Chapter 4
Mortality Differentials Across Germany's Districts

4.1 Introduction

Having assessed the overall, as well as cause-specific, mortality trends in East and West Germany and the German federal states, this chapter explores small-area mortality differentials in Germany and their determinants. First, the data and methods used in this chapter are described. Life expectancy variation across the 438 German districts is then described, and the changes in the spatial patterning and dispersion over time are investigated (Sect. 4.4). Next, the underlying cause-of-death structures are analyzed (Sect. 4.5). Districts with similar mortality patterns are then aggregated into functional regions, and the life expectancy and cause-specific mortality patterns of these regions are analyzed (Sects. 4.6 and 4.7). Finally, determinants of regional life expectancy patterns and trends are examined by means of a pooled cross-sectional time series analysis (Sect. 4.8).

4.2 Data

Several data issues should be noted before the analyses of small-area mortality differentials are discussed. The following sections explain the administrative structure of small areas in Germany and consider problems related to territorial changes. The territorial structure and its changes determine the data availability and the comparability of regions over time. Data availability is listed for population and death counts, cause-of-death statistics, and contextual variables.

E.U.B. Kibele, *Regional Mortality Differences in Germany*, Demographic Research Monographs, DOI 10.1007/978-94-007-4432-5_4,

Table 4.1 Mean, minimum, and maximum values of population size, area, and population density of NUTS-3 regions (districts) in Germany; 2005

	Mean	Minimum	Maximum
Population size in 1,000	188.2	35.2 (SKR Zweibrücken)	3,395.2 (SKR Berlin)
Area in km^2	815.2	35.7 (SKR Schweinfurt)	3,058.1 (LKR Uckermark)
Population density (population per km^2)	508.4	39.4 (LKR Müritz)	4,058.2 (SKR München)

Data source: Genesis online, accessed on October 24, 2008

4.2.1 Regions and Territorial Changes

4.2.1.1 Administrative Regions

The small-area analyses will be based on the administrative level of *Kreise* (districts), which refers to level 3 of the Nomenclature of Statistical Territorial Units (NUTS). In this hierarchy, as established by Eurostat, the countries are at NUTS-0 level, the German federal states are at NUTS-1 level, and the *Regierungsbezirke* are at the NUTS-2 level. According to Eurostat guidelines, NUTS-3 regions should have populations of between 150,000 and 800,000 (European Communities 2007). With populations ranging from 35,000 to 3.4 million, some districts in Germany are above or below the NUTS-3 level (Table 4.1).

In Germany, a number of services of the public utility infrastructure are organized at the subnational levels. At the district level, for example, services including portions of the health care and educational systems, waste disposal, rescue, child care, and social housing are organized.

As of December 31, 2006, there were 16 federal states (NUTS-1), 41 *Regierungsbezirke* (NUTS-2), and 439 districts (NUTS-3) in Germany (European Communities 2007). Those 439 districts are either urban districts (*kreisfreie Städte*, usually larger cities) or rural districts (*Landkreise*, usually smaller cities and surrounding communities combined). Figure 4.1 shows a map of Germany with the administrative borders for the three different levels.

In the GDR, from 1952 to 1990, the regions were divided into 14 *Bezirke* (plus Berlin), which were further divided into *Stadtkreise*, or urban districts, and *Landkreise*, or rural districts. After German reunification in 1990, the *Bezirke* were dissolved, and the federal states, which were created after World War II, were reestablished with minor changes. As in the western German federal states, the *kreisfreie Städte* and *Landkreise* in eastern Germany are subordinated.

Districts widely vary in terms of area, population size, and population density. Table 4.1 gives an overview of these basic features.

Other area classifications also exist, such as the 97 *Raumordnungsregionen,* or the 348 Microcensus regions (Bundesamt für Bauwesen und Raumordnung 2004; raumbeobachtung.de). However, these classifications constitute an aggregation of NUTS-3 regions, and this aggregation of units leads to a loss of information.

Fig. 4.1 Administrative borders of NUTS-1, NUTS-2, and NUTS-3 regions in Germany, as of January 1, 2004: NUTS-1: *Land* (federal state), NUTS-2: *Regierungsbezirk*, NUTS-3: *Kreisfreie Stadt* (urban district), *Kreis* (rural district). Note: Eisenach and Wartburgkreis are treated as one unit (Source: Easystat/Statistische Ämter des Bundes und der Länder (Eds.) 2005)

When conducting small-area mortality analyses, it is necessary to consider the population numbers and death counts in a region. The use of a more detailed classification of German regions than districts, such as the municipalities, is not appropriate. In addition to the problems that arise from limited data availability, the population size within the municipalities varies considerably, and some have fewer than ten inhabitants.

4.2.1.2 Territorial Structure and Changes

The aim of this section is to shed light on the territorial changes of administrative regions in Germany and their consequences for the availability of comparable data and analyses. For the subsequent mortality analysis, a detailed geographical resolution into districts, as mentioned above, is undertaken. Over time, territorial changes within German federal states were made, mainly to enhance the size of districts and to reduce administrative burdens (Table 4.2).

With the exception of Lower Saxony, all territorial changes (*Kreisreformen*) in West Germany took place before 1980, and therefore do not affect the period of observation in this study. In Lower Saxony in 2001, the urban and rural districts of Hannover were merged. This region of Hannover is used for all analyses in order to achieve comparability over time. Changes in the names of two districts in Rhineland-Palatinate did not involve any territorial change.

The transformation of GDR *Bezirke* into FRG federal states and subordinated districts involved territorial changes of small areas. This mainly took place between the mid- and late 1990s, and extended over several years in Saxony. In practical terms, such territorial changes of districts impeded the comparison of district features over time. Most data incorporated on the territory of the former GDR are, however, available according to different territorial structures. To ensure comparability over time, this study uses data based on the structure that was in place as of December 31, 2006. In 1998, the Thuringian district of Wartburgkreis was split up into the city of Eisenach (urban district) and the remaining part of Wartburgkreis (rural district). Since this distinction is not available for earlier years, these two districts are treated as one. This yields 438 districts as spatial units of observation.

4.2.2 Data Availability for Small-Area Analyses

4.2.2.1 Population and Death Counts

Data availability for the districts of population and death counts differ by federal state and by time period. The data collection for small areas is organized by the Federal State Offices of Statistics. Table 4.2 gives an overview of data availability according to the highest reported age group (75 years and above, or 90 years and above). Data could be obtained by 1-year age groups (with 90 and above being the highest age group for all districts) from 1992 onward for death counts, and from 1994

Table 4.2 Data availability of population as of December 31, and death counts by federal state

Federal state	# districts in 2006	Territorial changes 1980–2006	Population 75+	Population 90+	Death counts 75+	Death counts 90+
Schleswig-Holstein	15	–	1987–1993	1979–1986; 1994+		1980+
Hamburg	1	–		1979+		1980+
Lower Saxony[a]	46	2001	1979+	1994+	1980+	1992+
Bremen	2	–		1979+		1980+
North Rhine-Westphalia[b]	54	(2009)		1979+		1980+
Hesse	26	–		1979+	1980+	1985+
Rhineland-Palatinate	36	–	1979+	1994+	1980+	
Baden-Württemberg	44	–		1979+		1980+
Bavaria	96	–	1983+	1994+	1983+	1992+
Saarland	6	–		1979+	1980+	
Berlin	1	2001		1979+		1980+
Berlin West[c]		2001		1979–2004		1980–2004
Berlin East[c]		2001		1979–2004		1980–2004
Brandenburg	18	1993		1981+		1980+
Mecklenburg-Western Pomerania	18	1994		1981+		1980+
Saxony	29	1994/1996; (2008)	1982+	1994+		1980+
Saxony-Anhalt	24	1994; (2007)		1981+		1990+
Thuringia[d]	23	1994, 1998		1981+		1980+
$\sum$	439					

[a] Region Hannover is used throughout the entire observation period

[b] Due to municipal boundary modifications in 1976, the age structure at the municipal level was estimated until 1986; this leads to a discrepancy between the population sums of the districts and the federal states before 1987

[c] Making a distinction between East and West Berlin was no longer possible after 2001, but it was recalculated until 2004 by R. Scholz

[d] Eisenach and Wartburgkreis manually merged; only 22 districts used

onward for population as of the end of the year. In earlier years, some federal states only provided data by 5-year age groups. Mid-year population of year t is derived as the mean of year t and year $t-1$.

The quality of the population denominator at very old ages in Germany is questionable (Human Mortality Database 2008a; Jdanov et al. 2005). It is not clear how this is reflected on the small-area scale. Both data issues are largely minimized, as the maps are based on quintiles of districts, and other analyses deal mainly with aggregated regions.

To ensure complete data availability for districts in all federal states, analyses in subsequent sections focus on the period 1995–2006.

4.2.2.2 Causes of Death

The cause-of-death statistics by district are available via the Research Data Centers of the Federal Statistical Office and the Federal State Offices of Statistics in Germany for the years 1992 onward. Unlike the above-mentioned population statistics, the cause-of-death statistics are only available according to the territorial structure of the *respective* year, that is, the cause-of-death statistics of the year 1995 are available according to territorial structure in 1995, and are therefore not fully comparable to the 1996 data. This limits the analysis of small-area cause-specific mortality over time. Full comparisons of the 438 districts are possible for the period from 1996 to 2006.

Causes of death were originally coded using four-digit WHO codes and have been recoded into broader groups of causes (Table A.2).

4.2.2.3 Contextual Variables

Many contextual factors are available from 1995 onward. These contextual factors are likely to be associated with mortality trends, as described in the literature review in Chap. 2. Due to changes in the definition of factors, some variables are only available for certain time periods. Table 4.3 gives an overview of the years for which data are available for each indicator.[1]

It would have been desirable to obtain an index of income inequality (e.g., Gini index). Tax data are published for 13 income groups, which could theoretically be used to calculate the index. However, these groups are broad, and people with income not liable to income tax are not included. Furthermore, data are available for 2 years only (and for 1 year only for some federal states).

[1] The territorial changes in Saxony-Anhalt in 2007 took place after the current period of interest. However, they still affect the data availability for earlier years as data are calculated by the Federal State Offices of Statistics with a time lag. Several contextual factors of the year 2006 were formatted to the 2007 boundaries. Data on GDP and household income for the year 2006 were available only according to the 2007 district structure. Therefore, data were extrapolated according to trends from 1995 to 2005. The values were then adjusted so that the sum of district values adds up to the federal state value of Saxony-Anhalt. Districts not affected by the territorial changes are Altmarkkreis Salzwedel, LKR Stendal, Stadt Magdeburg, and Stadt Halle (Saale).

Table 4.3 Data availability of district-level context factors (incomplete data on other variables); 1995–2006

Variable	Year 95	96	97	98	99	00	01	02	03	04	05	06	Data source
Economy													
Unemployment rate [a]		X	X	X	X	X	X	X	X	X	X	X	A
Income p.c. in Euro [b]	X	X	X	X	X	X	X	X	X	X	X	X	B
GDP p.c. in Euro	X	X	X	X	X	X	X	X	X	X	X	X	B
% employed				X	X	X	X	X	X	X	X	X	B
% employed sec. sector [c]		X	X	X	X	X	X	X	X	X			B
% employed tert. sector [c]		X	X	X	X	X	X	X	X	X			B
Private indebtedness [d]									X	X	X	X	C
Net business registrations*				X	X	X	X	X	X	X	X	X	B
Social conditions													
Voter turnout [e]	94			X				X			X		B
Living space p.c. in m^2	X	X	X	X	X	X	X	X	X	X	X	X	B
Detached housing [f]	X	X	X	X	X	X	X	X	X	X	X	X	B
Divorce rate*		X	X	X	X	X	X	X	X	X	X	X	D
Welfare recipients[g]**		X	X	X	X	X	X	X	X	X			B
Education													
% empl. w university degree					X	X	X	X	X	X	X	X	B
% empl. w/o degree					X	X	X	X	X	X	X	X	B
% school graduates w *Abitur*	X	X	X	X	X	X	X	X	X	X	X	X	B
% school graduates w/o degree	X	X	X	X	X	X	X	X	X	X	X	X	B
Population													
% annual population change		X	X	X	X	X	X	X	X	X	X	X	E
% foreigners	X	X	X	X	X	X	X	X	X	X	X	X	B
Net migration***	X	X	X	X	X	X	X	X	X	X	X	X	B

(continued)

Table 4.3 (continued)

Variable	Year 95	96	97	98	99	00	01	02	03	04	05	06	Data source
Population density[h]	X	X	X	X	X	X	X	X	X	X	X	X	B
Urban vs. rural district	X	X	X	X	X	X	X	X	X	X	X	X	B
Population forecast 2010[i]								X					F
Population forecast 2020[i]								X					F
Health care and traffic accidents													
Hospital beds***	X	X	X	X	X	X	X	X	X	X	X		B
Physicians*	X	X	X	X		X	X	X	X	X	X		B
Traffic accidents*	X	X	X	X	X	X	X	X	X	X	X	X	B
Fatal traffic accidents[j]	X	X	X	X	X	X	X	X	X	X	X	X	B
Health care[k]		X	X	X	X	X	X	X	X	X	X	X	G
Health behavior[k]		X	X	X	X	X	X	X	X	X	X	X	G
Health policy[k]		X	X	X	X	X	X	X	X	X	X	X	G

Data sources: A—Bundesagentur für Arbeit; B—Regionaldatenbank Deutschland; C—Schufa Holding AG; D—Deutsches Jugendinstitut, Regionaldatenbank; E—Federal State Offices of Statistics, Germany; F—INKAR; G—Research Data Center of the Federal Statistical Office and the Federal State Offices of Statistics, Germany

Notes: Employed refers to employed in jobs liable to social insurance contributions; p.c.—per capita; *Abitur*—diploma from German secondary school qualifying for university admission

*per 100,000; **per 10,000; ***per 1,000 of population

[a] Registered unemployed relative to population in dependent employment

[b] Mean disposable household income

[c] Relative to all employed

[d] See Schufa Holding AG (2006, p. 70 ff.)

[e] In Bundestag elections, relative to population, eligible to vote

[f] As share of all residential buildings

[g] Data available for 2005–2006, but change in definition makes data incomparable

[h] Population per km^2

[i] Population relative to base year 2002

[j] Per 100,000 traffic accidents

[k] Percentage of deaths in age range 0–74 years considered amenable to health care/behavior/policy; sex-specific; see Sect. 5.8.2 for calculation of the indicator

4.3 Methods

This section deals with the methods applied throughout the chapter. The basic methods were described in Sect. 3.3.

4.3.1 Basic Methods

As most of the 438 German districts are small regional units, annual mortality shows random variation in time trends, especially due to the small numbers of deaths at younger ages. Data are therefore pooled over 3-year periods, unless otherwise indicated. Confidence intervals of life expectancy were calculated according to the Chiang method (Chiang 1984). Standard errors were less than 1% of life expectancy, largely depending on the district's population size (Fig. B.5 in the appendix). They were therefore not incorporated into the analyses. The direct age-standardization of death rates into standardized death rates (SDR) uses the European Standard Population as a population standard (WHO 1976). Age- and cause-specific decomposition of life expectancy is based on the methodology presented by Andreev et al. (2002). The dispersion measure of mortality, which was introduced in the previous chapter, is now applied to life expectancy in the 438 districts, instead of the federal states. E. Andreev provided a VBA Microsoft Excel macro for the age-specific decomposition of the dispersion measures of mortality, which is also based on Andreev et al. (2002).

4.3.2 Spatial Data Analysis

Maps are based on the data classification into quintiles, unless otherwise indicated (see Brewer and Pickle 2002; James et al. 2004 for the advantages and disadvantages of a quintile classification). For the interpretation of the spatial patterns, it must be taken into account that the boundaries of the life expectancy classes change over time, and that, due to quintile classification, districts in two neighboring classes can have more similar values than districts within one cluster.

The visual inspection of mortality patterns across districts can be complemented by an exploratory spatial analysis (James et al. 2004). These methods provide objective measures of the extent to which mortality is clustered spatially.

The Moran's I is a measure of global spatial autocorrelation (Wakefield et al. 2000). This indicator compares the spatial distribution of life expectancy in space to a complete random distribution of this variable. Moran's I usually ranges between -1 and 1 but is not bound to this range (Queste 2007; Wakefield et al. 2000). This indicator provides information about the presence of spatial autocorrelation. It is a global measure, and does not indicate the location where the spatial autocorrelation occurs. For this purpose, a local indicator of spatial autocorrelation, the Local Moran's I, is used to indicate the presence of local spots of autocorrelation (Anselin 1995; Hanson and Wieczorek 2002; Rosenberg et al. 1999).

Positive spatial autocorrelation exists if districts with high life expectancy are next to districts with high life expectancy, or if districts with low life expectancy border other districts with low life expectancy. Negative spatial autocorrelation therefore exists if districts with high life expectancy are surrounded by districts with low life expectancy (and vice versa).

Both Moran's I and Local Moran's I require the definition of neighborhood structures, given by the spatial weights matrix. A spatial weights matrix in which the neighborhood structure is defined by the distance of the district centroid to other districts is used. This distance is set as a 23.4 km radius from the district's center, which ensures that each district has at least one neighbor.

The formula for the Moran's I (Anselin 1995; Wakefield et al. 2000) is

$$I = \frac{N\sum_i \sum_j W_{ij}(Z_i - Z)(Z_j - Z)}{\left(\sum_i \sum_j W_{ij}\right)\sum_k (Z_k - Z)^2} \tag{4.1}$$

where $N = 438$, the number of districts, and Z is the variable of interest (here: life expectancy), and W_{ij} represents the spatial proximity of districts i and j, which is given by the spatial weights matrix. The expected value of I is $E(I) = -1/(N-1)$.

Local Moran's I (Anselin 1995) for a district i is defined as

$$I_i = \left(Z_i - \bar{Z}\right)\sum_j W_{ij}\left(Z_j - \bar{Z}\right) \tag{4.2}$$

The mean of the Local Moran's I summed over all districts i hence constitutes the (global) Moran's I. The local indicator of spatial autocorrelation can be both positive and negative.[2]

The base map was provided by German Federal Agency for Cartography and Geodesy (2007). S. Klüsener adjusted the base map so that the two Thuringian districts of Eisenach and Wartburgkreis form only one district.

[2] Calculations for Moran's I and Local Moran's I were also executed with a spatial weights matrix based on spatial contiguity, that is, districts are defined as neighbors if they share a common border. Depending on the definition of the spatial weights matrix, Moran's I values differ in level, but the qualitative trend is the same. Results for the Local Moran's I differ in that contiguous regions with many small-area districts – particularly the Ruhr area – reveal more districts with significant spatial autocorrelation under the distance-based spatial weights definition.

4.3.3 Random-Coefficient Model for Time Trends in Life Expectancy by District

In order to study the many regularities in the life expectancy increases across districts, it seems sensible to derive a pooled cross-sectional time-series model (panel model) that expresses features of the life expectancy differences between districts and simultaneously over time (Baltagi 2008).

Several covariates are included as predictors of the life expectancy changes:

1. Year varying from 1995 to 2006 (coded as 1–12): annual increase(x_1)
2. Year^2: quadratic term of annual increase (x_1^2)
3. Dummy variable = 1 for districts in East Germany (0 for West Germany) (x_2)
4. Dummy variable = 1 for urban districts (0 for rural districts) (x_3)

These variables enter the model as main effects, and in interactions and under different model specifications (i.e., random-intercept or random-coefficient model). All models were fitted separately for men and women. The model that yielded the best model fit—indicated by the lowest log likelihood—is presented here. Models were evaluated and compared to each other by means of likelihood ratio tests, which take into account the number of parameters used.

A simple model would estimate the increase in life expectancy across districts as a linear function of time, whereby each district is assigned a different intercept (random-intercept model). This model can be extended with a random coefficient in respect to time, which allows for differences in the pace of district-specific life expectancy increases (Rabe-Hesketh and Skrondal 2005).

In preliminary analyses, several combinations of the variables were tested in both random-intercept and random-coefficient models. In general, the random-coefficient model was found to provide a better fit (results not shown).

The final model is of the following form:

$$\begin{aligned} e_{0it} &= \beta_0 + \beta_{1\mathrm{W}} x_{1it} + \beta_{1\mathrm{E}} x_{1it} + \beta_{2\mathrm{W}} x_{1it}^2 + \beta_{2\mathrm{E}} x_{1it}^2 \\ &\quad + \beta_3 x_{2it} + \zeta_{1i} + \zeta_{2\mathrm{W}i} x_{1it} + \zeta_{2\mathrm{E}i} x_{1it} + \varepsilon_{it} \end{aligned} \tag{4.3}$$

It is a random-coefficient model in which a random intercept is estimated for each district i (ζ_{1i}), and which also includes random coefficients ($\zeta_{2\mathrm{W}i}$, $\zeta_{2\mathrm{E}i}$) that estimate different slopes (i.e., life expectancy increases) for each district. The error term over i and t is denoted by ε_{it} (Rabe-Hesketh and Skrondal 2005). Underscores E and W denote the coefficients for East and West Germany, respectively. The random parts are not directly estimated but are rather summarized by standard deviations.

The inclusion of a dummy variable for urban districts did not alter the model fit significantly, as was shown by a likelihood ratio test. Fitted life expectancy values for each district in every year were obtained by post-estimation. This pooled cross-sectional time series approach levels out the observed random fluctuation in annual life expectancy at the district level.

4.3.4 K-Means Clustering of Districts

A clustering of regions is intended to provide a regional classification of clusters with similar mortality experiences. The clustering of districts is based on life expectancy and the change of life expectancy over time of the 438 German districts for the period 1995 to 2006 (the mean life expectancy from 1995 to 2006, and the mean of annual life expectancy changes over the period 1995–2006, both for men and women). These four variables were z-standardized with a mean of 0 and a standard deviation of 1 before clustering.

The clustering procedure aims at identifying clusters that are the most different from each other, while, at the same time, containing the most homogeneous sets of districts within clusters. K-means clustering, which is a partition cluster method, was applied to the district-level data of the four variables. Thus, the districts are to be classified according to both levels and trends in life expectancy for males and females.

Before K-means clustering can be performed, the number k of desired clusters must be indicated. Values of k varying from 2 to 9 are considered. Initially, cluster centers are defined based on a randomly chosen initial partition of districts into k clusters. Then, districts are swapped between clusters and the cluster centers are recalculated. This reassignment is performed until the convergence criterion is met, that is, until there is little or no more change between the clusters, or there is little or no decrease in the squared error (Jain et al. 1999). The Euclidean distance is implemented as a similarity measure. As the initial cluster centers are defined randomly, the final clustering could differ. The cluster iteration was run 75,000 times to produce stable results for the optimal cluster partition.

The optimal partition into clusters is determined by a low value of SS_{within} and a high value of F-max. SS_{within} is the pooled within-cluster variance, which is the sum of the squared difference between the cluster variables' values, and the value of the cluster center for that respective variable. SS_{within} naturally decreases as k increases. It is summed over all cases (here: districts), and then over all cluster variables. Naturally, the more clusters k that are defined, the more simulation rounds that are needed in order to find a stable optimum solution.

Another index derived in the cluster procedure is the Calinski and Harabasz F-max (or pseudo-F index). A higher value of this index indicates a more distinct clustering, and hence a better solution. A low value of SS_{within} assures homogeneity within the clusters, and relates to a high F-max value (Rabe-Hesketh and Everitt 2004).

The selection of the optimal number of clusters is based on the optimum corresponding to low SS_{within} and high F-max in the 75,000 iteration rounds for each cluster number $k = 2, \ldots, 9$. The optimal number of clusters is where the clustering is distinct (high F-max) and the average distance of a district's value to the cluster center is low. The optimal number of clusters based on a low SS_{within} can be determined by the "elbow knick" (Bacher 1996), that is, until the transition where an additional cluster no longer yields a substantial reduction of SS_{within}.

The obtained clusters are compared in terms of their socioeconomic characteristics. The age- and cause-specific decomposition of differences in life expectancy between clusters is subsequently performed (Andreev et al. 2002).

4.3.5 Pooled Cross-Sectional Time Series Analysis

The clustering of spatial units in time is taken into account, and a cross-sectional time series analysis is performed in order to identify the determinants that explain the spatial pattern and the temporal changes of life expectancy across the districts. Three different models are applied in order to explain life expectancy differences between districts, over time, and simultaneously between districts and over time.

These three models are now described. The between-effects model (BE-model) averages all district-level values over time t and is therefore able to explain differences in the dependent variable from one unit i (here: district) to another, regardless of temporal developments:

$$\overline{e_{0i}} = \alpha_i + \sum_{k=1}^{K} \beta_k \overline{x}_{ki} + \overline{\varepsilon}_i \tag{4.4}$$

where α_i is the district-specific constant, k is the number of explanatory variables, x_{ki} are independent variables, β_k are their effects, and ε_i is an error term.

A fixed-effects model (FE-model) explains changes in the dependent variable over time t:

$$e_{0it} = \alpha_i + \sum_{k=1}^{K} \beta_k x_{kit} + t_{1995} + \cdots + t_{2005} + \varepsilon_{it} \tag{4.5}$$

Time-constant variables are swept out by the FE-model. Time dummies t are introduced for each year (reference year 2006). By introducing fixed period effects in the FE-model, it becomes a two-way FE-model (fixed effects for time and districts). In the FE-model, the district-specific constants α_i are fixed parameters, but may be correlated with the explanatory variables x_{kit} (Baltagi 2008; Engelhardt and Prskawetz 2005).

A random-effects model (RE-model) explains both changes in the dependent variable over time t and over districts i. The FE- and RE-models differ in their assumptions but are of a similar following form. In the RE-models, α_i can be considered as $\alpha_i = \alpha + \tau_i$. Thereby, τ_i is a district-specific disturbance term that does not change over time:

$$e_{0it} = \alpha + \tau_i + \sum_{k=1}^{K} \beta_k x_{kit} + t_{1995} + \cdots + t_{2005} + \varepsilon_{it} \tag{4.6}$$

In contrast to the FE-model, $\alpha_i = \alpha + \tau_i$ is distributed randomly in the RE-model and is not allowed to be correlated with x_{kit}. If they were correlated, biased and inconsistent estimators would result (Baltagi 2008; Halaby 2004). The RE-model is able to make predictions both between and within components, as it is a matrix-weighted average of the BE- and FE-models (StataCorp 2007). While BE- and FE-models request the OLS estimator, RE-models request the GLS estimator.

All models assume a random intercept, but the covariate effects are assumed to be constant across districts i. The models can be extended to random-coefficient models, as described in Sect. 4.3.3. Random-coefficient models assume that the association between dependent and independent variables is not fixed to be constant across sections (Gmel et al. 2001). Preliminary models with random coefficients for the independent variables were run. Only for the variable "population change" was a significant random coefficient found to exist. Given that the impact of this variable is minor (see results later), and is in trade-off with the more complicated model structure, this study focuses on models without random coefficients.

Several test statistics are applied. The Chow test reveals whether the time dummies and district effects are significant in the FE-models. Both the Hausman and the Breusch-Pagan tests are suitable for testing whether a FE- or a RE-model should be preferred over the other (Baltagi 2008; Engelhardt and Prskawetz 2005; Halaby 2004).

After the full FE- and RE-models were fitted, the same models were estimated and checked for serial autocorrelation in the residuals with the Durbin-Watson statistic. A correction of serial correlation is required when the value of the Durbin-Watson statistic deviates strongly from the value of 2 (Baltagi 2008; StataCorp 2007). This is not the case in the current models.

As the association between life expectancy and mortality determinants at the aggregate district level is studied, causal relationships between mortality and its determinants at the individual level cannot be established. Doing so could result in ecological fallacy. This is because the use of the district-specific means of (dependent or independent) variables hides the distribution of values of these variables over individuals living in the districts (Morgenstern 1995; Robinson 2009; Vaupel et al. 1979; Vaupel and Yashin 1985). Spijker (2004, p. 101) in a similar situation notes that "inferences to the individual cannot be made, even though the results presented […] are often similar to relationships that have been established at the individual level elsewhere."

While it is not possible to prevent the models from producing ecological fallacy, results can be interpreted carefully at the regional level. Thus, rather than allowing causal chains between mortality and individual risk factors to be elaborated, the results should be viewed as associations assessed at the aggregate level.

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

4.4 Life Expectancy Across Districts

This section describes how life expectancy at birth is distributed across the 438 German districts, and how it changes over time. The extent of spatial clustering, both locally and overall, will be assessed. Following a description of life expectancy patterns in 2004–2006 in Sects. 4.4.1 and 4.4.2 deals with the changes in life expectancy from 1995–1997 to 2004–2006 and points out the regions that underwent the greatest and the smallest improvements. Finally, time trends in life expectancy are summarized (Sect. 4.4.3) and spatial dispersion is assessed by a dispersion measure of mortality (Sect. 4.4.4).

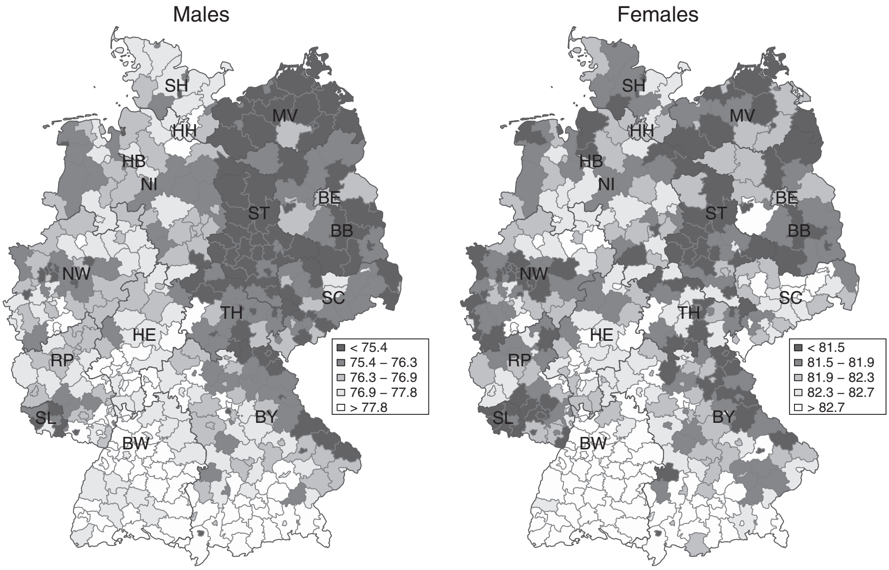

Fig. 4.2 Life expectancy by district; 2004–2006. *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western Pomerania, *SC* Saxony, *ST* Saxony-Anhalt, *TH* Thuringia (Data source: Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy 2007)

4.4.1 Spatial Distribution and Its Stability

Life expectancy in the German districts is displayed in Fig. 4.2.[3] It is complemented by a map of the local indicator of spatial autocorrelation Local Moran's I (Fig. 4.3), which indicates the local clustering (positive or negative) of high and low life expectancy. It shows that mortality is not spread randomly across districts.

With regard to life expectancy, there are three distinct areas in Germany in 2004–2006: high life expectancy in the South, low life expectancy in the East, and intermediate values and a more scattered picture in the West (Figs. 4.2 and 4.3).

More specifically, a contiguous area of high life expectancy—and, hence, a positive local spatial autocorrelation—is found in Baden-Württemberg, extending into southern Hesse and the southwest of Bavaria.

Higher life expectancies are also found in Münsterland (northern North Rhine-Westphalia), Saxony around the city of Dresden, and heterogeneous parts in Schleswig-Holstein and Lower Saxony. Broken down by gender, higher life expectancies are found in the Rhineland part of North Rhine-Westphalia (the region of Cologne-Bonn) for men and in southern eastern Germany (parts of Thuringia and Saxony) for women. In these areas in 2004–2006, male life expectancy was about 78 years, and female life expectancy was about 83 years.

[3] Figure B.5 in the appendix shows the standard errors relative to life expectancy.

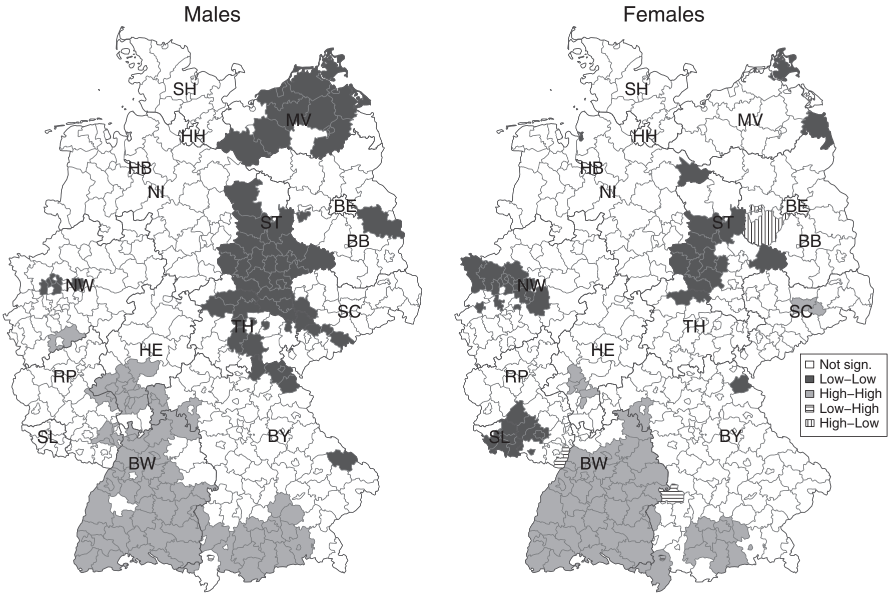

Fig. 4.3 Local Moran's I of life expectancy by district, only districts with significant autocorrelation ($p < 0.05$); 2004–2006. Legend description: Low-Low (*High-High*): Positive spatial autocorrelation; district with low (*high*) life expectancy surrounded by districts with low (*high*) life expectancy; Low-High (*High-Low*): Negative spatial autocorrelation; district with low (*high*) life expectancy surrounded by districts with high (*low*) life expectancy; only values significant at 5% level are shown. *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, *SC* Saxony, *ST* Saxony-Anhalt, *TH* Thuringia (Data source: Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy 2007)

By contrast, regions with low life expectancies (male life expectancy below approximately 75 years, female life expectancy below 81.5 years) are situated mainly in eastern Germany (excluding the above-mentioned areas), Saarland, the Ruhr area (central North Rhine-Westphalia), and the northeastern areas of Bavaria bordering Thuringia and the Czech Republic. Positive local spatial autocorrelation in low life expectancy areas is found in large parts of Saxony-Anhalt; among men, this also applies to Mecklenburg-Western Pomerania and several districts in Thuringia and Saxony. The Ruhr area, however, exhibits a pattern of contiguously low life expectancy mainly among women, whereas the pattern of adjacent districts with low male life expectancy also prevails in Saarland and its neighboring districts in Rhineland-Palatinate.[4]

[4] Border regions, such as the northeastern border of Bavaria, are not entirely captured by local spatial autocorrelation due to the definition of the spatial weights matrix.

Several regions within Germany cannot be clearly classified as high or low life expectancy regions. Life expectancy is either intermediate or low/high in a particular district, and high/low in the surrounding districts. Regions that are ambiguous in this sense are located in Schleswig-Holstein, Lower Saxony, Rhineland-Palatinate, and parts of Hesse (especially the northern part). Most districts lie within one standard deviation above or below the mean life expectancy (Fig. B.6 in the appendix). These are, for the most part, not captured by significant values of Local Moran's I, which refer to the more extreme life expectancy values (Fig. B.7 in the appendix).

This picture illustrates that regional mortality differences in Germany go beyond the borders of federal states. This is especially characteristic of the federal states of Bavaria and North Rhine-Westphalia, where the districts of both low and high life expectancy are situated. However, even within the seemingly homogenous life expectancies seen in the federal state of Baden-Württemberg, regional differences exist (von Gaudecker 2004), though the current representation partly masks this variation.

As may be expected, a positive local spatial autocorrelation prevails, and it is more pronounced among men. Negative local spatial autocorrelation—in which districts with high life expectancies border districts with low life expectancies, or the reverse—plays a minor role. This means that contiguous regions are rather uniform with respect to their mortality levels. Potsdam-Mittelmark can be singled out as an example of a district where significant negative spatial autocorrelation occurred among women in 2004–2006. Life expectancy in Potsdam-Mittelmark is in the upper quintile of all districts, but it is surrounded by districts with mainly very low life expectancy.

4.4.2 Spatial Life Expectancy Patterns Over Time

In this section, life expectancy changes over time in the districts are examined. In addition to showing where the increases were high or low, this section also includes an assessment of changing temporal spatial patterns.

From 1995 to 2006, life expectancy in Germany increased by 3.8 years among men and by 2.5 years among women, or by 0.32 and 0.21 years on average annually (Human Mortality Database 2008c). However, this increase did not affect all districts equally. Figure 4.4 shows the annual life expectancy changes by district. Men in the quintile of districts with the lowest life expectancy increases experienced annual increases of less than 0.26 years, while those in the highest-increase quintile gained more than 0.42 years. The figures for women were 0.16 and 0.31 years, respectively.

At first glance, it is obvious that large parts of eastern Germany experienced relatively high life expectancy gains. Exceptions to this pattern were found among women in the northern districts of Saxony-Anhalt and in Berlin, as well as in some of the districts of Brandenburg that border Berlin. Here, life expectancy increases were either intermediate or below average. As for men in eastern Germany, most

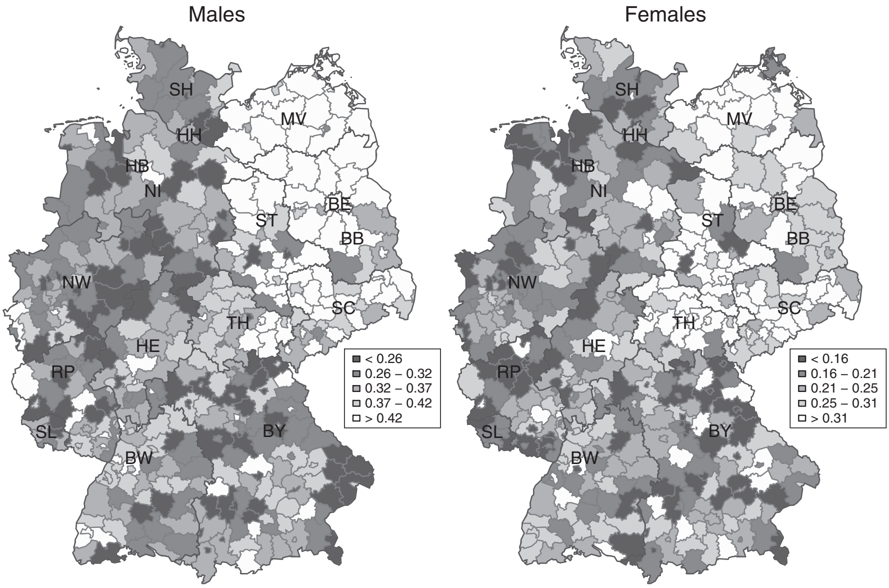

Fig. 4.4 Arithmetic mean of annual life expectancy changes; 1995–2006 by district. *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western Pomerania, *SC* Saxony, *ST* Saxony-Anhalt, *TH* Thuringia (Data source: Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy 2007)

districts in Saxony-Anhalt and some districts in Thuringia and Saxony were at intermediate levels. Apart from the districts in Saxony-Anhalt, which experienced relatively low life expectancy increases, the other eastern German districts had higher life expectancy levels than those measured in eastern Germany in 1995–1997 (see Fig. B.4 in the appendix).

In addition to these gains made in the East, increases in life expectancy were also seen in parts of western Germany, including in several parts of Baden-Württemberg and Bavaria. These were primarily areas that began the period studied with high levels of life expectancy (cf. Fig. B.4). Areas in Rhineland-Palatinate and North Rhine-Westphalia that had high life expectancy levels at the start of the period also showed large increases.

On the other hand, large parts of western Germany—excluding the South—experienced slower life expectancy increases between 1995 and 2006 or of less than 0.26 years for men and 0.16 years for women. This applies to the northeastern border of Bavaria, certain districts in Rhineland-Palatinate, and North Rhine-Westphalia (other than the above-mentioned ones), and districts in Saarland, Lower Saxony, and Hesse. The city-states of Bremen and Hamburg both had only small to intermediate gains in life expectancy over the time period studied.

In general, the correlation between life expectancy in 1995 and the average annual life expectancy change in the districts was significantly negative and strong.

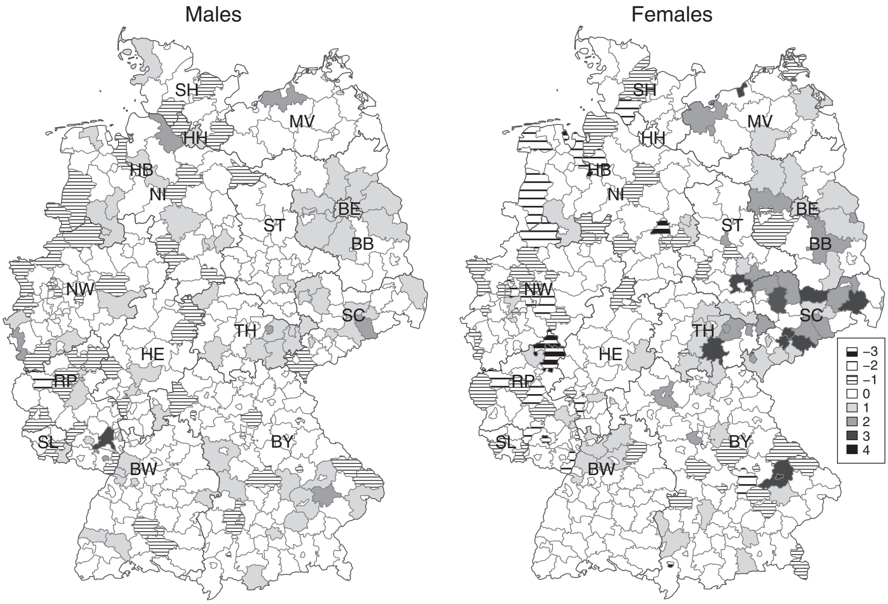

Fig. 4.5 Rank changes in life expectancy; 1995–1997 to 2004–2006 by district. *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western Pomerania, *SC* Saxony, *ST* Saxony-Anhalt, *TH* Thuringia (Data source: Federal State Offices of Statistics, Germany)

Across all German districts, the correlation coefficient was –0.62 among men and –0.64 among women. It was –0.69 among East German districts for men and –0.64 among East German districts for women. Correlation coefficients were lower across West German districts, with values of –0.27 for men and –0.43 for women.

In the following, the life expectancy changes are viewed from a different perspective. While absolute gains were found on average, changes between the districts are now considered. To analyze these changes, districts were divided into five ranks, or quintiles, based on life expectancy, and the changes in these ranks were measured between 1995–1997 and 2004–2006 (Brewer and Pickle 2002; James et al. 2004). As all districts experienced positive life expectancy changes between 1995–1997 and 2004–2006, improvements and deteriorations are measured as rank improvements or deteriorations (Fig. 4.5).

The spatial life expectancy pattern among women was found to be more plastic than among men. While the correlation coefficient between life expectancy in 1995–1997 and life expectancy in 2004–2006 was 0.88 among men, it was only 0.67 among women. In addition, the sex-specific patterns became more diverse over time. Figure 4.5 reveals that East German districts underwent most of the positive and the greatest rank changes from the mid-1990s to the mid-2000s. Especially Berlin and its surrounding areas in Brandenburg, as well as many districts in Saxony and Thuringia, underwent serious rank improvements. Other regions with positive

Table 4.4 Moran's I of life expectancy; 1995–2006

	Year											
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Males	0.551	0.567	0.484	0.472	0.484	0.465	0.455	0.456	0.493	0.462	0.504	0.564
Females	0.444	0.398	0.350	0.329	0.287	0.347	0.323	0.318	0.332	0.407	0.378	0.392

Data source: Federal State Offices of Statistics, Germany
All values significant at 0.1% level

rank changes are spread throughout the country. Several districts that underwent positive rank changes border districts that underwent rank changes in the negative direction. Most of the negative rank changes occurred in districts in the most western parts of the country, including in Rhineland-Palatinate, Saarland, western North Rhine-Westphalia, and western Lower Saxony.

Figure B.8 in the appendix further shows how many rank changes in either direction each district underwent over four time periods: 1995–1997, 1998–2000, 2001–2003, and 2004–2006. This shows the general trends of change and instability. For example, among women, many districts in Thuringia and Saxony underwent large changes over time. Women in general experienced greater plasticity. While 156 out of the 438 districts experienced two or more rank changes over time among women, this applied to 51 districts among men.

As a result of these trends, the life expectancy distribution across districts changed only a little in the time lapse among men (Fig. B.4 in the appendix). The spatial patterning roughly reproduced itself over time, even though the absolute differences in life expectancy diminished. Changes in the spatial structure were more pronounced among women, a group who also experienced decreasing absolute differences. The previously consistent low life expectancy area of eastern Germany underwent positive changes, and the pattern changed toward the pattern described above, with relatively high life expectancy changes seen in southern East Germany. On the other hand, districts in the Ruhr area and along the northeastern Bavarian border underwent several unfavorable rank changes.

Global spatial autocorrelation, as measured by Moran's I and reflecting the regional clustering of life expectancy across the districts, decreased during the 1990s (Table 4.4). This means that previously contiguous areas with similar life expectancies had dissolved since the mid-1990s. In the later years of the observation period, the spatial autocorrelation increased.

While the cluster of districts with low life expectancy in eastern Germany had partly dissolved, low life expectancy clusters in the West had emerged. In addition, a cluster of neighboring high life expectancy districts had appeared in the southwest (cf. Figs. B.4, B.5, B.6, and B.7 in the appendix).

At the start of the period, the higher spatial clustering mainly reflected the initially contiguous low life expectancy region of eastern Germany. As East German districts made great advances in life expectancy throughout the 1990s, this altered the picture of spatial autocorrelation. Higher life expectancy gains in the East German districts led to a partial dissolution of the clustering (especially among women). Regions like Berlin, the area surrounding Berlin, and Saxony were exceptions to this low life expectancy picture, and reduced spatial autocorrelation.

Generally, the East became more heterogenous with respect to life expectancy, contributing to a more equal spatial distribution of life expectancy, and hence to a smaller overall spatial autocorrelation.

At the same time, the cluster with the most significant positive local spatial autocorrelation, with high levels of life expectancy in northern North Rhine-Westphalia (northern Münsterland and eastern Westphalia) among women, had disappeared. This may be related to strong life expectancy increases in the East German districts. The area of significant spatial autocorrelation due to similarly low levels of life expectancy in districts in the Ruhr area had emerged since the late 1990s, and strengthened over time. This trend was particularly pronounced among women. A female cluster of low life expectancy in Saarland and neighboring districts in Rhineland-Palatinate also emerged over time (cf. Figs. B.4 and B.7 in the appendix). All of these trends contributed to the reemergence of higher spatial autocorrelation toward the mid-2000s.

4.4.3 Trends in Life Expectancy by District

The previous sections showed that life expectancy improvements differed spatially. The current section investigates how life expectancy in the German districts changed over the period. In Germany as a whole and in its individual federal states, a steady, fairly linear increase in life expectancy could be observed after 1990 (Sect. 3.4). This section incorporates the trend estimation of each district's life expectancy from 1995 to 2006.

In the process of finding a suitable model to describe the life expectancy trends, different variables were included in random-intercept and random-coefficient models, as described in the methods part of Sect. 4.3.3. The final model, which was deemed to provide the best fit among all the options considered, is a random-coefficient model (Table 4.5). This model explains life expectancy as a function of time, and time as a quadratic term (with each one being different for East and West German districts), and a dummy for East German districts with random coefficients for the annual life expectancy increase.

As Table 4.5 shows, the life expectancy constant was 76.9 for men and 81.8 years for women. Taking into account the standard deviations, 95% of the districts had a male life expectancy of between 75.0 and 78.7 years, and a female life expectancy of between 80.5 and 83.0 years. The annual linear increase was positive and greater among men, and was greater in East German districts. Among men, 95% of the western German districts experienced an annual life expectancy increase of between 0.23 and 0.37 years, while the increase among women in western Germany was between 0.19 and 0.30 years. In eastern Germany, the values were greater, and the degree of variation was greater as well: life expectancy increase in the districts ranged between 0.58 and 0.76 years among men and between 0.44 and 0.61 years

Table 4.5 Estimates from random-coefficient model for time trends in districts' life expectancy; 1995–2006

	Males	Females
Fixed part (β-coefficients)		
Constant	76.89 (0.000)	81.78 (0.000)
Year West Germany	0.299 (0.000)	0.246 (0.000)
Year East Germany	0.667 (0.000)	0.527 (0.000)
Year^2 West Germany	0.001 (0.368)	−0.003 (0.000)
Year^2 East Germany	−0.019 (0.000)	−0.016 (0.000)
Dummy East Germany	−3.315 (0.000)	−1.921 (0.000)
Random part (standard deviations)		
Constant	0.946 (0.000)	0.636 (0.000)
Year West Germany	0.037 (0.004)	0.029 (0.004)
Year East Germany	0.045 (0.007)	0.042 (0.006)
Residual	0.606 (0.000)	0.550 (0.000)
Log likelihood	−5,704	−5,060

Data source: Federal State Offices of Statistics, Germany
p-values in parentheses

among women. The annual life expectancy increase was discounted by a negative quadratic term for time (except for western German men, where this term is positive, but inconsequential). Again, the absolute life expectancy increase was greater in eastern Germany. Hence, men and women in West German districts had lower but steady life expectancy increases. In East German districts, life expectancy gains were strongest in the earlier years, and leveled off in later years.

Results are also displayed in Fig. 4.6. The left plot shows each district's life expectancy from 1995 to 2006, and the right plot shows the estimated trend. The East German districts are on the lower edge of all districts, but can be seen to catch up during the 1990s. However, the life expectancy increase in eastern Germany levels off to a greater extent than in the West, as indicated by the negative quadratic term for time. This term plays a minor role for men in western Germany, but is more important in eastern Germany. It captures the East-to-West convergence in mortality, with the pace of the convergence slowing down during the observation period. Eastern German women caught up disproportionately, and, by the end of the observation period, the majority of East German districts had surpassed the worst-performing West German districts. Very few of them, however, got close to the best performers. In general, the variation in life expectancy between the districts had decreased.

The two districts with the highest male life expectancy in the year 2006 were two Bavarian districts: the rural districts of Starnberg (80.6 years) and the rural district of Munich, which surrounds the city (80.3 years). The districts with the highest female life expectancy were again Starnberg (84.4 years) and the rural district of Tübingen (84.2 years) in Baden-Württemberg. Two districts in Mecklenburg-Western Pomerania had the lowest male life expectancy in 2006: Demmin (73.3 years) and Uecker-Randow (73.6 years), while two districts in West Germany experienced the

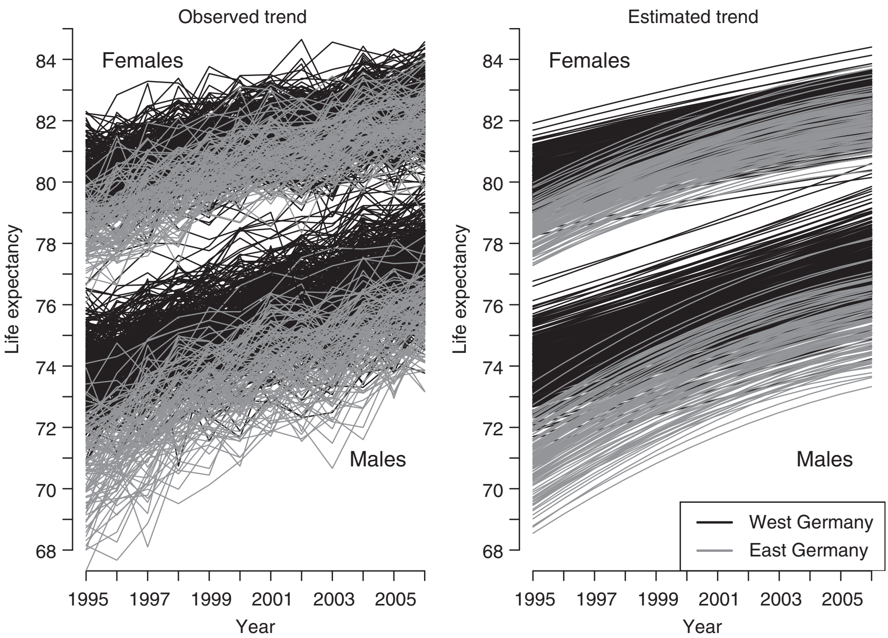

Fig. 4.6 Observed and estimated trend of life expectancy by district; 1995–2006 (Data source: Federal State Offices of Statistics, Germany)

lowest female life expectancy. These were the rural district Südwestpfalz (80.1 years), which includes the city of Pirmasens in Rhineland-Palatinate, and the city of Gelsenkirchen (80.4 years) in the Ruhr area in North Rhine-Westphalia.

4.4.4 Dispersion Across Districts and Its Changes

4.4.4.1 Time Trends in Regional Dispersion

The previous section pointed out the disparities in life expectancy across districts over time, and these are now summarized by the summary measure DMM (as was done in Sect. 3.4.3 for the federal states). Until now, no such regional mortality dispersion measure has been applied in Germany. Luy (2006) and Luy and Caselli (2007) used the minimum and maximum values and the range between the two to describe disparities in life expectancy between Germany's districts in the cross-section in 1997–1999. Luy (2006) used the same measure, but also looked at how the range in life expectancy across the German districts changed from 1981–1983 to 1991–1993 and 1997–1999, showing first an increase in the range from 1981–1983 to 1991–1993, and then a decrease from 1991–1993 to 1997–1999. An exception was the range in female life expectancy, which declined at all times.

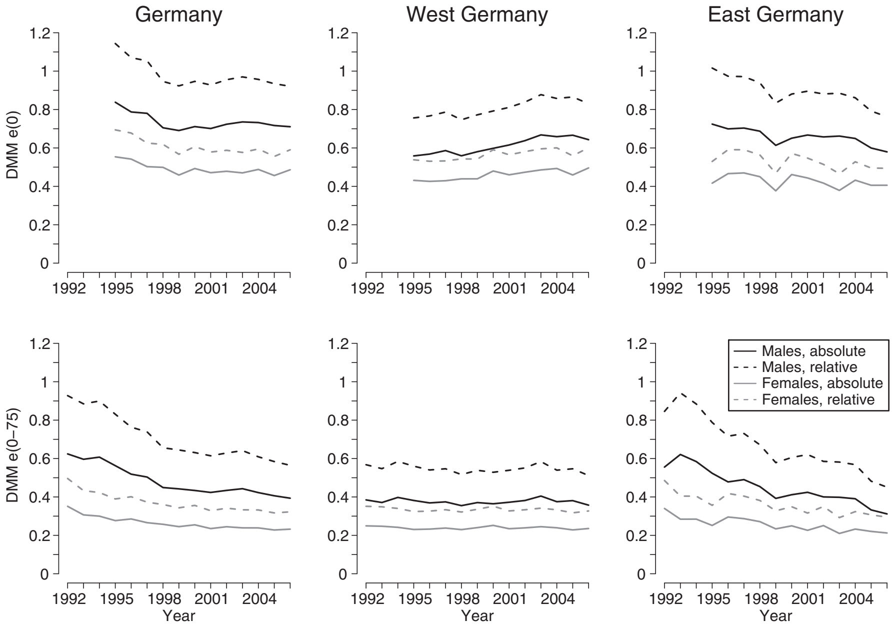

Fig. 4.7 DMM across districts for life expectancy at birth (e_0) and temporary life expectancy ($_{75}e_0$); 1992–2006. Absolute DMM in years, relative DMM in years relative to life expectancy; East Germany includes Berlin (Data source: Federal State Offices of Statistics, Germany)

Unlike the range, which only looks at the extremes, the DMM includes all life expectancy differences between each pair of districts, and therefore includes all values (cf. Sect. 3.4.3).

In Fig. 4.7, trends in DMM are shown from 1995 to 2006 for life expectancy at birth and for temporary life expectancy $_{75}e_0$ from 1992 to 2006.[5] Naturally, the dispersion is greater when measured across the 438 districts than across the 16 federal states. Rough trends were, however, found to be similar across federal states and across districts.

For Germany, the dispersion measure of mortality decreased until the late 1990s, and then leveled off and became stable. Absolute and relative dispersion was higher among men.

The dispersion trends differed between eastern and western Germany. In western Germany, dispersion increased slightly between 1995 and 2006. In eastern Germany, life expectancy dispersion across districts decreased slightly among men over that period, and remained fairly stable among women. Male relative dispersion was greater across all districts than DMM was across West or East German districts, which suggests the presence of an East-West life expectancy gap. This trend was apparent for women at the beginning of the observation period, but had disappeared by the late 1990s.

[5] As was the case for the federal states, the analysis of temporary life expectancy $_{75}e_0$ can be performed for a larger observation period due to greater data availability.

Trends in regional dispersion in temporary life expectancy ${}_{75}e_0$ across all German districts reveal a rapid decrease up to the late 1990s, and a slight decline during the 2000s. Across the West German districts, dispersion remained stable over time. The DMM trend among East Germans generally followed the overall German trend.

A comparison of trends in regional dispersion across districts between life expectancy at birth and temporary life expectancy ${}_{75}e_0$ leads to the conclusion that regional mortality disparities in old-age mortality contribute to higher overall levels of dispersion.

4.4.4.2 Age-Specific Contributions to Regional Dispersion

The impact of each age group on the total dispersion is revealed by an age-specific decomposition of DMM. Figure 4.8 shows the results by sex for all of Germany, for West Germany, and for East Germany for three time periods. Results are shown in relative figures, relative to the overall dispersion, so that the value is independent of the total DMM value.

Most of the regional dispersion in life expectancy across districts is due to variations in mortality rates after age 50 in the time periods 1995–1997, 2000–2002, and 2004–2006. Local peaks are seen in infancy and at young adult ages. The ages that have the greatest impact on regional dispersion are between 60 and 74 years among men and between 70 and 79 years among women. The West German pattern is very similar to the overall German pattern, but the regional mortality differences among young adults have less of an impact on overall dispersion. On the other hand, large regional mortality variation in young adults across East German districts results in greater contributions by this age group to the overall dispersion. In 1995–1997, the variation in mortality rates in the age group 15–19 was responsible for 6% of the overall dispersion in East German men and the age group 60–64 was responsible for 10% of the overall dispersion in East German men. Over the same time period, West German men in the same age groups had corresponding values of 2% and 12%. This indicates that there is a much greater degree of age-specific mortality variation at older ages, and that mortality variation among young adults is less important.

Over time, the regional dispersion of life expectancy across districts tended to be more and more influenced by older ages. Such a shift in importance toward older ages is observed in all three geographic entities considered.

4.5 Cause-Specific Mortality by Districts

Ongoing mortality changes differ substantially by age and cause of death, as has been shown for the federal states in Sect. 3.6. This section explores the cause-specific mortality patterns across districts, and how changes in cause-specific mortality affected the overall spatial mortality patterning. First, the small-area patterns in cause-specific

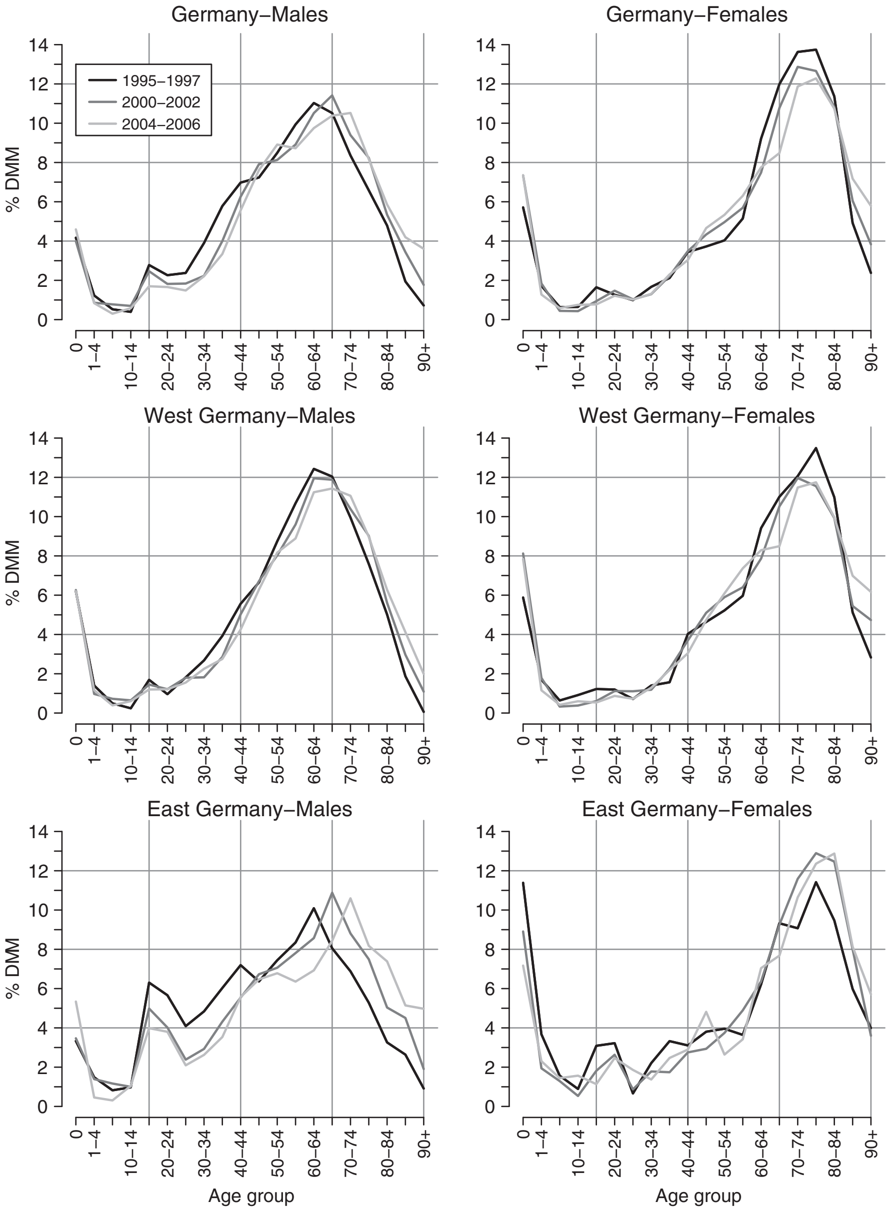

Fig. 4.8 Contribution of age-specific mortality to DMM of life expectancy at birth as percentage of total DMM; Germany, East and West Germany; 1995–1997, 2000–2002, 2004–2006. DMM Germany 0.77, 0.68, 0.69 (men), 0.49, 0.44, 0.44 (women). DMM West Germany 0.53, 0.58, 0.62 (men), 0.38, 0.43, 0.45 (women). DMM East Germany 0.66, 0.62, 0.57 (men), 0.39, 0.39, 0.37 (women) (Data source: Federal State Offices of Statistics, Germany)

mortality are presented together with global and local spatial clustering (expressed in terms of spatial autocorrelation). Second, the changing cause-specific patterns are analyzed and related to the overall change in mortality over time.[6]

4.5.1 Spatial Patterns of Cause-Specific Mortality in the Districts

Cause-specific mortality for leading causes of death in the districts is expressed by age-SDR. First, the clustering of cause-specific mortality across districts is briefly outlined. Moran's I in Table 4.6 shows the global spatial autocorrelation of SDR for the leading causes of death, that is, reflecting the objective strength of regional patterns.

Spatial autocorrelation is statistically significant for all causes and in all of the four time periods. Moran's I of all-cause mortality was stable between 1996–1998 and 2001–2003, but increased in 2004–2006. Generally, the highest spatial autocorrelation is observed for lung cancer, external causes, and cardiovascular causes. Low values are observed for cancers of all sites, and for female suicide and alcohol-related mortality.

The spatial patterns of cause-specific mortality are now described. The spatial distribution of all-cause mortality lines up well with the spatial pattern of life expectancy (in the reverse). Similar patterning can be found in many specific causes of death (Figs. 4.9 and 4.10; Table B.2). This is especially characteristic of mortality from cardiovascular diseases, which represents the largest share of deaths, and is spatially distributed in a manner similar to all-cause mortality. Furthermore, male cancer mortality, and, to a lesser extent, male lung cancer mortality, show similar patterns. Even though alcohol-related mortality accounts only for a minor share of all deaths, the spatial pattern is also similar to that of all-cause mortality among men.

In most cases, the districts with high all-cause mortality experience high mortality from cardiovascular causes, male cancer (also lung cancer), and—particularly in the East German districts—high alcohol-related and male external mortality. The West German districts with high all-cause mortality furthermore exhibit high other-cause and respiratory disease mortality (Figs. 4.9 and 4.10).

Similarly, but in the reverse, low-mortality regions are characterized by low mortality from cardiovascular causes, low male cancer mortality, and, in the south, also by low levels of respiratory mortality. At the same time, the spatial pattern of low all-cause mortality is not found in other-cause and alcohol-related mortality. In some cases, external-cause mortality is high in low-mortality regions.

[6] As mentioned in the data section, data on causes of death in the underlying district structure are only available from 1996 onward.

Table 4.6 Moran's I for SDR by leading causes of death; 1996–1998, 1998–2000, 2001–2003, 2004–2006

	1996–1998	1998–2000	2001–2003	2004–2006
Males				
All causes	0.555	0.542	0.546	0.605
Respiratory diseases	0.587	0.272	0.522	0.587
Cardiovascular diseases	0.660	0.609	0.587	0.607
Heart diseases	0.655	0.576	0.576	0.534
Cerebrovascular diseases	0.578	0.570	0.572	0.485
Neoplasms	0.396	0.487	0.426	0.484
Lung cancer	0.709	0.700	0.619	0.675
External causes	0.807	0.804	0.793	0.679
Traffic accidents	0.569	0.506	0.489	0.388
Suicide	0.554	0.564	0.398	0.414
Alcohol-related diseases	0.449	0.474	0.429	0.475
Other diseases	0.493	0.476	0.441	0.566
Females				
All causes	0.405	0.406	0.399	0.492
Respiratory diseases	0.418	0.457	0.638	0.718
Cardiovascular diseases	0.562	0.524	0.527	0.478
Heart diseases	0.546	0.493	0.555	0.376
Cerebrovascular diseases	0.555	0.544	0.560	0.450
Neoplasms	0.189	0.328	0.225	0.328
Lung cancer	0.776	0.761	0.690	0.803
External causes	0.720	0.701	0.677	0.500
Traffic accidents	0.454	0.387	0.295	0.284
Suicide	0.280	0.207	0.161	0.193
Alcohol-related diseases	0.276	0.264	0.142	0.122
Other diseases	0.538	0.485	0.442	0.443

Data source: Federal State Offices of Statistics, Germany; Research Data Center of the Federal Statistical Office and the Federal State Offices of Statistics, Germany
All values significant at 0.1% level

The spatial pattern of suicide mortality across the districts is the least connected to the general pattern of all-cause mortality. For example, North Rhine-Westphalia has both low- and high-mortality districts, but suicide mortality is low in the entire state.

Generally, the cause-specific spatial patterns are similar between the sexes, as the comparison of Figs. 4.9 and 4.10 shows. Exceptions are cancer and suicide mortality, for which the geographies between the sexes have little in common. Spatial patterns become slightly more diverse between the sexes over time, as the correlation coefficients between male and female cause-specific SDR confirm (Table B.3 in the appendix). Low correlation coefficients indicate a different spread of risk factors for specific causes; hence, it is not surprising that cancer mortality is spread differently in space for males and females. Cancer mortality is thus a major reason why the spatial pattern of all-cause mortality is different between the sexes (cf. Caselli et al. 2003).

Fig. 4.9 SDR by leading causes of death by district, males; 2004–2006 (Data source: Federal State Offices of Statistics, Germany; Research Data Center of the Federal Statistical. Office and the Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy 2007)

Fig. 4.10 SDR by leading causes of death by district, females; 2004–2006 (Data source: Federal State Offices of Statistics, Germany; Research Data Center of the Federal Statistical. Office and the Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy 2007)

4.5.2 Cause-Specific Mortality in the Districts and Changing Spatial Patterns of All-Cause Mortality

Spatial cause-specific mortality patterns are now investigated in the time lapse. Except for female lung cancer, all causes underwent mortality declines over time (see trends in federal states, Figs. A.14 and A.15 in the appendix). However, not all districts experienced equal mortality declines, and several low- and high-mortality hotspots emerged and dissolved.

The spatial patterns of cause-specific mortality are compared for the four time periods 1996–1998, 1998–2000, 2001–2003, and 2004–2006 (Figs. 4.9, 4.10, 4.11, and 4.12; Figs. B.9, B.10, B.11, B.12, B.13, B.14, B.15, B.16, B.17, B.18, B.19, and B.20 in the appendix). Absolute and relative changes in SDR from 1996–1998 to 2004–2006 are displayed in Figs. B.21, B.22, B.23, and B.24 in the appendix, and the local spatial autocorrelation of these changes is displayed in Figs. B.25, B.26, B.27, and B.28 in the appendix. Correlation coefficients between cause-specific SDR in the districts over time are given in Table B.4 in the appendix.

In general, many cause-specific spatial patterns are similar to each other, and persist over time. Cardiovascular mortality undergoes relatively little change in the spatial structure. Constituting the largest cause-of-death group, it contributes to the stability of the all-cause mortality pattern over time. Only the spatial patterns of suicide and other-cause mortality change significantly over time. To a lesser extent, the pattern of respiratory mortality changes. Among women, spatial patterns also change for external causes and single causes in this class, and for mortality from all cancers. Mortality declines in these causes vary markedly across the districts. They tend to be greater for women than for men (Table B.4 in the appendix).

All-cause mortality improvements in Berlin and the surrounding districts in Brandenburg, as well as in southern East Germany, are mostly associated with improvements in rates of heart disease, traffic accidents, and lung cancer. In addition, great improvements in alcohol-related mortality contribute to the overall improvement among women. On the other hand, the districts that experienced a relative deterioration in life expectancy and in all-cause mortality are mainly situated in the western parts of Germany, close to the Dutch and Belgium borders. The underlying causes of this trend are respiratory diseases and, for men, lung cancer and traffic-accident mortality (Figs. B.9, B.10, B.11, B.12, B.13, B.14, B.21, B.22. B.23, and B.24 in the appendix; Figs. 4.9 and 4.10).

Suicide mortality is clustered very little in space (Table 4.6), and the pattern of this cause of death changes with time. For example, for males, the high suicide area in eastern Germany partly dissolves and shifts toward the borders of Poland, the Czech Republic, and Austria. However, the suicide pattern has little impact on changing patterns of all-cause mortality.

In general, the causes of death that are related to health behavior and characterized by social gradients—such as cardiovascular mortality, lung cancer, and alcohol-related causes—determine the spatial mortality patterns and their changes (cf. Leon 2001).

Fig. 4.11 Local Moran's I of SDR by leading causes of death by district, only districts with significant autocorrelation ($p < 0.05$), males; 2004–2006. Legend description: Low-Low (*High-High*): Positive spatial autocorrelation; district with low (*high*) life expectancy surrounded by districts with low (*high*) life expectancy; Low-High (*High-Low*): Negative spatial autocorrelation; district with low (*high*) life expectancy surrounded by districts with high (*low*) life expectancy; only values significant at 5% level are shown (Data source: Federal State Offices of Statistics, Germany; Research Data Center of the Federal Statistical Office and the Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy 2007)

Fig. 4.12 Local Moran's I of SDR by leading causes of death by district, only districts with significant autocorrelation ($p < 0.05$), females; 2004–2006. Legend description: Low-Low (*High-High*): Positive spatial autocorrelation; district with low (*high*) life expectancy surrounded by districts with low (*high*) life expectancy; Low-High (*High-Low*): Negative spatial autocorrelation; district with low (*high*) life expectancy surrounded by districts with high (*low*) life expectancy; only values significant at 5% level are shown (Data source: Federal State Offices of Statistics, Germany; Research Data Center of the Federal Statistical Office and the Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy 2007)

External-cause mortality also generally falls into this category, but it is also determined by the local road infrastructure and the rural character of the regions. It must be kept in mind that the remainder category of causes of death also underwent—in some cases, substantial—changes in the spatial structure, thus reinforcing the changing spatial pattern of all-cause mortality and life expectancy.

4.6 Urban-Rural Life Expectancy Gap

Up to this point, mortality by districts has been the focus of this study. In the following, the districts that have similar features are grouped into greater regions, and their mortality structures and trends are compared in more detail. This section addresses the urban-rural life expectancy gap in Germany.

4.6.1 Urban-Rural Mortality Differences in Europe

While the existence of an urban-rural mortality gap has been demonstrated for several countries, the direction of this difference in Germany has not been entirely clear. Although a relationship between mortality and population density has been established in small-area studies within the federal states, this result has not been extended to the entire nation (Queste 2007). Researchers have speculated that the relationship may be different across regions, that is, that in western Germany, mortality rises with increasing population density, whereas the opposite is true for eastern Germany. Queste (2007) assumed that, even in rural West German areas lacking in infrastructure, the living standard is relatively high. Furthermore, West German rural areas are often close to an urbanized area, and therefore also benefit from the city's infrastructure. Several of the West German cities are, however, deteriorating industrial centers with less favored population compositions, such as towns in the Ruhr area, Saarland, and a few towns along the coast.

Meanwhile, people who live in East German rural areas are often farther away from bigger cities, and therefore have less access to urban infrastructure.

From a historical perspective, it may be generally observed that, prior to the twentieth century, urban mortality was much higher than rural mortality. At that time, poor sanitation and hygiene in the cities led to a mortality disadvantage (Woods 2003).

Today, several factors may result in worse health conditions in urban than in rural areas, such as higher levels of environmental pollution or higher levels of (life- and work-related) stress. However, bigger cities also tend to have better infrastructure, including access to specialized physicians and emergency medicine. In case of an emergency, ambulances can reach the site of an accident more quickly in the city than in the country, and urban residents are usually closer to an appropriate hospital (e.g., Cischinsky 2005; Wittwer-Backofen 1999).

In a study that looked at the long-term context, van Poppel (1981) found that the Western European urban population, including the FRG in the 1970s, had higher mortality than the populations of the rural or agricultural regions of Western Europe. Seeking to explain this finding, van Poppel speculated that the urban population may suffer from adverse (working and living) conditions associated with mining, dockyards, and heavy industry in general. While a mortality disadvantage among urbanized populations in the countries of Western Europe has also been shown for later periods (Senior et al. 2000; Shaw et al. 2002; van Hooijdonk et al. 2008), the size of this disadvantage was found to be variable depending on age and cause of death. Even assuming that a rural mortality advantage exists, young adult mortality may be elevated in rural areas due to higher rates of fatal traffic accidents (Ebel 2004; van Hooijdonk et al. 2008).

Eastern Europe showed a reverse pattern in the second half of the twentieth century: mortality was higher in rural areas. This gap has been demonstrated, for example, for Russia, Belarus, Estonia, Lithuania, Latvia, and Romania (Jasilionis 2003; Jasilionis et al. 2007; Krumins and Usackis 2000; Kunst et al. 2002a, b; Shakhotko 2003; Shkolnikov et al. 2000; Shkolnikov and Vassin 1994; Valkonen 2001). While life expectancy during 1970–1997 was higher in the urban regions of Eastern European countries, there was no urban-rural difference in longevity in Finland and among GDR women. At the same time, men in the GDR in rural areas experienced excess mortality. Poland also represented an exception to the Eastern European pattern, with life expectancy in rural areas being slightly higher than in the urban areas (Valkonen 2001).

With regard to mortality in eastern Germany today, the Eastern European pattern of elevated rural mortality seems to persist. Mai (2004) found that mortality in eastern Germany is higher in the rural areas than in the urban agglomerations. Generally, the urban-rural mortality differences are greater among men.

Given these results, it is not surprising that small-area studies of regional mortality differences in the whole of Germany do not show a clear urban-rural differential (Cischinsky 2005; Queste 2007). Furthermore, definitions of "urban" or "rural" areas can be ambiguous and variable. For example, these areas can be defined as urban or rural by administrative classifications, by the percentage of population living in urban municipalities, or by population density.

4.6.2 Results

For the subsequent analyses, the German districts are classified as urban or rural according to the administrative classification (see Fig. 4.1). Given the unclear mortality gradient in the whole of Germany, a distinction is made between eastern and western German urban and rural districts. In the West, about 30% of the population lives in urban areas, while in the East, this share amounts to about 40%.[7]

[7] The figures relate to the definition of urban and rural districts in Germany, and may deviate if other definitions, for example, based on population density are used.

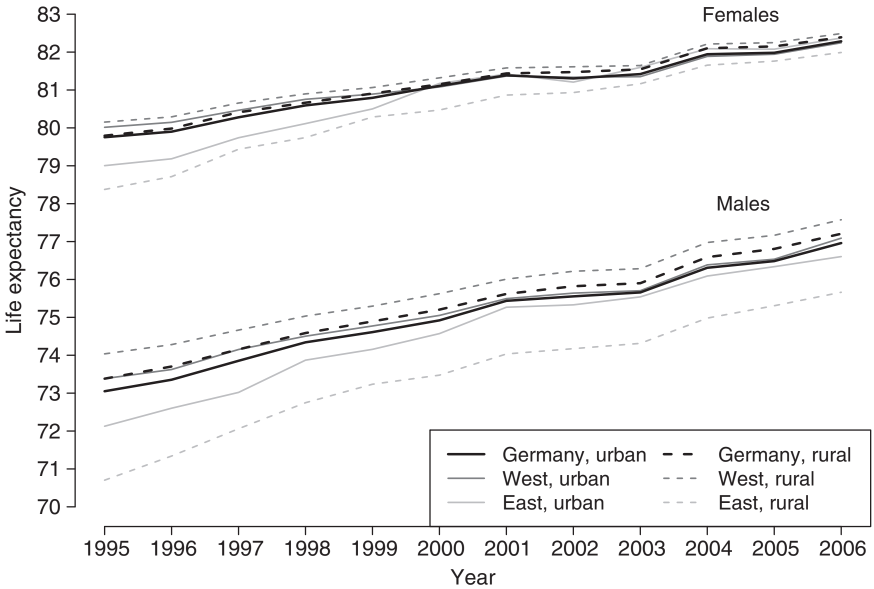

Fig. 4.13 Life expectancy in urban and rural regions of East and West Germany; 1995–2006 (Data source: Federal State Offices of Statistics, Germany)

First, life expectancy trends in the urban and rural areas are described. Then, age- and cause-specific differences are examined.

For the whole country, life expectancy is slightly higher in the rural than in the urban areas (Fig. 4.13). Amounting to less than 0.5 years, the urban-rural life expectancy gap is small in the observation period from 1995 to 2006. Dividing Germany into East and West reveals considerable differences between the two regions. Whereas in western Germany, rural areas experience higher life expectancy, the opposite is true in the East. The differences are more or less stable over time, and are larger for men than for women. Among men in the West, the gap constitutes about 0.5 years, while in the East, it exceeds 1 year.

Looking only at life expectancy masks important age-specific mortality patterns, which also differ between East and West. Thus, the urban-rural life expectancy gap is decomposed by age in order to determine which age groups cause the gap. The periods 1996–1997 and 2004–2006 are investigated (Fig. 4.14). Table B.5 in the appendix gives the respective figures for a more detailed cause-of-death classification, including a breakdown of cardiovascular diseases, cancer, and external mortality.

Life expectancy is higher in West German rural areas than in West German urban areas due to lower mortality below the age of 15, and also between the ages of 30 and 70 (left upper plot in Fig. 4.14). This is partly counterbalanced by excess rural mortality in the age group 15–29 (less pronounced among women) and ages beyond 70.

In eastern Germany, where urban life expectancy is higher, men living in rural areas face excess mortality over the entire age range. This is most pronounced in the

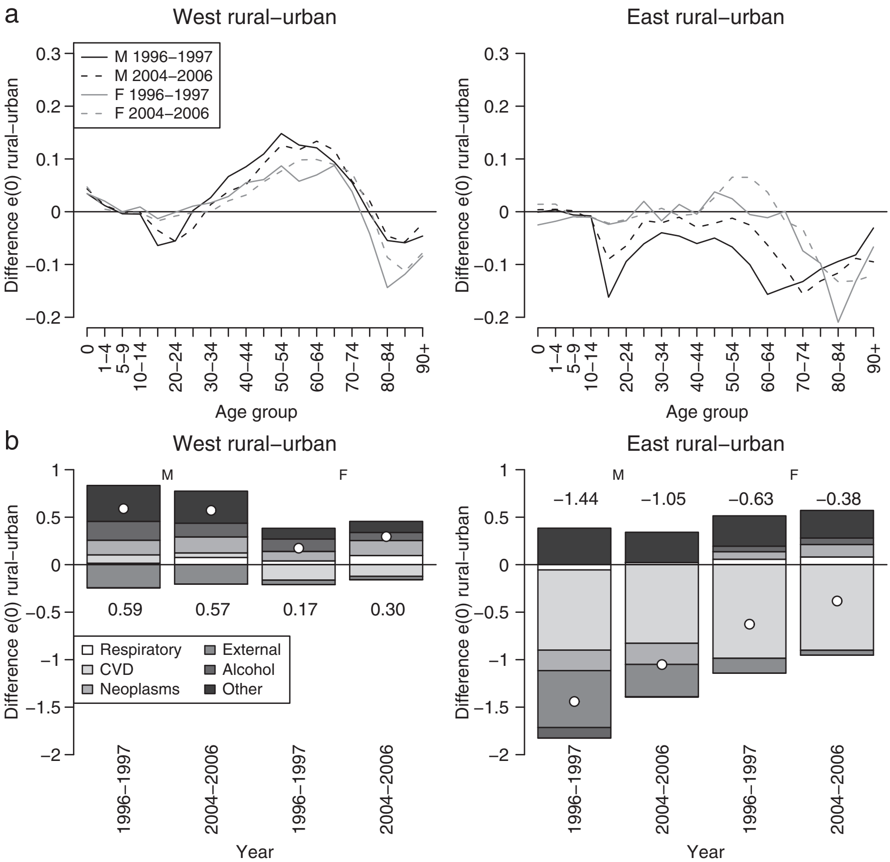

Fig. 4.14 Contribution of age- and cause-specific mortality to differences in life expectancy between rural and urban areas; 1996–1997 and 2004–2006. (**a**) Contribution of age-specific mortality to the total rural-urban life expectancy difference. (**b**) Contribution of cause-specific mortality to the total rural-urban life expectancy difference. Note: *Circles* and *numbers* indicate absolute differences between rural and urban life expectancy in years (Data source: Federal State Offices of Statistics, Germany; Research Data Center of the Federal Statistical Office and the Federal State Offices of Statistics, Germany)

age group 15–29 and at ages over 55. Women show a pattern more similar to that of the West: excess urban mortality roughly between the ages of 40 and 60 contrasts with excess rural mortality after age 65. This leads to a small advantage in life expectancy for women in rural Eastern areas.

In addition, the cause-specific mortality patterns differ between rural and urban areas in eastern and western Germany (lower plot in Fig. 4.14). In western Germany, the life expectancy advantage of rural areas is explicable by lower rural mortality in most causes of death.

Lung cancer represents a large share of the contribution of cancer mortality (Table B.5 in the appendix). However, lower rural mortality in most cases is counteracted by excess rural external mortality (mainly from traffic accidents, Table B.5) and, among women, by higher rural cardiovascular mortality.

In eastern Germany, women exhibit a similar cause-of-death structure, with rural excess mortality in external and cardiovascular causes. In contrast to their western German counterparts, the contribution of higher rural cardiovascular mortality is greater, and contributes to the female life expectancy disadvantage in eastern German rural areas. Men in eastern Germany experience excess rural mortality in all but "other" causes of death. By 2004–2006, male respiratory mortality is slightly higher in the urban areas, and there is no urban mortality difference in alcohol-related mortality.

For both eastern and western Germany, there is a clear pattern in the urban-rural divide related to excess rural mortality from traffic accidents (Table B.5). On the other hand, excess urban mortality from (lung) cancer and alcohol-related causes (excluding eastern German men) and from other causes (e.g., infectious diseases) can also be observed.

These findings suggest that the "old" Western and Eastern European patterns persisted in 1995–2006 in both western and eastern Germany. However, the Eastern pattern is disappearing among female eastern Germans, and is becoming similar to the Western European pattern.

4.7 Spatial Mortality Clusters

In this section, districts with similar mortality features are grouped together through clustering, and their socioeconomic features and mortality patterns are then compared. First, a few general observations are made about cluster regions and mortality. The derived clusters are then compared with regard to their life expectancy and socioeconomic features. Finally, the age- and cause-specific mortality patterns in the clusters are studied.

4.7.1 Cluster Regions and Mortality

As seen above (Sect. 4.4), the spatial distribution of life expectancy across Germany's districts demonstrates the presence of clear vanguard and laggard regions. At the same time, life expectancy was found to have increased at different speeds across the districts. Both the longevity level and the pace of its improvement determine the position of a district. Clustering helps to identify regions with different combinations of life expectancy and magnitudes of life expectancy increase. A comparison of the clusters will show to what extent the geographical mortality division is associated with socioeconomic correlates.

Prior analyses in Germany and worldwide have shown that clusters with different mortality structures also show different features with regard to social and economic variables and population composition (Caselli et al. 1993; Cischinsky 2005; Day et al. 2008; Fox et al. 1984; Murray et al. 2006; Ruger and Kim 2006; Spijker 2004; Strohmeier et al. 2007). It is known that, within Germany (and also within eastern Germany and within western Germany), the high life expectancy regions are also the most prosperous regions (e.g., Cischinsky 2005; Razum et al. 2008; Strohmeier et al. 2007).

4.7.2 Results

The clustering based on the districts' performance in life expectancy and change in life expectancy indicated that a classification of districts into four clusters is the most appropriate one. It is the most distinct form of clustering (highest value of F-max), and the homogeneity within the cluster is given (low SS_{within} given the number of k; see Fig. B.29 in the appendix).

The features of each cluster are now described, including the cluster's composition by districts, its life expectancy level, its expectancy increases over time, and its socioeconomic performance. Thereafter, the age- and cause-specific mortality differences are assessed.

The map in Fig. 4.15 shows the classification of the German districts into the four clusters. It is remarkable that each cluster mainly consists of spatially contiguous districts. The values of the cluster variables and selected socioeconomic indicators by cluster are given in Table 4.7. Life expectancy trends in the clusters are shown in Fig. 4.16.

Cluster 1 consists of districts mainly situated in southern Germany, that is, in Baden-Württemberg and Bavaria, and also the Rhine-Main area (federal states: Hesse and Rhineland-Palatinate). Other districts belonging to this cluster are Bonn and Münster in North Rhine-Westphalia, Osnabrück in the southwest of Lower Saxony, and Harburg, which is located south of Hamburg in Lower Saxony. Two eastern German cities belong to this cluster as well, namely Jena and Dresden. A total of 64 districts with a population of more than 14 million people make up the cluster. It has the highest life expectancy and has undergone some of the greatest life expectancy increases over time. The life expectancy level of the cluster is similar to that of Sweden. Cluster 1 is also the most prosperous cluster in the country, with the lowest unemployment rate and highest income. It experiences (relatively) high positive net migration and high levels of voter turnout, indicators associated with greater social capital (Table 4.7, Fig. 4.16). In short, Cluster 1 can be referred to as the "Prosperous South."

Cluster 2 consists of various districts situated mainly in West Germany, and can be referred to as the "Wealthy West." This cluster is made up primarily of established, wealthy districts. Altogether, it comprises 136 districts with a total population of 27.3 million. Among these districts are large parts of Westphalia, excluding the Ruhr area, the middle part of Bavaria, and the northern part of Baden-Württemberg.

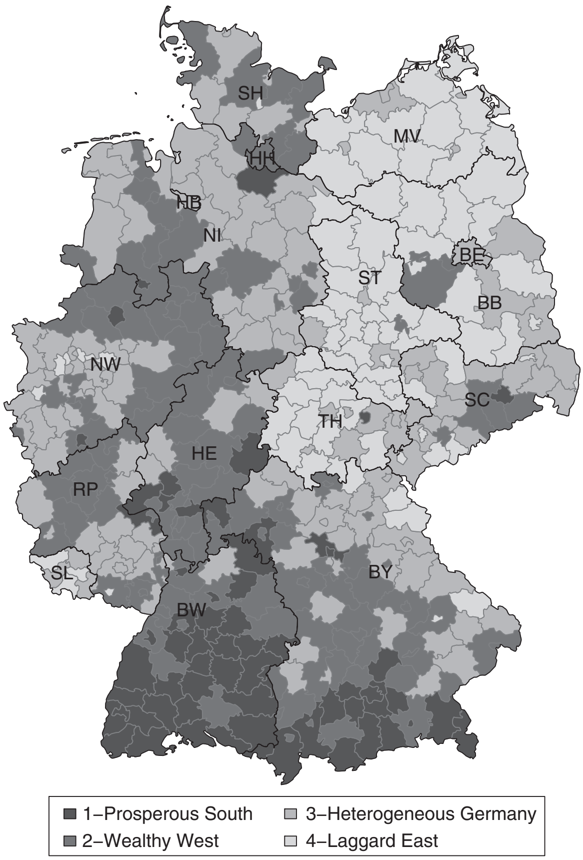

Fig. 4.15 Classification of districts into four clusters according to life expectancy level and change by district; 1995–2006 (pooled). *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western Pomerania, *SC* Saxony, *ST* Saxony-Anhalt, *TH* Thuringia (Data source: Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy 2007)

In addition, some other districts, situated in Hesse, Rhineland-Palatinate, Lower Saxony, and Schleswig-Holstein, fall into this cluster. The city-state of Hamburg also belongs to this cluster. Among the eight eastern German districts in Cluster 2, there are districts in the southwest of Berlin and in Saxony (Fig. 4.15). This cluster is characterized by the second-highest life expectancy of all clusters, but the lowest

Table 4.7 Clustering variables for the classification of districts according to life expectancy level and change and selected socioeconomic context factors by cluster; 1995–2006 (pooled)

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	
	Prosperous South	Wealthy West	Heterogeneous Germany	Laggard East	Germany
# districts	64	136	154	84	438
Cluster variables					
e_0, males (years)	76.91	75.77	74.70	73.09	75.05
Δe_0, males (years)	0.343	0.318	0.336	0.415	0.347
e_0, females (years)	82.28	81.46	80.80	80.06	81.08
Δe_0, females (years)	0.233	0.207	0.230	0.291	0.235
Population					
Population size (in mio.)	14.1	27.3	30.3	10.5	82.2
Population density (per km^2)[a]	305	248	255	128	230
Net migration (per 1,000)	3.6	3.7	1.4	–3.0	1.4
Socioeconomic conditions					
Unemployment rate (%)	7.1	9.3	12.5	18.7	11.9
Income p.c. (in Euro)	17,946	16,500	15,307	13,481	15,808
GDP p.c. (in Euro)	28,093	25,686	22,168	17,534	23,372
Voter turnout (%)[b]	80.9	80.2	78.5	73.8	78.3
Employees w univ. degr. (%)	10.6	8.0	7.2	7.3	8.3

Data source: See Table 4.3 for more information and data sources of variables
[a] Population weighed
[b] Average of years 1994, 1998, 2002, 2005

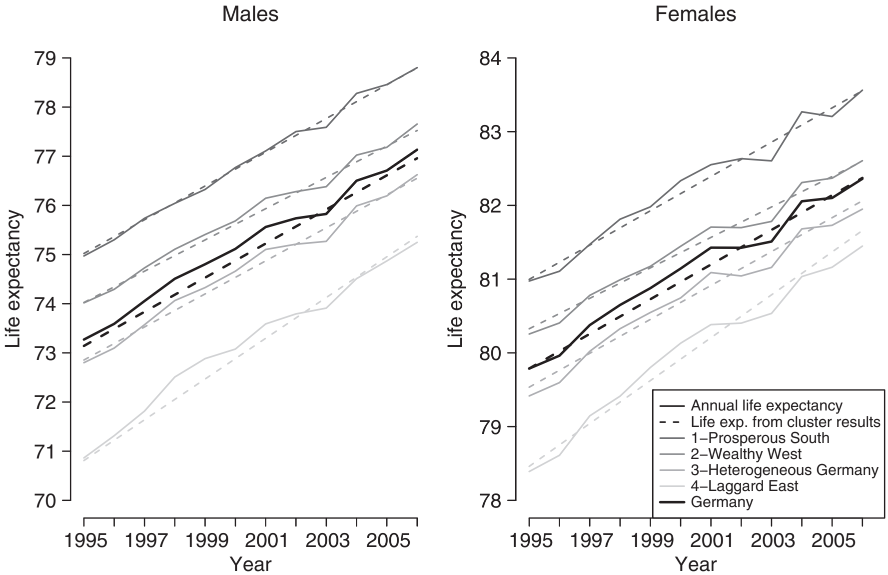

Fig. 4.16 Life expectancy by cluster; 1995–2006. *Dashed lines* show cluster results as in Table 4.7, *solid lines* show population-weighed life expectancy; 1995–2006 (Data source: Federal State Offices of Statistics, Germany)

life expectancy increases over time, and therefore diverges from the Prosperous South cluster. The economic performance of this cluster is strong, with a low unemployment rate and high average income. Levels of positive net migration are slightly above average in this cluster, and voter turnout is almost as high as in the Prosperous South (Table 4.7).

Cluster 3 can be described as the "heterogeneous laggard West and the better-off East," or, for short, "Heterogeneous Germany." It is the biggest cluster, with 154 districts and a population of 30.3 million. It is also the most heterogeneous cluster in terms of geography. In eastern Germany, mainly the southeastern districts belong to Cluster 3. Berlin and urban regions of Saxony-Anhalt and Mecklenburg-Western Pomerania also belong to this cluster. The West German regions in this cluster include the former *Zonenrandgebiet*, or the areas of West German that once bordered the GDR, including the northeastern border of Bavaria (the regions of Franconia and eastern Bavaria). The other districts belonging to Cluster 3 are situated mainly in Rhineland-Palatinate, North Rhine-Westphalia (Ruhr area and districts south of it), Lower Saxony, but also in Schleswig-Holstein and Saarland (Fig. 4.15). Cluster 3 has the second-lowest life expectancy, but absolute life expectancy increases are almost as high as in the Prosperous South cluster. The socioeconomic position of this cluster is slightly below the German average. This also holds for net migration and voter turnout, which may be seen as measures of social capital (Table 4.7).

The remainder of the districts belong to Cluster 4, the "Laggard East." The majority of East German districts make up this cluster. Even though it is the laggard cluster, it has experienced a mortality catch-up, mainly during the 1990s. Despite its name, some of the East German districts, as mentioned above, belong to the other clusters—mainly Saxon districts—while a few West German districts also fall into Cluster 4 (Fig. 4.15). These include several Bavarian districts along or close to the northeastern border with the Czech Republic, three (out of six) districts in Saarland, several Ruhr area cities, as well as Pirmasens (Rhineland-Palatinate), Bremerhaven (Bremen), and Neumünster (Schleswig-Holstein). Cluster 4 has the lowest life expectancy level, but it also experienced the highest life expectancy increase of all of the four clusters. This feature results in a convergence of life expectancy among the clusters. The cluster encompasses 84 districts with a population of 10.5 million. Districts within this cluster are relatively poor. The average unemployment rate is close to 19%, and GDP as well as income per capita are considerably below the national average. Net migration is negative. Voter turnout is the lowest among all the clusters (Table 4.7).

Mortality patterns are now analyzed in more detail, with life expectancy in the Prosperous South cluster being compared to life expectancy in the other clusters.

Figure 4.17 shows the results of the decomposition of the differences in life expectancy between the leading cluster and the three other clusters in 1996–1997 and 2004–2006. While the four upper plots show the varying effects of age-specific mortality on the life expectancy differences, the lower two plots show the cause-specific contributions to life expectancy differences. The values of the cause-specific components of the life expectancy difference are also provided in Table B.6 in the

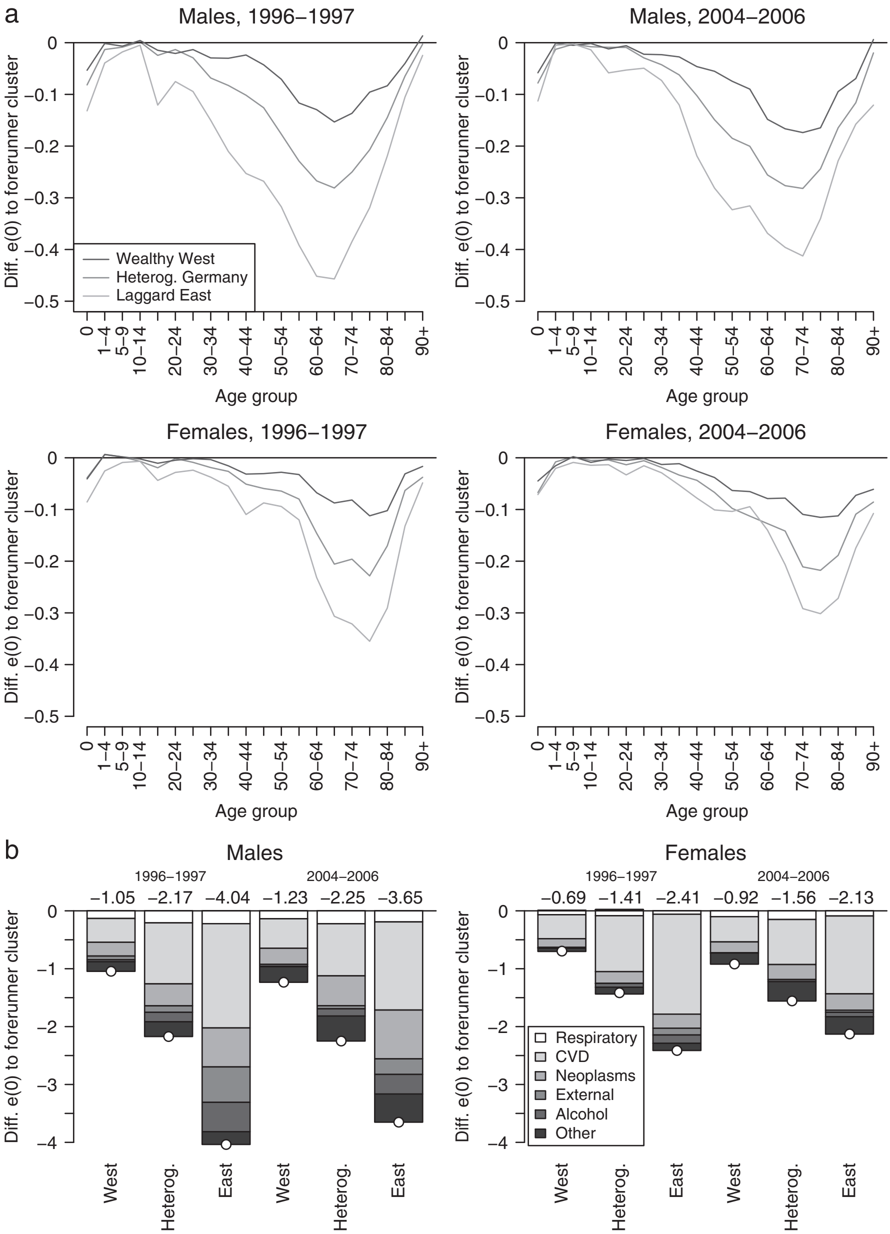

Fig. 4.17 Contribution of age- and cause-specific mortality to differences in life expectancy between the Prosperous South cluster and the three other clusters; 1996–1997 and 2004–2006. (**a**) Contribution of age-specific mortality to life expectancy differences. (**b**) Contribution of cause-specific mortality to life expectancy differences. Note: *Circles* and *numbers* indicate absolute life expectancy difference in years (Data source: Federal State Offices of Statistics, Germany; Research Data Center of the Federal Statistical Office and the Federal State Offices of Statistics, Germany)

appendix, along with more detailed cause-of-death categories, such as lung cancer and heart and cerebrovascular diseases, as well as traffic accidents, suicides, and alcohol-related causes.

Life expectancy is highest in the Prosperous South, where the lowest mortality rates in virtually all age groups and cause-of-death groups are observed. Most of the life expectancy differences between the Prosperous South and the remaining clusters are caused by old-age mortality. Among men, the Prosperous South has the lowest old-age mortality of all the clusters, as well as considerably lower mortality at ages 25–50. The Laggard East shows an accident hump in the age group 15–19, which diminishes with time.

The life expectancy advantage of the Prosperous South relative to the other clusters stems from lower mortality in most causes of death. Only suicide and external mortality as a whole are partly higher than in other clusters, but these small disadvantages hardly influence the overall life expectancy differences (Fig. 4.17 and Table B.6 in the appendix). Lower levels of life expectancy compared to the forerunner cluster are largely due to cardiovascular mortality, followed by cancer and other-cause mortality. Lung cancer constitutes a large part of the cancer mortality contribution. Among men, about half of the life expectancy difference is due to this type of cancer.

Excess external and alcohol-related mortality is another important contributor to the difference in life expectancy between the forerunner and the laggard cluster. In 1996–1997, out of the 4-year difference in life expectancy, 1.1 years can be attributed to these causes. Excess mortality from these causes can also be seen in the Heterogeneous Germany cluster. In all clusters, the impact of these causes decreases over time. The reduction of external and alcohol-related deaths contributed to a great extent to the convergence in life expectancy between the East German laggard cluster and the other clusters. The impact of respiratory mortality on the life expectancy differences relative to the forerunner cluster remains approximately stable over time. Other causes of death make up an increasing share in the life expectancy gap relative to the forerunner cluster.

While there is growing divergence between the West German clusters, the East German laggard cluster converges with the three other clusters. The extent of regional dispersion in life expectancy is well captured by the clusters (cf. Fig. 4.6). The longevity differences between the clusters show up in many causes of death and in many age groups. Apart from the differing levels of mortality, there are no considerable differences in cause-of-death structures.

As expected, mortality differences among the four clusters are associated with different sociostructural traits. The differences in life expectancy correspond to differences in economic development, net migration, and social participation (Table 4.7). Clusters with higher life expectancy have considerably better economic performance, higher population gains due to in-migration, and higher social capital. Interestingly, mortality by cluster does not correspond to the educational differences between all clusters. This only holds true for the predominantly West German clusters.

4.8 Determinants of Spatiotemporal Mortality Patterns: A Pooled Cross-Sectional Time Series Analysis

In this section, the focus shifts to associations between mortality and socioeconomic variables. Having identified the profile of spatial differences in life expectancy across districts and their changes over time, these differences are now connected to trends in district-level mortality determinants.

The preceding cluster analysis showed that clusters that performed well in terms of life expectancy also performed well in terms of social and economic indicators, and vice versa. Other studies of either all of Germany's districts, or of districts within a certain German federal state, have found a similar association in the cross-section. However, the factors that establish the picture in the cross-section are not necessarily the same ones that drive the changes over time (Deaton 2003; Or 2001; Preston 1975; Shkolnikov et al. 2011).

4.8.1 Mortality Determinants in Germany

Several ecological analyses of spatial mortality differences in Germany or regions in Germany, and their relationship to socioeconomic indicators, have confirmed an association between the two (Albrecht et al. 1998; Brzoska and Razum 2008; Cischinsky 2005; Gatzweiler and Stiens 1982; Kemper and Thieme 1991; Kuhn et al. 2006; Lhachimi 2008; Queste 2007; Strohmeier et al. 2007; Wittwer-Backofen 2002). A major drawback of these studies is their cross-sectional setup, as this does not allow for any causal inference to be drawn. The current study is, therefore, a step forward, as it includes a longitudinal component.

Four broad groups of macro-level determinants of regional mortality determinants were discussed in the literature review (i.e., demographic structures and population composition, socioeconomic conditions, medical care provision, and environmental conditions). Before incorporating corresponding explanatory variables into this pooled cross-sectional time series analysis, this section will explore whether there is already some evidence that the indicators of these groups can explain the cross-sectional regional mortality pattern or the changes in regional mortality patterns over time, or even both.

4.8.1.1 Cross-Section

Determinants of regional mortality variation (in Germany) were reviewed in the literature review. Thus, only the most important study results from the more recent ecological mortality studies in Germany shall be mentioned here. Generalizations on the basis of existing studies are possible, even though the time points and the dependent and independent variables used in each of these studies differ.

All of these studies stressed the importance of the association between average income or economic performance and mortality differences in regions. Just as, at the individual level, poorer people tend to die earlier than wealthier people, wealthier regions also exhibit lower mortality. Economic factors seem to drive spatial mortality variations.

Mobility factors have also been shown to be correlated with mortality. Regions with higher in-migration have lower mortality than regions that report higher rates of emigration. Migration is selective, as migrants tend to be healthier, to have better education, and to move to more prosperous areas, which may eventually lead to an accumulation of positive risks and lower mortality. Such a healthy migrant effect is hard to prove, as regions receiving large numbers of in-migrants are usually also the regions with favorable socioeconomic structures.

A correlation between the education of a population and mortality indicators has not been consistently shown. For example, Kuhn et al. (2006) showed that low mortality in Bavarian districts is associated with larger shares of highly qualified employees. The study found that the presence of higher shares of high-school graduates with the *Abitur* degree could explain only an insignificant share of the mortality variation across all German districts (Queste 2007).

The relationship between population structure, such as population density, and mortality is unclear, but the evidence suggests that it has little explanatory power. Mortality and general indicators of health care provision and of environmental pollution usually could not be related (Brzoska and Razum 2008; Cischinsky 2005; Kuhn et al. 2006; Lhachimi 2008; Queste 2007; von Gaudecker 2004; Wittwer-Backofen 1999).

While the dominance of economic and mobility indicators is clear, this brief review of regional mortality determinants also reveals some inherent problems. From a theoretical point of view—which has, for example, been proven using individual-level data—education and the availability of timely and high-quality health care affect the mortality outcome. Environmental factors usually have a weak impact on mortality (cf. von Gaudecker 2004). Most likely, the available indicators in the respective fields do not capture adequately what they are supposed to capture.

4.8.1.2 Time Lapse

There is less evidence in the German context about which determinants can explain mortality changes over time. There are two studies based on pooled cross-sectional time series analysis, which seek to explain mortality at a regional level, and these are described in more detail here.

In a study on regional mortality variation within Baden-Württemberg (44 districts), von Gaudecker (2004) used cross-sectional panel data and applied a RE-model. Sex-specific all-cause mortality was measured for all age groups, for the working-age population groups, and for retired people. A variety of explanatory factors were used to represent socioeconomic conditions, infrastructure, health care, and environmental pollution. As data were not consistently available for all years, regression models were fitted with differing sets of explanatory variables for three time periods between 1983 and 2002. Results differed widely for different types of dependent variables. Income and mortality were consistently found to be negatively correlated. Mortality showed inconsistent associations with education, unemployment, and migration. By contrast, no association was found between health care indicators, environmental pollution, and mortality.

Another study dealt with district-level male under-65 mortality from ischemic heart disease, the most important single cause of death in Germany in 1996–2004 (Schwierz and Wübker 2009). The explanatory factors included in a fixed effects model covered the fields of structural indicators specific to the treatment of IHD, the structure of the acute care hospital features, and socioeconomic factors. Apart from a significant time trend, only intracardiac catheter facilities were shown to significantly explain Germany-wide variations; socioeconomic variables were not found to be associated with IHD mortality.

Apart from these two studies, no similar investigations of the determinants of regional and time variation of mortality in the German context are known. However, Voigtländer et al. (2010) looked at the spatial and temporal variability of potential health-related context factors over the period 1995–2005/2006. Unlike the life expectancy improvements leading to convergence across the districts observed during the 1990s, and the stable dispersion seen during the 2000s, most of the socioeconomic indicators showed growing dispersion across all German districts, with growing disparities emerging within both eastern and western Germany. If the considered factors were drivers of the temporal mortality changes, the trends should be similar in both socioeconomic and mortality indicators. However, Voigtländer et al. did not relate the health-relevant context factors to health indicators.

A few pooled cross-sectional time series studies analyzed different mortality outcomes from the 1970s to the 1990s (main period) in mostly OECD countries (Arah et al. 2005; Macinko et al. 2003; Or 2000, 2001; Spijker 2004). These provided strong evidence to support the contention that income and mortality across countries are negatively related. Health care indicators were partly associated with mortality performance, but these findings depended to a large extent on the type of health care indicator chosen. Other explanatory factors, such as environmental factors or lifestyle behaviors, were found to be partly significant. A direct comparison between studies is, however, impeded due to differing country, time, and indicator selections.

4.8.2 Selection of Possible Mortality Determinants

The theoretical relevance of manifold contextual factors in the groups of economy, social conditions, population education, population structure, and health care has been depicted in the literature review. Table 4.3 showed the contextual factors for the 438 districts and their availability in the years 1995–2006.

For the current analysis, those—mainly readily available—indicators have been complemented by indicators on health behavior and health care performance. Previous analyses have shown that the conventional health care indicators do not seem to be related to mortality outcomes (also seen in Tables 4.8 and 4.9). Young (2001) noted that many indicators are meaningless, as they are confounded by underlying structural factors. Still, the assessment of the quality of the health care system appears to be crucial in explaining high or low mortality. Direct indicators of health behavior at the district level are not available.[8]

Therefore, the concept of mortality amenable to health care and policy was applied (i.e., "avoidable" mortality). This concept makes it possible to quantify the number of deaths that could be averted through timely and effective health care and through effective health policies. Three indicators were constructed, including one on the amenability due to health care, and one on the amenability due to health behavior. The third indicator is a combination of the two, and is labeled the health policy indicator. All indicators were calculated as the SDR from the respective causes of death under age 75 (Nolte and McKee 2004, 2008; Nolte et al. 2002). The SDR (on health care, health behavior, or the combined health policy) is then expressed as a share of the total SDR. The indicator hence reflects the share of "unnecessary" deaths among all deaths. Among the causes responsive to health care are deaths from infectious diseases and certain types of cancer (skin, breast, cervix uteri, testis), as well as several cardiovascular diseases. However, only half of the deaths from ischemic heart diseases were included, as the direct medical impact on this disease is not entirely quantifiable (a list of causes with their respective ICD codes is given in the appendix, Table B.7). Health behavior is reflected in deaths from lung cancer and liver cirrhosis.[9] The combined indicator of health care– and health behavior–related deaths reveals the overall efficiency of health policy.

While it is certainly the case that the sum of cause-specific mortality relates to life expectancy, the health policy indicator makes up only 20% of male and 18% of female deaths (see Tables B.9 and B.10 in the appendix).

After a pre-selection of regional factors possibly associated with mortality (Table 4.3), the selection of specific variables for the cross-sectional time series analysis was based on correlation results and the following criteria:

1. Correlation coefficient between life expectancy and explanatory variables $|\rho|>0.3$ in at least three time points, and data availability for at least ten time points.
2. Low correlation ($|\rho|<0.6$) among the selected variables; in case of high correlation among selected variables, selection of the most meaningful indicators and preference of variables with greater data availability.

[8] The German Microcensus includes questions on health status and health behavior only on an irregular basis. If these fragmentary data were included in the analysis, this would lead to a further reduction of spatial units from 438 districts to 348 Microcensus regions. The GSOEP regularly includes health-related questions, but these suffer from small sample size at the district level, and are sensitive to outliers.

[9] Unlike in other classifications, deaths from traffic accidents were not included here. These deaths are strongly related to population density, and a separate variable on traffic accidents exists.

Table 4.8 Correlation coefficients between life expectancy and district-level context variables, males; 1995–2006

Males	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Economy												
Unemployment rate	**–0.53**	**–0.80**	**–0.75**	**–0.75**	**–0.71**	**–0.72**	**–0.69**	**–0.70**	**–0.70**	**–0.70**	**–0.71**	**–0.70**
Income p.c. in Euro	**0.73**	**0.74**	**0.68**	**0.66**	**0.66**	**0.68**	**0.65**	**0.65**	**0.66**	**0.65**	**0.62**	**0.65**
GDP p.c. in Euro	**0.39**	**0.41**	**0.37**	**0.33**	**0.34**	**0.35**	**0.33**	**0.30**	**0.31**	**0.30**	**0.26**	**0.32**
% employed				–0.14	–0.10	–0.01	0.12	0.16	**0.21**	0.15	**0.26**	0.15
% employed sec. sector		–0.04	0.02	0.03	0.03	0.05	0.05	0.07	0.09	0.09		
% employed tert. sector		0.07	0.03	0.02	0.01	0.00	–0.01	–0.03	–0.04	–0.06		
Private indebtedness									**–0.49**	**–0.54**	**–0.55**	**–0.53**
Net business registrations				**0.19**	**0.17**	**0.47**	**0.52**	**0.42**	**0.27**	0.15	**0.35**	**0.33**
Social conditions												
Voter turnout	**0.62**			**0.40**				**0.68**			**0.66**	
Living space p.c. in m^2	**0.63**	**0.61**	**0.53**	**0.47**	**0.41**	**0.39**	**0.29**	**0.28**	**0.24**	**0.29**	**0.21**	**0.22**
Detached housing	**0.21**	**0.19**	**0.20**	0.14	0.14	0.13	0.09	0.10	0.10	0.13	0.12	0.09
Divorce rate		0.14	0.10	0.13	0.12	0.12	0.14	0.14	0.15	0.13	0.15	**0.18**
Welfare recipients				–0.09	–0.14	**–0.20**	**–0.24**	**–0.28**	**–0.30**	**–0.33**		
Education												
% empl. w university degree					**0.21**	**0.24**	**0.28**	**0.26**	**0.31**	**0.31**	**0.30**	**0.32**
% empl. w/o degree					**0.38**	**0.37**	**0.32**	**0.34**	**0.33**	**0.33**	**0.31**	**0.37**
% school graduates w *Abitur*	–0.03	–0.05	–0.08	–0.07	–0.01	–0.01	**0.32**	0.04	0.04	–0.01	–0.08	–0.03
% school graduates w/o degree	**–0.37**	**–0.33**	**–0.30**	**–0.38**	**–0.42**	**–0.36**	**–0.47**	**–0.42**	**–0.43**	**–0.48**	**–0.44**	**–0.53**
Population												
% annual population change		**0.36**	**0.28**	**0.32**	0.09	**0.53**	**0.62**	**0.63**	**0.52**	**0.59**	**0.57**	**0.59**
% foreigners	**0.54**	**0.53**	**0.51**	**0.49**	**0.45**	**0.48**	**0.45**	**0.44**	**0.45**	**0.41**	**0.42**	**0.48**
Net migration	0.14	0.12	0.08	**0.20**	**0.35**	**0.51**	**0.55**	**0.55**	**0.52**	**0.54**	**0.43**	**0.44**
Population density	0.07	0.06	0.05	0.07	0.04	0.05	0.06	0.05	0.06	0.03	0.04	0.08

(continued)

Table 4.8 (continued)

Males	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Health care and traffic accidents												
Hospital beds	–0.01	0.00	–0.01	–0.01	–0.04	–0.03	–0.03	–0.05	–0.06	–0.07	–0.09	
Physicians	0.14	0.14	**0.16**	0.15		**0.20**	**0.19**	**0.17**	**0.18**	**0.16**	0.14	
Traffic accidents	**–0.53**	**–0.47**	**–0.39**	**–0.29**	**–0.24**	–0.09	–0.03	0.00	0.01	0.00	–0.04	0.09
Fatal traffic accidents	**–0.31**	**–0.26**	**–0.26**	**–0.26**	**–0.21**	**–0.26**	**–0.25**	**–0.19**	**–0.25**	**–0.17**	**–0.18**	**–0.18**
Health care, m		**–0.50**	**–0.49**	**–0.44**	**–0.46**	**–0.36**	**–0.44**	**–0.44**	**–0.45**	**–0.39**	**–0.36**	**–0.46**
Health behavior, m		**–0.59**	**–0.49**	**–0.54**	**–0.48**	**–0.46**	**–0.45**	**–0.47**	**–0.35**	**–0.41**	**–0.39**	**–0.32**
Health policy, m		**–0.69**	**–0.63**	**–0.63**	**–0.59**	**–0.57**	**–0.63**	**–0.60**	**–0.54**	**–0.54**	**–0.52**	**–0.56**

See Table 4.3 for more information and data sources of variables
Bold figures indicate values significant at 0.1% level

Table 4.9 Correlation coefficients between life expectancy and district-level context variables, females; 1995–2006

Females	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Economy												
Unemployment rate	**–0.34**	**–0.64**	**–0.55**	**–0.57**	**–0.48**	**–0.46**	**–0.44**	**–0.44**	**–0.31**	**–0.41**	**–0.40**	**–0.42**
Income p.c. in Euro	**0.65**	**0.63**	**0.55**	**0.54**	**0.49**	**0.45**	**0.44**	**0.43**	**0.39**	**0.44**	**0.38**	**0.41**
GDP p.c. in Euro	**0.43**	**0.39**	**0.36**	**0.35**	**0.30**	**0.26**	**0.26**	**0.22**	**0.17**	**0.22**	**0.20**	**0.21**
% employed				–0.13	–0.02	0.05	0.11	**0.16**	**0.19**	**0.24**	**0.22**	**0.21**
% employed sec. sector		0.00	–0.02	–0.01	0.00	–0.04	0.04	0.08	0.07	0.13		
% employed tert. sector		0.04	0.06	0.06	0.04	0.05	–0.01	–0.06	–0.04	–0.11		
Private indebtedness									**–0.47**	**–0.55**	**–0.53**	**–0.53**
Net business registrations				0.03	**0.15**	**0.26**	**0.32**	**0.26**	0.15	0.06	**0.26**	**0.21**
Social conditions												
Voter turnout	**0.49**			**0.28**				**0.46**			**0.38**	
Living space p.c. in m²	**0.48**	**0.45**	**0.31**	**0.33**	**0.25**	**0.24**	**0.16**	0.14	0.04	0.06	–0.01	–0.03
Detached housing	0.08	0.08	0.05	0.05	0.04	0.00	0.02	0.01	–0.01	0.01	–0.02	–0.04
Divorce rate		0.07	0.06	0.06	0.05	0.03	0.07	0.03	0.02	0.03	0.05	0.08
Welfare recipients				**–0.04**	**–0.16**	**–0.22**	**–0.25**	**–0.26**	**–0.21**	**–0.33**		
Education												
% empl. w university degree					**0.26**	**0.25**	**0.31**	**0.27**	**0.31**	**0.34**	**0.35**	**0.35**
% empl. w/o degree					**0.21**	**0.21**	**0.20**	**0.20**	0.07	0.15	0.09	0.15
% school graduates w *Abitur*	0.04	–0.01	–0.03	–0.04	0.05	0.05	**0.20**	0.01	0.01	0.00	–0.03	0.04
% school graduates w/o degree	**–0.37**	**–0.29**	**–0.29**	**–0.33**	**–0.31**	**–0.30**	**–0.29**	**–0.28**	**–0.24**	**–0.34**	**–0.29**	**–0.38**
Population												
% annual population change		**0.23**	**0.17**	**0.18**	0.08	**0.30**	**0.43**	**0.39**	**0.22**	**0.32**	**0.34**	**0.38**
% foreigners	**0.53**	**0.49**	**0.41**	**0.42**	**0.31**	**0.29**	**0.26**	**0.27**	**0.17**	**0.22**	**0.21**	**0.26**
Net migration	0.05	0.04	–0.02	0.06	**0.20**	**0.26**	**0.36**	**0.32**	**0.21**	**0.25**	**0.22**	**0.26**
Population density	0.11	0.11	0.07	0.09	0.01	0.03	0.02	0.01	–0.02	–0.03	–0.01	–0.01

(continued)

Table 4.9 (continued)

Females	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Health care and traffic accidents												
Hospital beds	0.08	0.06	0.10	0.07	0.08	0.07	0.03	0.01	0.01	–0.03	–0.03	
Physicians	**0.25**	**0.19**	**0.22**	**0.22**		**0.22**	**0.20**	0.16	0.13	0.15	0.14	
Traffic accidents	**–0.43**	**–0.42**	**–0.28**	**–0.16**	–0.09	–0.01	0.00	–0.01	–0.01	0.01	–0.02	–0.05
Fatal traffic accidents	**–0.27**	**–0.23**	**–0.24**	**–0.26**	–0.15	**–0.17**	**–0.16**	–0.10	–0.13	–0.09	–0.09	–0.13
Health care, f		**–0.36**	**–0.34**	**–0.32**	**–0.24**	**–0.36**	**–0.24**	**–0.32**	**–0.27**	**–0.23**	**–0.27**	**–0.36**
Health behavior, f		**–0.16**	–0.10	–0.08	–0.12	–0.10	–0.03	–0.14	–0.10	–0.06	–0.09	–0.06
Health policy, f		**–0.39**	**–0.35**	**–0.30**	**–0.26**	**–0.36**	**–0.21**	**–0.34**	**–0.28**	**–0.23**	**–0.27**	**–0.34**

See Table 4.3 for more information and data sources of variables
Bold figures indicate values significant at 0.1% level

3. Treatment of variables with high correlation with life expectancy and data availability for fewer than ten time points:
   (a) Data availability for six to nine time points: check if high correlation with other selected variables justifies drop-out; otherwise imputation of missing values to obtain ten data points per district.
   (b) Data availability for five or fewer time points: formal check if high correlation with other selected variables justifies drop-out.
4. Preferably same indicators for men and women.
5. Preferably coverage of several fields of explanatory factors.

Tables 4.8 and 4.9 show the correlation coefficients between male and female life expectancy and the various independent variables for all years between 1995 and 2006 in the 438 districts, respectively.

According to the first criterion, the following variables were selected for both sexes: unemployment rate, income, GDP, living space, share of school graduates without any degree, the annual population change, the share of foreigners, and the health care and health policy indicators (sex-specific indicators); among men, net migration, traffic accidents, and the indicator of health behavior were also selected.

In the second step, the question of whether there is a high degree of correlation among these variables was investigated. This was found to be the case for unemployment, which is highly correlated with income (≈−0.7 in most years). Unlike the trend in per capita income, the unemployment trend was found to be nonlinear, and differing definitions over time complicate a comparison in any case. Thus, the variable "per capita income" was chosen due to its more straightforward interpretation in the time lapse. The share of foreigners is highly correlated with GDP per capita (≈0.7 in most years). The share of foreigners was excluded from the further analysis because it seems to reflect the economic performance more than it does the mortality-relevant population structure. Annual population change and net migration, the two indicators of population change, are also highly correlated to each other in most years (correlation coefficients are mainly between 0.7 and 0.94). Given these strong similarities, the annual population change is included in further analyses, as it correlates with both male and female life expectancy. Traffic accidents correlate highly with male life expectancy in the first three time points. As this tends to be less true for women, and because insignificant correlations prevail in the following years, this variable is no longer considered for further analyses. The health care indicators are highly correlated to each other. The health policy indicator was chosen, as it was found to have the greatest degree of correlation with sex-specific life expectancy.

Three variables are correlated with a correlation coefficient of $|\rho|>0.3$ at more than three time points, but are available for only eight or nine time points: the net business registrations, the share of employees with a university degree, and the share of employees without any professional degree. Because these variables are highly correlated with several of the selected variables, their nonuse is preferred over the imputation of missing data.

Table 4.10 Correlation coefficients between life expectancy and explanatory variables selected for pooled cross-sectional time series analysis for Germany, East and West Germany; 1996–2006 (pooled)

	Germany		West Germany		East Germany	
	Males	Females	Males	Females	Males	Females
GDP	0.35	0.32	0.19	0.22	0.40	0.36
Income	0.61	0.46	0.47	0.42	0.59	0.50
Living space	0.49	0.37	0.24	0.22	0.46	0.42
Share school graduates without degree	–0.38	–0.29	–0.28	–0.23	–0.17	–0.17
Population change	0.18	0.07	0.13	0.05[a]	–0.03[b]	–0.06[c]
Health policy (sex-specific)	–0.61	–0.41	–0.47	–0.36	–0.56	–0.50

Data source: Federal State Offices of Statistics; see Table 4.3 for more information and data sources of contextual variables
All values significant at 0.1% level if not indicated otherwise
[a] Significant at 1% level
[b] Not significant
[c] Significant at 5% level

Two variables show a strong association to life expectancy, but the relevant data are only available for four time points: the Schufa index of indebtedness and voter turnout. The Schufa index of indebtedness shows a strong inverse relationship with per capita income. Voter turnout is correlated with several other selected variables, especially at the later time points. Given the high degree of correlation with selected variables, the Schufa index of indebtedness and voter turnout were not considered in the later analyses.

The final selection of independent variables includes household income per capita and GDP per capita, which represent economic conditions, living space as an indicator of social conditions, the share of school graduates without any degree, the annual population change, and the health policy indicator (sex-specific). Complete data for these variables are available from 1996 to 2006, and the analyses are based on this period.

The selection procedure of independent variables excluded those with the highest correlations in order to avoid multicollinearity. Out of the selected independent variables, no correlation coefficient between any of the other variables exceeds 0.5. This value is found between GDP and income per capita. Income is, overall, the variable with the highest correlation to the other independent variables (Table B.8 in the appendix).

Table 4.10 gives a first indication of the results that might be expected from the regression analysis. Correlation coefficients between life expectancy as the dependent, and the six independent variables, are shown, whereby the highest correlations in Germany are with income, living space, and the health policy indicator. This also holds true in the western and eastern German subgroups. The strength of association differs, however, between Germany and the eastern and western German subsamples. Regarding the correlation between life expectancy and population change, the signs are reversed, and are hence negative in eastern Germany, but are not highly statistically significant.

Table B.9 in the appendix shows the descriptive statistics (mean and standard deviation) of the dependent and independent variables for all of Germany and for eastern and western Germany. Table B.10 in the appendix shows the descriptive statistics for the dependent and independent variables in Germany for each year between 1996 and 2006.

4.8.3 Results: Mortality Determinants in the Cross-Section and in the Time Lapse

In this section, the results for the BE-, FE-, and RE-models for Germany (Tables 4.11 and 4.12) and its eastern and western German parts are described (Tables 4.13 and 4.14). If the same factors were determining the difference in life expectancy between the districts, and the increase in life expectancy in the districts over time, this should be reflected in the significance of the same factors in both the BE- and the FE-models. Subsequently, the same significant factors should be revealed by the RE-model. Differing significant factors in the three models hence point to differing explanatory factors of the life expectancy pattern over time and over space. The established links should be viewed as district-level associations, rather than as causal relationships, in order to avoid ecological fallacy.

Before the explanatory variables are discussed, the test statistics are described. RE-models are slightly preferable to FE-models, according to the Hausman statistics. The Breusch-Pagan test indicates that there is a randomly distributed district-specific term. The Chow test indicates significant fixed effects for districts and years.

Models without autoregressive error terms are appropriate because the Durbin-Watson statistic for men and women is just under two, indicating that there is no significant serial autocorrelation of residuals. This is not surprising as structures differ little from one year to another. It could, however, be possible that mortality-determining factors are not captured by the current analysis because of long causal lags (Spijker 2004).

The different R^2s, expressing the share of explained variance—R^2_{within} for the BE-model, and R^2_{within} and R^2_{overall} for the FE- and RE-models, respectively—are mainly above 0.5. R^2_{within} is always above 0.6. Temporal changes of life expectancy are hence best explained by the mortality determinants. The values for the R^2s are always higher for men (Tables 4.11, 4.12, 4.13, and 4.14).

In the following, the results for all German districts are described and complemented by the results for a model including all German districts and a dummy variable for East German districts. Models for the East and West German districts are

Table 4.11 Estimates from pooled cross-sectional time series analysis (between-effects (BE), fixed-effects (FE), and random-effects (RE) models), Germany (438 districts); 1996–2006

	Males			Females		
	BE	FE	RE	BE	FE	RE
Income	**0.161** (0.000)	**0.056** (0.027)	**0.263** (0.000)	**0.123** (0.000)	**0.070** (0.002)	**0.143** (0.000)
GDP	**0.012** (0.001)	–0.011 (0.107)	**0.009** (0.007)	**0.015** (0.000)	–0.012 (0.056)	**0.007** (0.015)
Living space	–0.014 (0.156)	**0.054** (0.000)	**0.058** (0.000)	–0.014 (0.104)	**0.058** (0.000)	**0.016** (0.020)
Share school graduates w/o degree	**–0.057** (0.001)	–0.009 (0.166)	**–0.030** (0.000)	**–0.047** (0.001)	0.005 (0.339)	–0.006 (0.250)
Population change	**0.118** (0.025)	–0.013 (0.135)	0.007 (0.417)	0.040 (0.354)	–0.003 (0.729)	0.001 (0.867)
Health policy (sex-specific)	**–0.425** (0.000)	**–0.046** (0.000)	**–0.075** (0.000)	**–0.206** (0.000)	**–0.065** (0.000)	**–0.074** (0.000)
Year 1996[a]		**–3.161** (0.000)	**–2.771** (0.000)		**–1.969** (0.000)	**–1.974** (0.000)
Year 1997		**–2.688** (0.000)	**–2.304** (0.000)		**–1.598** (0.000)	**–1.585** (0.000)
Year 1998		**–2.322** (0.000)	**–1.968** (0.000)		**–1.400** (0.000)	**–1.382** (0.000)
Year 1999		**–2.058** (0.000)	**–1.814** (0.000)		**–1.216** (0.000)	**–1.215** (0.000)
Year 2000		**–1.800** (0.000)	**–1.635** (0.000)		**–0.995** (0.000)	**–1.003** (0.000)
Year 2001		**–1.382** (0.000)	**–1.225** (0.000)		**–0.769** (0.000)	**–0.765** (0.000)
Year 2002		**–1.232** (0.000)	**–1.084** (0.000)		**–0.773** (0.000)	**–0.765** (0.000)
Year 2003		**–1.216** (0.000)	**–1.120** (0.000)		**–0.741** (0.000)	**–0.738** (0.000)
Year 2004		**–0.541** (0.000)	**–0.462** (0.000)		**–0.191** (0.000)	**–0.182** (0.000)
Year 2005		**–0.391** (0.000)	**–0.340** (0.000)		**–0.215** (0.000)	**–0.203** (0.000)
Constant	**81.745** (0.000)	**74.926** (0.000)	**70.408** (0.000)	**83.425** (0.000)	**80.103** (0.000)	**80.268** (0.000)

R^2_{within}	0.174	0.764	0.758	0.221	0.654	0.651
R^2_{between}	0.780	0.422	0.641	0.498	0.169	0.425
R^2_{overall}	0.485	0.499	0.689	0.333	0.459	0.557
Corr (u_i, Xb)		0.133			–0.009	
Chow		15.35 (0.000)			10.79 (0.000)	
Hausman			–340.75 (na)			148.89 (0.000)
Breusch-Pagan			5,231.92 (0.000)			4,768.52 (0.000)
Durbin-Watson		1.76			1.74	

Data source: Federal State Offices of Statistics; see Table 4.3 for data sources of contextual variables
p-values in parentheses; bold figures indicate β-coefficients significant at 5% level
[a] Reference year: 2006

then considered, and the results are highlighted if they differ from the all-German results.

In the BE-model for Germany, the level effects are indicated, that is, why life expectancy differs from one district to another (Table 4.11). For both sexes, there are highly significant effects of income, GDP, the share of school graduates without any degree, and the health policy indicator. Income and health policy have the strongest effects (determined by the size of β-coefficients relative to the mean of the respective variable). A district with an average annual income that is 1,000 euros higher than the national average is expected to have life expectancies that are 0.16 years higher for men and for 0.12 years higher for women. If the health policy indicator in a district is one unit higher than in another, this yields a life expectancy that is 0.43 years lower for men and 0.21 years lower for women. This is the case when the share of deaths avoidable due to health care or health policy in a certain district is 1% point higher than in another district.

The pace effect in the FE-model, which determines the change of life expectancy over time within districts, is mainly driven by changes in income, living space, and the health policy indicator. The latter factor, however, changes little over time, and therefore has a smaller absolute effect on life expectancy changes than changes in income and living space.

In the RE-model, which is in fact a weighted combination of the BE- and FE-models, income, living space, and health policy again play the most important roles. Furthermore, GDP and, among men, the share of school graduates without a degree are significant. In this model, income has by far the strongest effect on life expectancy.

Thus, the results for Germany in Table 4.11 show that several explanatory factors (income, health policy, living space) have significant roles to play in explaining both the level and the pace of mortality change across districts and time. The life expectancy effects of population change are mainly insignificant.

In order to check whether there is an independent effect of East German districts, a dummy variable indicating the affiliation to eastern Germany was included in the model that encompasses all German districts (Table 4.12). Including this dummy variable yields insignificant effects for women. Among men, the effect is significant and negative in the RE-model. The qualitative direction of the results from the other independent variables remains unchanged. This implies that changes in the population composition determine life expectancy differences between districts, rather than structural East-West differences.

In eastern and western Germany, the most important mortality determinants in terms of effect size are similar to those for Germany as a whole (Tables 4.13 and 4.14). In western Germany, population change, and, in part, the share of school graduates without a degree, also play important roles.

The results for western Germany are very similar to the results for all German districts (Table 4.13). Income has the strongest effect. Other than in the models for Germany, population change in western Germany is significant in most models, and even has a strong role in explaining life expectancy differences between the districts.

Table 4.12 Estimates from pooled cross-sectional time series analysis with dummy for East Germany (between-effects (BE), fixed-effects (FE), and random-effects (RE) models), Germany (438 districts); 1996–2006

	Males			Females		
	BE	FE	RE	BE	FE	RE
Income	**0.179** (0.000)	**0.056** (0.027)	**0.217** (0.000)	**0.134** (0.000)	**0.070** (0.002)	**0.146** (0.000)
GDP	**0.015** (0.000)	–0.011 (0.107)	0.003 (0.318)	**0.016** (0.003)	–0.012 (0.056)	**0.007** (0.013)
Living space	0.007 (0.586)	**0.054** (0.000)	**0.023** (0.019)	–0.002 (0.830)	**0.058** (0.000)	**0.018** (0.033)
Share school graduates w/o degree	**–0.066** (0.000)	–0.009 (0.166)	**–0.025** (0.000)	**–0.052** (0.000)	0.005 (0.339)	–0.006 (0.231)
Population change	**0.131** (0.012)	–0.013 (0.135)	0.003 (0.782)	0.056 (0.206)	–0.003 (0.729)	0.002 (0.836)
Health policy (sex-specific)	**–0.442** (0.000)	**–0.046** (0.000)	**–0.071** (0.000)	**–0.202** (0.000)	**–0.065** (0.000)	**–0.074** (0.000)
Year 1996[a]		**–3.161** (0.000)	**–3.017** (0.000)		**–1.969** (0.000)	**–1.961** (0.000)
Year 1997		**–2.688** (0.000)	**–2.529** (0.000)		**–1.598** (0.000)	**–1.573** (0.000)
Year 1998		**–2.322** (0.000)	**–2.168** (0.000)		**–1.400** (0.000)	**–1.371** (0.000)
Year 1999		**–2.058** (0.000)	**–1.969** (0.000)		**–1.216** (0.000)	**–1.206** (0.000)
Year 2000		**–1.800** (0.000)	**–1.753** (0.000)		**–0.995** (0.000)	**–0.997** (0.000)
Year 2001		**–1.382** (0.000)	**–1.328** (0.000)		**–0.769** (0.000)	**–0.760** (0.000)
Year 2002		**–1.232** (0.000)	**–1.172** (0.000)		**–0.773** (0.000)	**–0.760** (0.000)
Year 2003		**–1.216** (0.000)	**–1.185** (0.000)		**–0.741** (0.000)	**–0.734** (0.000)
Year 2004		**–0.541** (0.000)	**–0.508** (0.000)		**–0.191** (0.000)	**–0.180** (0.000)
Year 2005		**–0.391** (0.000)	**–0.367** (0.000)		**–0.215** (0.000)	**–0.202** (0.000)
Dummy East Germany	**0.379** (0.006)		**–0.711** (0.000)	0.187 (0.110)		0.039 (0.683)
Constant	**80.854** (0.000)	**74.926** (0.000)	**73.313** (0.000)	**82.680** (0.000)	**80.013** (0.000)	**80.126** (0.000)

(continued)

Table 4.12 (continued)

	Males			Females		
	BE	FE	RE	BE	FE	RE
R^2_{within}	0.203	0.764	0.760	0.245	0.654	0.651
R^2_{between}	0.783	0.422	0.631	0.501	0.169	0.427
R^2_{overall}	0.501	0.499	0.689	0.348	0.459	0.558
Corr (u_i, Xb)		0.133			−0.009	
Chow		15.34 (0.000)			10.75 (0.000)	
Hausman			−622.77 (na)			−151.36 (na)
Breusch-Pagan			5,303.80 (0.000)			4,724.54 (0.000)
Durbin-Watson		1.76			1.74	

Data source: Federal State Offices of Statistics; see Table 4.3 for data sources of contextual variables
p-values in parentheses; bold figures indicate β-coefficients significant at 5% level
[a] Reference year: 2006

Table 4.13 Estimates from pooled cross-sectional time series analysis (between-effects (BE), fixed-effects (FE), and random-effects (RE) models), West Germany (326 districts); 1996–2006

	Males			Females		
	BE	FE	RE	BE	FE	RE
Income	**0.164** (0.000)	**0.056** (0.032)	**0.197** (0.000)	**0.130** (0.000)	**0.065** (0.006)	**0.135** (0.000)
GDP	**0.016** (0.006)	–0.006 (0.342)	0.002 (0.540)	**0.016** (0.000)	–0.011 (0.084)	0.006 (0.058)
Living space	0.011 (0.381)	**–0.078** (0.000)	0.000 (0.982)	0.006 (0.584)	**–0.045** (0.022)	–0.001 (0.934)
Share school graduates w/o degree	**–0.054** (0.004)	**–0.032** (0.000)	**–0.043** (0.000)	**–0.035** (0.039)	–0.005 (0.482)	–0.013 (0.051)
Population change	**0.446** (0.000)	**0.074** (0.039)	**0.265** (0.000)	**0.291** (0.000)	0.003 (0.938)	**0.089** (0.001)
Health policy (sex-specific)	**–0.393** (0.000)	**–0.032** (0.000)	**–0.054** (0.000)	**–0.169** (0.000)	**–0.056** (0.000)	**–0.063** (0.000)
Year 1996[a]		**–3.543** (0.000)	**–3.105** (0.000)		**–2.189** (0.000)	**–1.889** (0.000)
Year 1997		**–3.034** (0.000)	**–2.589** (0.000)		**–1.844** (0.000)	**–1.548** (0.000)
Year 1998		**–2.687** (0.000)	**–2.286** (0.000)		**–1.585** (0.000)	**–1.323** (0.000)
Year 1999		**–2.407** (0.000)	**–2.122** (0.000)		**–1.437** (0.000)	**–1.239** (0.000)
Year 2000		**–2.053** (0.000)	**–1.858** (0.000)		**–1.154** (0.000)	**–1.012** (0.000)
Year 2001		**–1.664** (0.000)	**–1.521** (0.000)		**–0.906** (0.000)	**–0.795** (0.000)
Year 2002		**–1.436** (0.000)	**–1.305** (0.000)		**–0.873** (0.000)	**–0.775** (0.000)
Year 2003		**–1.381** (0.000)	**–1.282** (0.000)		**–0.876** (0.000)	**–0.796** (0.000)
Year 2004		**–0.643** (0.000)	**–0.555** (0.000)		**–0.262** (0.000)	**–0.197** (0.000)
Year 2005		**–0.475** (0.000)	**–0.436** (0.000)		**–0.271** (0.000)	**–0.235** (0.000)
Constant	**79.800** (0.000)	**80.668** (0.000)	**75.049** (0.000)	**81.624** (0.000)	**84.387** (0.000)	**80.985** (0.000)

(continued)

Table 4.13 (continued)

	Males			Females		
	BE	FE	RE	BE	FE	RE
R^2_{within}	0.133	0.764	0.758	0.164	0.629	0.626
$R^2_{between}$	0.667	0.193	0.512	0.445	0.150	0.386
$R^2_{overall}$	0.351	0.503	0.627	0.282	0.424	0.513
Corr (u_i, Xb)		0.048			0.033	
Chow		15.07 (0.000)			11.71 (0.000)	
Hausman			217.23 (0.000)			108.70 (0.000)
Breusch-Pagan			3,999.46 (0.000)			3,887.24 (0.000)
Durbin-Watson		1.83			1.85	

Data source: Federal State Offices of Statistics; see Table 4.3 for data sources of contextual variables
p-values in parentheses; bold figures indicate β-coefficients significant at 5% level
[a] Reference year: 2006

Table 4.14 Estimates from pooled cross-sectional time series analysis (between-effects (BE), fixed-effects (FE), and random-effects (RE) models), East Germany (112 districts); 1996–2006

	Males			Females		
	BE	FE	RE	BE	FE	RE
Income	**0.580** (0.000)	0.027 (0.723)	**0.347** (0.000)	**0.213** (0.020)	–0.005 (0.938)	**0.144** (0.008)
GDP	0.025 (0.119)	**–0.046** (0.016)	0.016 (0.190)	**0.036** (0.011)	–0.017 (0.317)	0.018 (0.087)
Living space	**–0.069** (0.041)	0.034 (0.231)	–0.018 (0.410)	**–0.075** (0.011)	–0.048 (0.061)	**–0.073** (0.000)
Share school graduates w/o degree	**–0.063** (0.050)	–0.009 (0.395)	–0.019 (0.068)	**–0.081** (0.004)	0.006 (0.530)	–0.005 (0.554)
Population change	0.000 (0.995)	–0.017 (0.096)	–0.011 (0.277)	–0.041 (0.436)	0.000 (0.980)	0.002 (0.866)
Health policy (sex-specific)	**–0.389** (0.000)	**–0.036** (0.003)	**–0.065** (0.000)	**–0.168** (0.001)	**–0.046** (0.000)	**–0.053** (0.000)
Year 1996[a]		**–4.101** (0.000)	**–3.719** (0.000)		**–3.408** (0.000)	**–3.221** (0.000)
Year 1997		**–3.449** (0.000)	**–3.127** (0.000)		**–2.700** (0.000)	**–2.542** (0.000)
Year 1998		**–2.752** (0.000)	**–2.386** (0.000)		**–2.415** (0.000)	**–2.232** (0.000)
Year 1999		**–2.303** (0.000)	**–2.109** (0.000)		**–1.843** (0.000)	**–1.737** (0.000)
Year 2000		**–2.093** (0.000)	**–2.006** (0.000)		**–1.528** (0.000)	**–1.466** (0.000)
Year 2001		**–1.442** (0.000)	**–1.349** (0.000)		**–1.186** (0.000)	**–1.114** (0.000)
Year 2002		**–1.387** (0.000)	**–1.341** (0.000)		**–1.132** (0.000)	**–1.093** (0.000)
Year 2003		**–1.280** (0.000)	**–1.297** (0.000)		**–0.807** (0.000)	**–0.806** (0.000)
Year 2004		**–0.626** (0.000)	**–0.634** (0.000)		**–0.316** (0.000)	**–0.316** (0.000)
Year 2005		**–0.351** (0.000)	**–0.303** (0.000)		**–0.230** (0.000)	**–0.203** (0.000)
Constant	**76.788** (0.000)	**75.687** (0.000)	**72.544** (0.000)	**83.591** (0.000)	**84.918** (0.000)	**83.278** (0.000)

(continued)

Table 4.14 (continued)

	Males			Females		
	BE	FE	RE	BE	FE	RE
R^2_{within}	0.321	0.804	0.797	0.220	0.749	0.746
$R^2_{between}$	0.654	0.014	0.547	0.407	0.027	0.344
$R^2_{overall}$	0.428	0.522	0.656	0.262	0.574	0.631
Corr (u_i, Xb)		–0.038			–0.006	
Chow		12.56 (0.000)			8.54 (0.000)	
Hausman			58.03 (0.000)			688.71 (0.000)
Breusch-Pagan			997.61 (0.000)			862.34 (0.000)
Durbin-Watson		1.90			1.80	

Data source: Federal State Offices of Statistics; see Table 4.3 for data sources of contextual variables
p-values in parentheses; bold figures indicate β-coefficients significant at 5% level
[a] Reference year: 2006

In the models for eastern Germany, only health policy and income (except FE-models) consistently have significant effects. Income has a very large role in explaining life expectancy differences between the districts. In the FE-models, apart from health policy, only GDP is highly significant among men, though with a negative sign. The time effects are stronger than in Germany as a whole and in West Germany. Even though only a few variables are significant, the R^2s are high.

It is possible to imagine that the model fits have been "artificially" increased through the inclusion of time dummies. In fact, however, R^2s in the FE- and RE-models decrease to a small extent if the models are run without the time dummies (cf. Spijker 2004, pp. 106–107). The time dummies are favored over first-differenced data, as they directly capture the general trend in life expectancy. Similarly, qualitative results do not change when the health policy indicator is excluded. This was done to check whether the indicator, which was built upon cause-specific deaths, artificially increases the explanatory power. It appears, however, that this is not the case (results not shown).

In addition to the full models, Table B.11 in the appendix shows the stepwise procedure in the three different model types. Starting with the variable in which the inclusion yields the highest respective R^2 (within, between, or overall), the next-best variables are subsequently introduced. This shows the overwhelming importance of income and effective health policy implementation in explaining both temporal as well as spatial trends.

Income and GDP are highly correlated, but both were included in the regression models according to the selection criteria (see Table B.8 in the appendix). Including GDP as a single explanatory factor yields significant (and strong) effects, which, however, disappear after including income. Income, in contrast to GDP, includes state transfers in income and financial redistributions, and therefore makes the economic situation more equal.

When comparing the BE-models (which explain the association between life expectancy and mortality determinants), in the cross-section to the FE- and RE-models (which also incorporate the temporal change), it is necessary to take into account the peculiarities of the data selection. The variables were selected based on repeated cross-sectional association with the dependent variable life expectancy. And, indeed, the BE results show that most variables have an independent effect on the cross-sectional life expectancy differences. However, in the model that includes all independent variables, it would still be possible that only some factors actually determine the variation of life expectancy in time and space. In general, income and health policy consistently determine the regional pattern of life expectancy, as well as its changes. East-West differences in life expectancy can be explained by the independent variables considered.

4.9 Summary

The results presented in this chapter extend previous analyses considerably, as the small-area perspective was taken here. All German districts were included in these analyses over the 12-year time period spanning 1995–2006. Life expectancy and cause-specific mortality patterns were compared over time, including means of exploratory spatial statistics. Two different functional classifications of districts were undertaken, and life expectancy and cause-specific mortality between the corresponding clusters were compared. Finally, contextual factors of mainly socioeconomic and structural nature were used to explain spatiotemporal variation in life expectancy.

In the first instance, and from a small-area perspective, it was interesting to discover to what extent life expectancy varies geographically, how this pattern altered, and how regional dispersion of life expectancy changed. In the mid-1990s, low levels of life expectancy in the (north)east contrasted with high life expectancy in southwest of Germany. The cluster of low life expectancy in eastern Germany has partly dissolved over time, especially among women. Among women, high spatial autocorrelation of low life expectancy emerged in the Ruhr area and Saarland with neighboring districts in Rhineland-Palatinate. In general, women show smaller life expectancy differences between the districts, a more plastic spatial pattern over time, and less spatial autocorrelation. Although the dominant spatial pattern remained the same, the spatial heterogeneity has diminished.

A random-coefficient model estimated life expectancy changes from 1995 to 2006 for each district. Levels of life expectancy were converging over time, especially in the 1990s. A quadratic growth curve most closely approximated the life expectancy increases in eastern Germany over time, while in western Germany, an almost linear trend prevailed. The effect was stronger among men. Life expectancy increases were larger in eastern Germany, but this strong increase leveled off over time. As a result, life expectancy in the East and West German districts converged (mainly) before 2000.

These trends were also found to be reflected in changes of life expectancy dispersion across districts. Dispersion—with higher values among men—declined until the late 1990s, and remained stable thereafter. While dispersion across West German districts increased slightly during the observation period, it decreased in eastern Germany. Similar to lifespan disparity, regional variation in district-level life expectancy dispersion was found to be determined by age groups in which a considerable number of deaths occur and in which remaining life expectancy is still considerable. The highest impact was produced by ages 60–74 for men and by ages 70–79 for women, shifting toward higher ages with time.

In the next step, cause-specific mortality in the districts was analyzed. Along with all-cause mortality (and hence life expectancy), similar spatial patterns could be found in cardiovascular, alcohol-related mortality, and male cancer mortality. The highest spatial autocorrelation was found in lung cancer, external, and cardiovascular mortality. Few changes in the spatial pattern of cardiovascular mortality over time contributed to the stability of the all-cause mortality pattern. Relative (rank) improvements in East German districts were related to disproportionate improvements in heart disease and traffic accident mortality, male cancer, and female alcohol-related mortality. On the other hand, relative deteriorations in West German districts were associated with relative deteriorations in respiratory mortality, male lung cancer, and traffic accident mortality. This shows the importance of behavior-related causes in regional patterns of excess mortality.

Spatial autocorrelation decreased between the mid-1990s and early 2000s, and increased thereafter. The factors driving this U-shape trend were dissolving, with clustering occurring in eastern Germany in the beginning of the observation period, and increased clustering taking place in the West later on.

After all of the German districts had been studied, two functional regional divides were established. First, a comparison of mortality in urban and rural regions of eastern and western Germany was made. Second, districts were clustered based on their mortality levels and trends.

In the urban-rural mortality comparison, it is essential to include the East-West perspective, as life expectancy has been higher in rural areas of the West, but in urban areas of the East. The urban-rural differences were shown to be greater among men. The urban-rural gap was small and stable in the West, and it was declining in the East. In western Germany, excess mortality in rural areas was found among young adults, especially among young men, and among the elderly, while a mortality advantage was found for the rural working-age population in the West. In eastern Germany, excess rural mortality existed in almost all age groups, but, again, young adults and the elderly were most affected.

Excess rural mortality among young adults was due to excess mortality from traffic accidents. Excess rural mortality in the East was mainly caused by high cardiovascular mortality. Urban excess mortality—affecting men and women in western Germany and women in the East—was mainly generated by excess mortality from lung cancer, alcohol-related, and other-cause mortality.

For the second functional distinction of regions, four distinct clusters with different life expectancy levels and different average annual life expectancy changes were identified. These four clusters—Prosperous South, Wealthy West, Heterogeneous Germany consisting of laggard West and better-off East districts, and Laggard East—principally captured the extent of district-level life expectancy differences. Many districts within a cluster were neighboring districts. At the same time, similarities in mortality profiles indeed extended over the boundaries of federal states, but the East-West and North-South divides were still pronounced. Interestingly, several distinct outliers interrupted the continuity of the geographical patterns. It was also demonstrated that the socioeconomic performance of the clusters was more favorable where life expectancy was higher.

Out of the four clusters, two experienced roughly average life expectancy increases. The Laggard East had a lower life expectancy level, but experienced steeper increases over time. The cluster Wealthy West lost in relative terms, and also diverged from the highest life expectancy cluster over time. Age- and cause-specific structures appeared to be similar in all of the four clusters, but the mortality levels were different.

Finally, the sociostructural determinants of regional mortality differences at the district level were assessed. A pooled cross-sectional time series analysis for the years 1996–2006 sought to locate determinants of differences in life expectancy across the districts and over time. This made it possible to distinguish between space and time components of the mortality variation. Six variables were selected, covering a variety of social and economic conditions in the districts. These were average disposable income per capita, GDP per capita, living space, the share of school graduates without any degree (reflecting educational status), annual population change, and a health policy indicator based on the share of avoidable deaths due to health care and health-related behavior.

In the models for Germany and western Germany, many variables had significant effects, especially in the BE-models explaining the spatial variation in life expectancy. The strongest associations were found between life expectancy differences—in space and over time—and income and health policy. These two factors explained a large portion of the life expectancy differences between districts, that is, districts with higher average income and more successful health policy implementation experienced higher levels of life expectancy. Although these two factors were also able to explain life expectancy changes over time, increasing average living space and GDP were associated with life expectancy increases as well. While the educational level of school graduates was shown to be associated with life expectancy in the cross-sectional distribution of life expectancy, there were few associations found in the changes. Population changes were only slightly related to regional life expectancy differences in space and time.

Existing East-West mortality differences mainly disappeared once the socioeconomic background of the districts was accounted for; the inclusion of an East-West dummy added virtually no effect. Observable East-West differences can hence be related to different socioeconomic structures in the East and the West.

4.10 Discussion

This chapter has shown the power of the small-area mortality analyses to substantially add to the prior state-level analyses. This section will open with an exploration of some (data) problems, and will then move toward a discussion of the deducted implications.

A general study limitation was the small number of deaths (and small population sizes) in some districts. It is unclear how this could have biased the results. It is also unclear how the questionable quality of the population denominator at old ages (Human Mortality Database 2008a; Jdanov et al. 2005) is reflected in the small-area analyses. In both cases, it can be assumed that these issues have a minor impact on the qualitative meaning of the presented results, as the data were usually aggregated over 3 years, maps were based on data quintiles, and other aggregations were carried out.

Unfortunately, limited data availability for several federal states inhibited the study of longer time series. Partly, limited data availability refers to territorial changes of the East German districts, which makes it impossible to construct comparable regional time series over a long time period. Furthermore, territorial changes are not captured at all in the cause-of-death statistics at the district level that are provided by the Research Data Center of the German Federal Statistical Office and the German Federal State Offices of Statistics. This meant that a direct comparison was only possible for the years 1996–2006.

Associations between mortality and crude, readily available health care indicators have not been found so far in Germany. These indicators of the health care system appear to be meaningless, as they result from a purely administrative form of delivery that does not provide information about the quality or effectiveness of the system. However, it seems that more refined health care indicators in fact reveal an association with mortality (Schwierz and Wübker 2009), as does the incorporated indicator on health policy implementation. The health policy variable reflects both the quality of health care and the effectiveness of health policies acting on health behavior.

Apart from the implied meaning, the independent variables can have more complex meaning. Graduates without any degree may not only reflect the educational status. This variable could also be seen as an indicator of social performance, as graduation rates are partly related to political will. Educational policies are developed by the federal states, and therefore differ regionally. The amount of available living space is greater in the countryside than in the cities, where single-person households are more prevalent. Eastern Germany experienced greater increases in living space than western Germany. The unexpected directions seen in the mortality effects of living space may therefore mirror the complexity of this variable.

In addition to the problem with health care indicators, several other desirable contextual factors are not available at the district level. No data of reasonable quality exist, for example, for nutrition and smoking or environmental pollution. This may be one reason why most of the environmental indicators are found to be insignificant in other studies (cf. von Gaudecker 2004). An examination of the impact of smoking on mortality (Ezzati et al. 2002) and on mortality differences between population groups (Pampel and Rogers 2004; Rogers et al. 2005) suggests that smoking habits likely contribute to regional mortality differences. As smoking behavior exhibits a social gradient, it is likely that the association between socioeconomic district characteristics and mortality is more directly related to smoking. Further studies could assess the contribution of smoking behavior on regional mortality differences by applying indirect methods of smoking-attributable mortality (Peto et al. 1992; Preston et al. 2010).

The comparison of mortality trends in the urban and rural areas of Germany was based on the administrative classification of districts. This classification may mask differences, as some rural districts include a city. Further analyses could be made, incorporating, for example, the proximity of rural areas to bigger cities. Incorporating different urban-rural classifications goes beyond the scope of this work.

Ecological fallacy is a potential problem in the pooled cross-sectional time series analysis, as associations between mortality and dependent contextual variables cannot be automatically transferred to the individual level. Therefore, the associations at the regional level should not be viewed as causal relationships. However, interpreting the established links between mortality and contextual variables as regional-level associations provides considerable insight into the problems of high-mortality regions.

Lower urban mortality at old ages may be explained by two lines of reasoning. First, excess mortality at working ages may lead to the survival of the strongest into old age, and may therefore constitute a selection effect. Second—a direct effect—urban regions may provide better and more timely medical care, which affects mainly elderly people.

Along with mortality, population and infrastructure differ between East and West German urban and rural regions. From the western German countryside, urban facilities are reachable within a reasonable amount of time (cf. Queste 2007). The eastern German countryside is less densely populated and is more remote, and the degree of car dependency may be higher. Settlement of young families in the outskirts of West German cities starting in the 1960s reinforced the described mortality structures. Previous studies have shown that a strong urban-rural divide exists in Mecklenburg Western-Pomerania but have also found low levels of mortality in the outskirts of Rostock, where young families settled after reunification (Kibele 2005). This suggests that a Western settlement pattern may have extended to the major eastern German centers after 1990 and also demonstrates the heterogeneity in rural settlements. Towns close to bigger cities are likely to be very different from those situated more remotely.

An advantage of the cluster approach is that it incorporates the temporal dimension. In fact, marked differences in the life expectancy increase were found between some of the clusters (three different life expectancy growth patterns in four clusters).

As expected, a clear association was found between life expectancy and socioeconomic indicators. This finding agrees with other studies that either clustered regions based on mortality, and then related them to socioeconomic and health care indicators (Ruger and Kim 2006; Shelton et al. 2006), or clustered according to socioeconomic indicators, and then compared mortality between the clusters (Murray et al. 2006; Spijker 2004; Strohmeier et al. 2007).

As the observed East-West differences in life expectancy can be related to different socioeconomic structures in the East and the West, this implies that the elimination of these differing circumstances could lead to an elimination of East-West mortality differences. However, differences in lifestyle and health behavior are greatly mediated by socioeconomic factors. Hence, these differences likely strengthen the observable association between socioeconomic structures and regional mortality differences.

Given the widening social inequalities in morbidity and mortality in Europe, including Germany (Kunst et al. 2004; Lampert and Kroll 2008; Mielck 2008; Rau et al. 2008; Scholz and Schulz 2008), it is remarkable that a convergence of regional mortality has taken place in Germany. This is mainly attributable to large mortality decreases in East German regions. It is possible that wealthier people in particular benefited from this mortality decline, which has led to overall regional mortality convergence.

A recent mortality study on Germany in 2002 dealt with the clustering of the districts in the federal state of North Rhine-Westphalia (Strohmeier et al. 2007). Though this study clustered the 54 districts into six regions according to socio-structural variables, the classification is similar to the one chosen for this study. This confirms the results, and additionally shows that clustering, whether based on socio-economic determinants or on mortality patterns, yields consistent results.

The pooled cross-sectional time series analysis is unique in the sense that it extends the spatial entity to the whole of Germany with all its districts, and covers the period from 1996 to 2006.

Income and a health policy indicator mainly determine both spatial differences, as well as temporal changes of life expectancy. This income-mortality association is in line with findings from other studies involving the longitudinal perspective (Spijker 2004; von Gaudecker 2004), and even more so with findings from studies involving the cross-regional perspective (Brzoska and Razum 2008; Cischinsky 2005; Kuhn et al. 2006; Lhachimi 2008). Even though income and GDP are correlated, these two factors have independent effects on life expectancy differences and changes. This demonstrates the importance of fiscal policy, which leads to a redistribution of income, and which is not captured by the GDP variable.

Incorporating longer time series would certainly be beneficial. This would allow for the inclusion of time lags (cf. Spijker 2004) and should result in stronger associations between context and mortality outcome.

In the following, the implications of these results are assessed, and the question of what regional mortality scenarios may be expected in the future is considered.

Over time, the female pattern diverged from the male pattern. Women seem to adjust more quickly to current conditions. Less risky behaviors spread more rapidly among women, as reflected in the trends of external and alcohol-related mortality.

In order to decrease regional excess mortality and its regional variation, excess mortality from behavior-related causes of death must be reduced. As in the case of lifespan disparity, those age groups among whom a considerable number of deaths occur, and among whom spatial variation is apparent, should be targeted in order to decrease spatial dispersion.

Evidence shows that, in the short run, a continuation of the current spatial life expectancy pattern can be expected. Mortality trends will continue to be strongly dependent on economic development. Sociostructural trends in small areas tend to be rather stable over time, but the East German trends constitute an exception. For example, in Bavaria, the regional pattern of prosperous and laggard regions—and, along with them, a mortality gradient—emerged many decades ago, and remained stable thereafter (Kuhn et al. 2006). Furthermore, from a European perspective, it has been shown that the patterns of within-country mortality differences have remained stable since at least the 1960s, even though large mortality improvements have occurred (Valkonen 2001). In addition to eastern Germany, there are also western German regions that are undergoing significant economic structural changes, and these changes are partly reflected in mortality. These regions are situated in the Ruhr area and Saarland, and also include several smaller areas, like Bremerhaven or Pirmasens.

A suspected time trend could be a twofold division of mortality trends, arising from a greater divergence between regions with good and bad performance, and, at the same time, an assimilation of mortality trends within these groups takes place. This is supported, for example, by the new results on spatial autocorrelation, which have revealed that, after the dissolution of regional mortality clusters, other clusters have emerged. The East-West mortality divide is marked by structural differences, as the results of the pooled cross-sectional panel analysis have shown.

In the East, it is likely that the rural infrastructure in remote areas will worsen due to depopulation. In combination with selective migration to larger cities and their surroundings, mortality in the remote rural areas may worsen in relative terms. It is clear that the mortality decline in East German districts will not continue at the same rapid pace that was seen until recently. Generally, for all regions, policies should focus on reducing fatal traffic accidents and improving medical treatment for the elderly in the rural areas. In urban areas, health policies should aim at improving mortality directly related to behavior.