and another cluster consisting of Hamburg and Hesse. Hamburg and Hesse have very low cardiovascular mortality rates but the highest levels of external-cause mortality. Bremen and Berlin have low cardiovascular and low external mortality. For 1999–2002, the western German area-states are split up into two clusters, with the first containing Bremen, Rhineland-Palatinate, North Rhine-Westphalia, and Saarland and the second consisting of Lower Saxony, Hesse, Baden-Württemberg, Bavaria, and Schleswig-Holstein. The mortality differences are small between the clusters, but the second cluster, which has lower overall mortality than the first cluster, also has lower cardiovascular and alcohol-related mortality, but higher external mortality.

In the last time period, 2003–2006, previous structures of female cause-specific mortality dissolve, and only three clusters exist. Most western German area-states form one cluster, together with the city-state of Bremen and the East German states of Brandenburg and Mecklenburg-Western Pomerania. The city-states of Hamburg and Berlin and Saarland constitute another cluster. It is marked by high cancer, alcohol-related, and other mortality and by low cardiovascular (Hamburg and Berlin only) and external mortality (Berlin and Saarland only). In the eastern German cluster, Saxony, Thuringia, and Saxony-Anhalt are left with low cancer and respiratory mortality, but high cardiovascular mortality.

3.7 Summary

The aim of this chapter was to present regional mortality patterns at an aggregate level in East and West Germany and for the 16 federal states of the country. To this end, regional life expectancy trends were studied, summarized by a dispersion measure, and complemented by the analysis of lifespan disparity in the regions. An analysis of mortality by causes of death revealed underlying age and time trends of regional mortality.

West Germany has had higher life expectancy than East Germany since the mid-1970s, as it has achieved greater mortality declines at middle and old ages. Immediately after 1989–1990, life expectancy in East Germany decreased. The West German advantage over East Germany hence rose until 1990. However, during the 1990s, East Germany underwent strong mortality declines, particularly at old ages, leading to a narrowing of the East-West gap. For women, this gap had virtually disappeared by the mid-2000s.

Although life expectancy in the East and West German federal states followed the overall East and West German trends, respectively, there were also substantial regional peculiarities. For example, Saarland had low life expectancy from the West German perspective, and Saxony had high life expectancy from the East German perspective. Geographically, the southern part of West Germany (Baden-Württemberg, Bavaria, Hesse) was, with its high life expectancy, contrasted sharply with the northern part of eastern Germany (Mecklenburg-Western Pomerania, Saxony-Anhalt, Brandenburg), which had lower life expectancy. The greatest longevity gains were achieved by the East German federal states after reunification. Baden-Württemberg, the leading German federal state, experienced life expectancy levels that were close to those seen in countries with the world's lowest mortality. In general, the gains in life expectancy were higher in those federal states which had lower initial levels of life expectancy. These trends were leading to a convergence of life expectancy levels.

As a consequence of diverse state-specific life expectancy trends over time, dispersion across the federal states had also changed. Dispersion in life expectancy across the German federal states, measured here as the average interstate difference in life expectancy, was at its highest levels shortly after reunification. A steep decrease had occurred by the late 1990s. Afterward, regional dispersion across all of German states increased slightly. Within West Germany, dispersion was roughly constant but increased slightly after the late 1990s. High levels of dispersion in male life expectancy, initially prevailing in East Germany, fell during the 1990s. Female dispersion of life expectancy in East Germany remained stable at a lower level.

Usually—and this was the case for West Germany—lifespan disparity decreases as life expectancy increases. Lifespan disparity as a measure of interindividual health inequality within populations complemented the analysis of life expectancy and revealed substantial differences between the two parts of Germany. At the same life expectancy levels, East and West Germany experienced similar values of lifespan disparity until the late 1960s. From then until 1989, East Germany deviated toward lower lifespan disparity. During the reunification period, East Germany adjusted to higher West German levels. Lower inequality was the result of relatively lower mortality at younger ages, but higher mortality at older ages in the East relative to the West. Finally, the disparity levels in the two parts of Germany drew closer due to the accelerated mortality decrease at older ages, despite the fact that excess East German mortality had previously prevailed. Men in East Germany experienced somewhat higher levels of lifespan disparity than their West German counterparts following reunification due to excess mortality among young adults.

Unexpectedly, lifespan disparity trends in the East and West German federal states did not reveal a clear East and West German division. Comparing lifespan disparity at the same life expectancy level suggested that the city-states experienced relatively high levels lifespan disparity. In addition, men in Mecklenburg-Western Pomerania and women in Lower Saxony exhibited unfavorable age-specific mortality profiles, leading to high levels of lifespan disparity. The federal states which experienced low levels of lifespan disparity were North Rhine-Westphalia, Rhineland-Palatinate, and Thuringia among men and the East German states (except

Berlin) among women. This pattern has been stable over time, in spite of the increasing average length of life. In federal states with low levels of lifespan disparity, deaths were centered around the mean age of death. High-disparity states were characterized by higher mortality among middle-aged adults, coupled with lower mortality at very old ages.

The cause-specific mortality trends underlying these patterns of general mortality in the federal states have been spatially diverse. The greatest relative regional differences were found in external and in alcohol-related mortality, while these differences were smallest for neoplasms. Regional variation in all-cause mortality was found to be smaller than in most of the cause-of-death groups, reflecting the diversity in cause-of-death patterns across the federal states. While, for example, North Rhine-Westphalia held a medium position in the all-cause mortality and in many cause-of-death groups, it had the lowest level of mortality from external causes among all of the federal states.

As the spatial patterns by cause-of-death mortality were very diverse, a cluster analysis was performed in order to group federal states with similar cause-of-death structures. Three main clusters were identified: the first cluster contained the West German area-states (mostly low mortality), the second cluster consisted of the city-states (medium mortality in most causes of death, high alcohol-related, and other-cause mortality), and the third cluster was composed of the eastern German states (high mortality in most causes, low other-cause mortality). Among men, Mecklenburg-Western Pomerania constituted a single cluster. While the clustering was very stable over time for men, the clustering was more dynamic for women. The clusters of city-states and of eastern German states, which had been consistently found among men, did not persist. This demonstrates a convergence of eastern German female cause-of-death structures to western German structures.

3.8 Discussion

The interpretation of these results must take into account the shortcomings of the data. They are related to different definitions of live births in the FRG and GDR, an overestimation of the old-age population, and regionally varying cause-of-death coding practices.

Infant mortality in the GDR was found to be lower than in the FRG from the late 1960s through the late 1970s. Questions have arisen as to whether this finding is biased by differences in infant death registration. However, there is indeed evidence for excess infant mortality in the FRG in the 1960s and 1970s relative to other industrialized countries. It appears that the quality of the GDR health care system declined starting in the 1970s (Diehl 2008; Nolte et al. 2000a; Thara 1997). As a result, the finding that infant mortality levels were lower in the GDR than in the FRG in the aforementioned time period is likely to be based in reality.

In Germany, the population at old ages appears to be overestimated. This is especially the case for West German men, and the problem appears to have grown worse since the last census (Human Mortality Database 2008a; Jdanov et al. 2005; Kibele et al. 2008; Scholz and Jdanov 2007). Fortunately, life expectancy at birth is little affected by this error. However, lifespan disparity is more sensitive to mortality at high ages. Calculations of lifespan disparity are therefore restricted to the age range (0–90) years. Given the high correlations between ${}_{90}e_0^{\dagger}$, e_0, and ${}_{90}e_0$, conclusions are likely to be transferable to the overall lifespan.

There are some regional variations in the cause-of-death coding (Schelhase and Weber 2007), which are reflected, for example, in the share of deaths coded as ill-defined deaths. This in turn affects the distribution of deaths in all other cause-of-death groups. In order to obtain reliable results, a remainder category with all causes not attributable to any of the selected categories was built and incorporated into the analyses. Hence, all death counts are considered. Dealing with broad cause-of-death groups minimizes potential coding bias.

It is remarkable that life expectancy in East Germany converged to such an extent with West German longevity within a short period of time after reunification. This fact was stressed in earlier studies (Diehl 2008; Gjonça et al. 2000; Kibele and Scholz 2008; Vaupel et al. 2003). The current study suggests, however, that the East-West convergence had begun to level off by the late 1990s. In addition, the regional dispersion across the federal states did not decrease further after the late 1990s. Similarly, an economic convergence between East and West was seen until the late 1990s and was followed by a leveling off (Razum et al. 2008). West and East German trends of initial mortality divergence and subsequent convergence were also observed between Western and Eastern Europe in general (Vallin and Meslé 2004).

The results on regional dispersion in the past raise the question of the future development of regional dispersion. Even though regional dispersion of life expectancy appears to be constant, and the East-West convergence seems to have stopped, disparities other than the East-West divide may become more apparent. For example, within western Germany, Saarland may fall farther behind, and Hamburg may continue to improve at a fast pace. Meanwhile, Saxony may continue to be the leading federal state in eastern Germany.

Mortality reduction among people aged 60+ was one of the main reasons why West Germans initially had a life expectancy advantage over East Germans. At the same time, East Germany experienced lower lifespan disparity at the same levels of average longevity, a common pattern for Eastern European countries (Smits and Monden 2009, online material). As East Germany was successful in reducing old-age mortality after reunification, this led to steep life expectancy increases during the 1990s. However, reductions in old-age mortality also led to increased levels of lifespan disparity. Among men, excess mortality in young adults may have also contributed to this trend.

Lifespan disparity is a new dimension of inequality, and it has not been previously addressed in any study of regional mortality in Germany. An advantage of the measure of lifespan disparity $e^{\dagger}$ applied here over other disparity measures (e.g., S_{10}, IQR) is that it incorporates the entire age range. Analyses revealed important contributions at both tails of the age distribution to the dynamics and regional variation of this measure. What is advantageous in terms of overall population health—declining mortality rates—is not always advantageous in terms of health equity. Therefore, it makes sense to analyze life expectancy in conjunction with lifespan disparity. In order to achieve both greater population health and greater health equality, it may be advisable to focus first on the reduction of early deaths, especially in eastern Germany. This suggests that a more "efficient" strategy for age-specific mortality reductions could be needed in the future.

Regional cause-of-death structures are marked by considerable variety. Regional clusters are mainly determined by causes which exhibit greater regional variation, such as alcohol-related and external causes of death. Although these causes constitute a minor share of all deaths, they seriously influenced the regional clustering by cause-of-death structures. However, it is reasonable to assume that this does not bias the results but rather reflects the features of the federal states (cf. Shelton et al. 2006).

Whereas the patterns among men change little over time, there are marked changes in the female cause-of-death patterns. This is likely to continue in the future, as, for example, the smoking habits of women become more similar to male patterns but also differ by region (Helmert and Buitkamp 2004; Völzke et al. 2006). In the future, it can be expected that these trends will be reflected in cause-specific mortality differentials, such as in lung cancer, as well as in respiratory and cardiovascular mortality.

As many causes show a social gradient (Erikson and Torssander 2008; Kunst et al. 1998; Saurel-Cubizolles et al. 2009), it is likely that the observed regional mortality variation is related to socioeconomic and other mortality-determining factors.

As there is heterogeneity within the federal states in respect to population structures, life conditions, and health, the analyses will be extended by the forthcoming small-area analyses.