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Eva U.B. Kibele

Regional Mortality Differences in Germany

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Regional Mortality Differences in Germany

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Foreword

This volume, Regional Mortality Differences in Germany, by Dr. Eva Kibele, is the 10th book of the series of Demographic Research Monographs published by Springer-Verlag. Dr. Kibele is currently working as a postdoctoral researcher at the Population Research Centre at the University of Groningen. The book is based on her doctoral dissertation, which was completed at the Max Planck Institute for Demographic Research in Rostock and was defended at the University of Rostock.

Dr. Kibele's study is an innovative, systematic, and comprehensive work that represents an important contribution to knowledge on the geography of death. It establishes a higher standard for studies in this research field. This thorough and systematic analysis addresses almost all aspects of regional mortality patterns and their temporal changes in Germany and uses all available data sources related to the topic. The study is the first to introduce analysis of the combined effects of individual- and contextual-level determinants of old-age mortality across the entire national population. All of the analyses returned a range of intriguing, substantive results. The book has the potential to become a conventional reference for future studies on differential and regional mortality in Germany and other developed countries.

The book begins with a literature review that provides a critical appraisal of existing knowledge on mortality in Germany, the East-West mortality differential, and regional patterns. The next chapters present original research that is grouped into three analytical blocks devoted to regional mortality patterns and trends at the level of the German federal states (*Bundesländer*); detailed spatial and temporal mortality variation across small-area units, the districts (*Landkreise* and *kreisfreie Städte*); and, finally, individual and area-level variation in the hazard of death for German pensioners aged 65 and older.

These analytical blocks address a sequence of important demographic and health issues. First, the principal patterns and peculiar nuances of spatial mortality variation are identified. The study shows how differential mortality decline modifies these patterns in such a way that some of them tend to persist, while others become less pronounced. Second, the major age and cause-of-death components of changes in the length of life across space and time are assessed. Third, the factors that underlie geographical and longitudinal mortality variation and similarities and differences between mortality patterns are highlighted. Fourth, the factors that determine mortality variation among individuals are assessed. Finally, Dr. Kibele analyzes how contextual influences modify the risks associated with individual characteristics.

The study is very successful in obtaining meaningful results from huge amounts of multidimensional data by means of both established and novel instruments. Specifically, the lifetime losses measure is used for expressing the amount of diversity in age-at-death distributions, the dispersion measure of mortality is used for assessing the amount of regional diversity in length of life, the k-means clustering approach is used for forming clusters of areas with similar longevity trends and patterns, panel regression variants are used for explaining time trends and cross-sectional variation of mortality, and multilevel modeling is used for assessing individual- and contextual-level effects and cross-level interactions between individual and contextual levels.

The study includes meaningful and somewhat unexpected results that cast new light on mortality patterns in Germany. The findings indicate that, apart from general East-West and North-South mortality gradients, some new problem areas are emerging in the West, and some new healthier areas are emerging in the East. While disparity in lifetimes in the GDR was lower than in the FRG, this difference between East and West is diminishing as the life expectancy gap between the two parts of Germany becomes smaller. Some big cities in the North-West experience particularly high lifetime disparities, combined with average or even higher-than-average mean lifespans. Two analyses of the space-time mortality variation across districts and of the mortality risk by type of medical insurance at the individual level suggest that health care plays an important role. The significance of this factor in the results is in contrast to the findings of many prior studies, which failed to show any relationship between mortality and medical care. Multilevel modeling shows that area contexts matter for people's health even after accounting for important individual-level characteristics. In addition, it appears that the strength of the effects of individual-level factors depends on context factors.

Readers will find in the book information about many aspects of German mortality, as well as novel findings and excellent illustrations of the application of the methods to real data. The book will be useful for scholars and students of demography, population geography, public health, epidemiology, and other humanitarian disciplines.

The series of Demographic Research Monographs is under the editorial supervision of the Max Planck Institute for Demographic Research. Prof. James W. Vaupel is Editor-in-Chief. He is advised by an Editorial Board that currently consists of Prof. Elisabetta Barbi (Sapienza University of Rome, Italy), Prof. Gabriele Doblhammer (Rostock University, Germany), Dr. Jutta Gampe (Max Planck Institute), Prof. Joshua Goldstein (Max Planck Institute), and Prof. Bernard Jeune (University of Southern Denmark). Additional members are temporarily appointed to the Editorial Board as needed to review manuscripts submitted for possible publication. The current manuscript was reviewed and accepted by Prof. Gabriele Doblhammer, Dr. Vladimir M. Shkolnikov, and myself. The Editors thank Miriam Hils for helping prepare the manuscript for publication.

The Demographic Research Monographs series can be considered the successor to the series called Odense Monographs on Population Aging, edited by Jeune and me. The volumes in this now-terminated series were first published as hardcover books by an academic publisher, Odense University Press, and subsequently made available online at www.demogr.mpg.de/books/odense. The nine Odense Monographs on Population Aging include two collections of research articles that focus on specific subjects on the frontier of demographic research, three volumes by senior researchers that present path-breaking findings, a review of research on a topic of emerging interest, a presentation of a new method for analysis of demographic data, and outstanding doctoral dissertations, and a unique collection of important demographic data on nonhuman species.

The series of Demographic Research Monographs continues this mix, with books that are often under 200 pages in length but can, like the current volume, be much longer, that have a clear focus, and that significantly advance demographic knowledge. Research related to population aging continues to be a focus on the series, but it is not the only one. We hope that eventually the series will embrace all of demography, broadly defined.

Each volume in the Demographic Research Monographs series will have a substantial link to the Max Planck Institute for Demographic Research. As well as being published as hardcover books by Springer-Verlag, the volumes of the Max Planck series of Demographic Research Monographs will subsequently be available at www.demogr.mpg.de/books/drm. The online version may include color graphs, supplemental analyses, databases, and other ancillary or enhanced material. Parallel publication online and in print is a significant innovation that will make the monograph series particularly useful to scholars and students around the world.

Editor-in-Chief

James W. Vaupel
and
Vladimir M. Shkolnikov

Preface/Acknowledgments

This dissertation was written at the Max Planck Institute for Demographic Research (MPIDR). The institute provided an excellent and inspiring work environment and allowed me to engage in daily exchanges with excellent researchers. While at MPIDR, I especially benefited from participating in the European Doctoral School in Demography, in courses provided by the International Max Planck Research School for Demography, participating in conferences, and interacting with teachers, students, and other researchers.

I would like to thank my supervisors James W. Vaupel and Gabriele Doblhammer for their supervision and guidance throughout this thesis. Vladimir Shkolnikov has guided me as a mentor on all issues related to this dissertation. He provided advice on specific details, in addition to always making sure I remained focused and on track. I highly appreciate his support and encouragement over the last few years. His contribution is hard to put into words but deserves a big thank you!

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I am especially grateful to Domantas Jasilionis and Sebastian Klüsener for their willingness to provide me with critical and encouraging feedback on various parts of my thesis. Alyson van Raalte, Marleen Dettmann, and Hilko Cords read and commented on parts of the thesis. In addition to giving me scientific feedback, they all shared their excitement with me and kept my spirits up, even when my enthusiasm flagged. Giancarlo Camarda and Sabine Schnabel were among those who encouraged me to use R and LATEX, and they kept their promises to help me when trouble arose.

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Apart from those I have already mentioned, I wish to thank my dear partner, the many friends, family members, and colleagues who shared my life over the last few years, and who found time to talk with me about my work. Their individual contributions to this thesis—sometimes simply by providing a welcome distraction from work—are hard to quantify. Yet, their generous support has been invaluable and is appreciated as much as the assistance I received from those mentioned above.

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Chapter 1
Introduction

Since reunification, great efforts have been made in Germany to achieve comparable social and economic conditions in the two parts of the country, including in the area of health. By the 2000s, the East-West life expectancy gap had closed among women, though it persisted among men. Amid these ambitious campaigns to equalize social and economic conditions at the macro level, the small-scale differences that remained attracted less attention. Although Germany is a country with a federal system, attempts were nonetheless made to create comparable living conditions (*gleichwertige Lebensverhältnisse*) throughout the country, as is prescribed in the German Constitution (Barlösius 2006).

The variation in regional mortality in Germany is the subject of this book. From a broader European perspective, regional mortality differences in Germany are at a medium level, but discrepancies of several years in life expectancy at birth can still be found between the regions (European Communities 2009; Valkonen 2001). Studying Germany's regional mortality patterns is particularly interesting given the German divide, which provides researchers with the opportunity to study the short- and long-term effects of different regimes. Spatial patterns and temporal trends at different regional levels are investigated for a period of time before and after German reunification. While the analyses go beyond East-West differences, given the "natural social experiment" of the German divide, these differences are incorporated into the analyses. Together with the study of patterns and trends, mortality determinants at the individual and at the contextual level are investigated.

Demographic change—as determined by processes in fertility, migration, and mortality—across Germany's regions and the societal and political implications of these changes are topics that have sparked considerable debate. However, very little research has been devoted to the component of regional mortality differences. This section will first discuss how regional mortality differences are embedded into research on health inequalities. The aim of the study is then described, and the approach used in this study to address these objectives is outlined.

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Health is a key human right, and health equity is a central principle in social justice (Sen 2002; World Health Organization Europe 1998). Equity in health is stated as a general goal of the World Health Organization (WHO), and is especially important in their framework "health for all in the twenty-first century," which has been adopted by all of the WHO member states (Zöllner 2002). Furthermore, the reduction of health inequities is considered a cost-efficient way to improve general population health (Dahlgren and Whitehead 2007). By contrast, the costs associated with bad health—including, for example, high treatment costs and absences from work—are high. As a result, health equity triggers population wealth and well-being, and vice versa (Anand 2002; Leon and Walt 2001; Zöllner 2002).

A distinction should be made between health equity and health inequality. The latter refers to the existence of unequal conditions in health. Unequal conditions in health will always exist due to differences in the population that cannot be altered (age, sex, genetics; Dahlgren and Whitehead 2007). Health equity judges whether these inequalities are fair or not. Inequity presents the part of inequality that is "avoidable by reasonable action" (Marmot et al. 2008, p. 1661).

Measuring health inequalities is an important step toward assessing health equity. The assessment of health inequalities is usually based on comparisons between geographical areas (countries or subnational entities), or on comparisons between groups of people, such as between different socioeconomic classes within geographical areas (Leon 2001; Marmot 2005; WHO Commission on Social Determinants of Health 2008; Zöllner 2002).

A few examples highlight the issue of mortality differences between and within countries. Between countries, differences in life expectancy at birth can be more than 30 years worldwide, and up to 10 years across OECD countries (Human Mortality Database 2008b; WHO Commission on Social Determinants of Health 2008). Between the regions of one country, large differences may also exist. Life expectancy differences in 1999 across 2,068 county units in the USA constituted 11 years among men and 7.5 years among women. These values refer to the 2.5% of the US population with the highest life expectancy, and the same percentage of the population with the lowest life expectancy. While life expectancy in the USA rose by several years in the second half of the twentieth century, this life expectancy increase was unevenly spread across the county units. Most strikingly, almost 10% of the county units experienced a decline in female life expectancy toward the end of the twentieth century (Ezzati et al. 2008).

These results illustrate that there are not only great mortality differentials between regions, but also that trends observed at the population level can be counteracted by trends in certain population groups that are moving in the opposite direction.

Within each region, mortality is further differentiated by the socioeconomic status of the population. It has long been known that people with lower socioeconomic status tend to have higher mortality risks than those with higher status (Antonovsky 1967). The Black Report on inequalities in health in the UK, which was commissioned by the Department of Health and Social Security, attracted considerable attention when it was published in 1980 (Townsend and Davidson 1992). Subsequently, social gradients in health and mortality were established for many other countries.

While there is no consensus regarding absolute mortality inequalities, it is generally acknowledged that relative mortality inequalities by socioeconomic status have been widening over the last few decades (Kunst et al. 2004; Valkonen 2001).

Parallels between the mortality differentials within and between countries are visible. Several causes of death with a strong mortality gradient across socioeconomic groups have also been found to have a similar gradient across countries and regions (Leon 2001).

Combining the dimensions of inequalities between regions and population subgroups yields the greatest differentials. For example, Murray et al. (2006) divided the US population by county and race (and a few other county-level indicators) into eight distinct groups. They are called the "Eight Americas," because the groups differ considerably with respect to race, several socioeconomic characteristics, and location, as well as in their mortality levels and structures. Life expectancy between the best- and worst-performing "Americas" (Asian versus high-risk urban black) constituted 15.4 years among men and 12.8 years among women in 2001.

More recently, different sources of information on geographical, as well as on individual health variation, have been combined in order to assess whether there is an independent effect of geographical context on health apart from individual risk factors. This line of research reveals that regional context effects are present, and that people with lower socioeconomic status tend to exert greater detrimental regional effects on health (Pickett and Pearl 2001; Riva et al. 2007).

In line with the international situation, Germany exhibits both regional mortality differences and mortality differences between population groups. Both perspectives are increasingly gaining scientific and political recognition (e.g., Cromm and Scholz 2002; Gans 2008; Luy 2006; Mielck 2008; Razum et al. 2008; Shkolnikov et al. 2008).

When the performance of German regions is compared, the roughest division is usually the one between eastern and western Germany. Considered a natural social experiment, the division of Germany produced different structures, which, at least in part, persist 20 years after reunification. The division of Germany was also reflected in mortality differences between East and West. The differing economic, social, medical, and environmental conditions in the two parts of Germany were therefore thought to explain East German excess mortality (Diehl 2008; Dinkel 2000; Gjonça et al. 2000; Luy 2004). Large small-area mortality differentials both within East and within West Germany were thereby disregarded (Razum et al. 2008). However, these differences often exceeded East-West differences. This study provides empirical evidence on mortality trends in small regional units, the German districts. These trends are then connected to East-West differentials.

There are even greater mortality differentials between population groups than between regions in Germany (Geyer and Peter 1999; Helmert 2005; Lampert and Kroll 2006; Luy 2006; Mielck 2005; Reil-Held 2000; Shkolnikov et al. 2008). Life expectancy differences between population groups—according to occupational status, education, or income level—amount to several years. Regional populations in Germany differ, however, with regard to their socioeconomic structures, which are often imposed by the predominant economic branches (Statistisches Bundesamt 2006; Voigtländer et al. 2010). These differing population compositions imply that at least part of the regional mortality differences can be traced to such compositional differences. It is, however, unclear to what extent this is the case, and whether or how the individual mortality risks are related to the regional context. This study is the first to explore these relationships for Germany.

The observation of regional mortality differences in Germany is not only interesting from the perspective of health equity. These differences are also part of demographic change in Germany, which affects the regions to varying degrees. Demographic change and its consequences for the population size and population composition of Germany's regions have been fixtures of the political debate in Germany over the past decade. Among the major demographic issues raised in this debate are the challenges and even threats posed by aging and population changes due to migration and fertility trends (Bertelsmann Stiftung 2006; Bundesministerium für Familie, Senioren, Frauen und Jugend et al. 2007; Kröhnert et al. 2006; Neu 2006; Swiaczny et al. 2009; Weber and Klingholz 2009). Longevity is yet another factor in the aging of the population. However, because having a longer lifespan often means more time spent in better health (Christensen et al. 2009), longevity is regarded more positively than the other factors underlying demographic change. Among the demographic factors driving regional population changes in Germany, longevity has been the least-studied in the regional context, and thus deserves additional attention (Mielck 2007; Razum et al. 2008).

Earlier regional mortality research in Germany was missing some important features. Previous research mainly focused on either the federal states or on the districts; and, in the latter case, most studies looked at districts only within a particular federal state. So far, almost all regional mortality analyses in Germany have neglected longitudinal considerations, both in the investigation of mortality patterns as well as in the explanation of these patterns.

Previous research on regional mortality differences in Germany sought to explain these differentials at the regional level only. However, it is known that substantial mortality differences exist between population groups, such as socioeconomic groups, and that the population composition differs regionally. How these regional and compositional differences interact with each other is not known.

This study seeks to fill this research gap. More specifically, the study investigates regional mortality differences within Germany at different spatial levels over time. It attempts to identify mortality determinants over space *and* time. Underlying age- and cause-specific patterns are investigated. The role of the East-West differentials in the mortality variation across space and time are assessed. This study further takes into account the knowledge about regionally varying population composition and differential mortality between population groups. It seeks to demonstrate whether regional mortality differences are attributable to regional differences in population composition, to regional context, or to an interplay between the two factors.

In the following, this study's approach to the research topic will be described. The study begins with an analysis of the differences between East and West. This is followed by a comparison of the mortality structures in the German federal states, and then in the districts at the small-area level. The traditional approach of looking at mortality differences based on life expectancy is complemented by an examination of lifespan disparity, which provides new insights into inequalities in age at death.

Life expectancy trends are not identical to trends in lifespan disparity, which makes it possible to identify which ages determine the lifetime losses. For the first time, cause-specific mortality in the German federal states is not only compared in the cross-section, but also in the longitudinal perspective from 1991 to 2006. Different regional cause-specific patterns are derived, and the changes over time are examined.

The underlying trends in the smaller areas are invisible at the level of the federal states, and therefore deserve special attention. Previous analyses by other researchers are enhanced through the application of exploratory spatial data analysis techniques that provide objective measures of spatial clustering trends. Special attention is paid to changes in the spatial patterns related to the steep life expectancy increases in the East German regions in the 1990s, immediately following reunification. This sharp rise led to a regional mortality convergence, and to a decrease in regional dispersion.

Regions with similar socioeconomic features usually display similar mortality patterns. In order to present a consolidated overview of mortality trends and cause-of-death structures, two different region classifications are adopted. The analysis shows that the more deprived areas have excess mortality, especially in behavior-related causes. This study further provides enhanced evidence that general prosperity in the regions is not only reflected in the spatial life expectancy pattern, but that greater prosperity gains lead to greater life expectancy increases.

The most innovative part of the study is its combination of individual- with regional-level data in a multilevel approach. This approach takes account of the fact that the regional population composition cannot only be captured by aggregate-level characteristics (such an approach has also been put forward by Mielck 2007; Razum et al. 2008). Individual-level data are drawn from the German Federal Pension Fund, a data source that has been available to the scientific community since 2004. The analysis confirms that mortality differentials between people belonging to different socioeconomic groups are large, and persist into old age. In the German context, this is the first study that shows that differential population composition in the districts cannot explain all existing regional mortality variation. This implies that the regional environment significantly affects the mortality risk of individuals. The study vividly illustrates that people with the same risk profile have different mortality risks depending on the region in which they live. People with lower socio-economic status are even more vulnerable if they live in a deprived area.

In sum, the different parts of the study show that large-scale spatial mortality differences persist over time, while changes occur at the small-area scale.

The book consists of six chapters. A literature review follows this introductory chapter. The next three chapters deal with the empirical analyses of regional mortality differentials. All of the chapters can be read separately, but each chapter builds upon the previous chapter in terms of geographical and methodological detail. The synthesis of the chapters provides the most meaningful conclusions. The research questions cannot always be answered by one analysis alone. Instead, some of the questions are addressed by several analyses, and the results of these analyses taken together provide full responses to these questions.

Each chapter with empirical results describes the specific data used and the methods applied. The specific results are summarized and discussed at the end of each chapter.

Chapter 2 consists of a literature review on regional mortality differentials and their determinants in Germany. First, data sources used by researchers on regional mortality differences are discussed in brief. Second, the East-West mortality differences and their possible determinants during the division of Germany are outlined. Third, regional mortality structures in Germany and their trends are summarized. Finally, the possible determinants of regional mortality differences are discussed. They are divided into regional- and individual-level factors. The research questions for this study are presented at the end of Chap. 2.

Chapter 3 deals with general mortality trends in Germany. This chapter enhances previous work through the inclusion of all of the German federal states in a longitudinal perspective and through the application of innovative methods. Life expectancy trends in East and West Germany (reaching back to 1956), as well as in the federal states (starting in 1980), are complemented by the examination of lifespan disparity. Regional dispersion of life expectancy across the federal states is assessed in the time lapse. The presentation of a model that relates general mortality trends to underlying causes of death completes this chapter.

Chapter 4 looks at mortality patterns and trends from a small-area perspective. The analyses of both all-cause and cause-specific mortality across 438 German districts present fresh perspectives on regional mortality differentials in Germany. Most importantly, this approach makes it possible to determine which regions are changing. Two distinct functional region structures are created to relate mortality trends to specific regional features, such as an urban-rural division. Finally, the regional life expectancy patterns and their temporal changes are related to regional context factors to assess regional mortality determinants.

Chapter 5 takes into account the importance of the individual mortality risk factors. A multilevel model combines individual-level data of the population aged 65 years and older in 438 districts, with contextual data of the districts. The extent of regional mortality variation is assessed following the inclusion of the first individual-level characteristics, and then of the contextual factors. In particular, the interplay between the two levels is addressed.

Chapter 6 completes the work by providing a general summary and discussion of the findings. The research questions are assessed in light of the empirical results from different regional levels outlined in the three preceding chapters.

Several territorial units in Germany are dealt with throughout this book. The crudest differentiation is made between East and West Germany (often referred to simply as the East or the West). West Germany refers to the territory of the Federal Republic of Germany (FRG) as it was before 1990 (federal states Baden-Württemberg, Bavaria, Hesse, Saarland, Rhineland-Palatinate, North Rhine-Westphalia, Hamburg, Bremen, Schleswig-Holstein, West Berlin). East Germany refers to the territory of the former German Democratic Republic (GDR; federal states Mecklenburg-Western Pomerania, Brandenburg, Saxony-Anhalt, Saxony, Thuringia, East Berlin), as well as the former West Berlin for the period after reunification. Meanwhile, the term eastern Germany refers to the territories of the former GDR and Berlin after 1990; while western Germany refers to the other federal states. The 16 federal states are sometimes referred to as area-states and city-states. City-states are the federal states of (the cities of) Berlin, Hamburg, and Bremen. All other federal states are area-states. The small-area analyses are based on the NUTS-3 level of districts. Other territorial units, such as a group of districts, are generally referred to as regions (Fig. 4.1 shows a map of Germany's regional division).

Chapter 2
Literature Review and Research Questions

2.1 Introduction

This literature review deals with the results of previous studies on regional mortality differences in Germany and their possible determinants. Prior to the actual review, early approaches to the topic are illustrated, and possible data sources for regional mortality research in Germany are briefly discussed (Sect. 2.2).

A general review of literature on East-West differences is given in Sect. 2.3. Past findings of mortality differences across German federal states are summarized in Sect. 2.4. This includes a description of known small-area mortality differentials within the federal states. After the description of mortality trends, the literature review looks at some possible explanatory factors. A number of factors that may determine mortality differentials are derived from the existing literature (Sect. 2.5).

The chapter closes with a presentation of the research questions for this study, which serve as a guideline for the following analyses (Sect. 2.6).

2.2 Early Regional Mortality Research in Germany and Data Sources

It has long been clear that there is considerable regional diversity in the economic, social, and environmental conditions in Germany. When more data became available in computerized form, researchers were inspired to start studying regional mortality differentials in Germany.

Around 1980, the exploration of regional mortality differentials was rather popular in Germany. Many of the early analyses on regional mortality variation were performed by the population departments in the statistical offices of the German

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federal states. Data and technical limitations made these studies mainly descriptive until the mid-1980s (Birg 1982; Böing et al. 1985; Gatzweiler and Stiens 1982; Gröner 1983; Heins 1985, 1991; Heins and Stiens 1984; Howe 1986; Ickler 1984; Kern and Braun 1987; Neubauer 1988, 1990; Obladen 1985; Paulus 1983; van der Veen 1994; van Kevelaer 1982; van Poppel 1981). Environmental factors, such as harmful substances in air and water, were thought to explain a large share of existing regional mortality differences. At that time, socioeconomic differences had just emerged as an explanation for a large share of the regional differences within Germany (e.g., Gatzweiler and Stiens 1982; Howe 1986; van Kevelaer 1982).

The focus had shifted away from regional mortality differences by the late 1980s, but interest in the subject rose again during the reunification period, when researchers began to explore the impact of the political division on various spheres of life (Brückner 1993; Dinkel 1999; Eberstadt 1994; Hertzman et al. 1996; McKee et al. 1996; Mielck 1991; Riphahn 1999; Schott et al. 1994, 1995). Since environmental factors could not successfully explain regional differentials, more and more emphasis was placed on (socio)economic factors (Brenner et al. 1991). However, because data sources for mortality analyses on the micro level were scarce, and researchers could only incorporate small sample sizes in specific areas, there were no overall regional analyses (Helmert and Voges 2002). While the situation for morbidity research was better, it still was not comprehensive. Thus, many studies had a cross-section or a small-scale longitudinal design (Breckenkamp et al. 2007; Helmert 2003a, 2005; Klein 2000; Mielck 2005).

Interest in small-area mortality analyses in the GDR was low, with a few exceptions (Berndt and Gregor 1975; Giersdorf and Lorenz 1986). Most research in East Germany took place after reunification (cf. Häussler et al. 1995; Hoffmeister et al. 1990; Höhn and Pollard 1991; Wildner et al. 1998 and later research).

After reunification, the East-West mortality differentials in particular were studied, as the division of the country was viewed as a "natural social experiment." The temporary division of Germany provided researchers with a tremendous opportunity to study the impact of different social, economic, and political conditions on two populations in one country (Chruscz 1992; Cockerham 1999; Dinkel 1992; Häussler et al. 1995; Vaupel et al. 2003).

In 2002, a collection of articles was published by Cromm and Scholz, which dealt with regional mortality in Germany. The book included mortality analyses at small-area levels for the majority of federal states. It provided mainly descriptive insights into the topic, some of which will be discussed later.

Data sources for regional mortality analyses can be divided into two categories: aggregate data at the regional level and individual-level data, which allow for the identification of individuals' places of residence.

In the aggregate data, population and death counts in Germany are usually available by standard demographic indicators like age, sex, and time. Some data are also available by causes of death, marital status, religion, and nationality.

Data for individual-level mortality analyses that also allow for regional distinctions are scarce in Germany, and are unsatisfactory for the purposes of conducting regional analyses.[1] Such micro-level data are limited in their regional and population coverage, and in their sample sizes. This is because the primary aim of these studies is not to analyze mortality but rather to explore health or sociological questions. The most important data sources are briefly introduced here.

Regional analyses with the GSOEP (German Socio-Economic Panel Study) are possible, although in practice the sample size only allows for a distinction to be made between the eastern and western parts of the country for the purposes of mortality research. It is, however, the most comprehensive longitudinal study in Germany, incorporating manifold variables. The GSOEP started in 1986, and contained more than 20,000 individuals in 2006 (Becker 1998; Brockmann and Klein 2002; Klein 1999; Klein and Unger 2006; Lampert and Kroll 2006; Razum et al. 2000; Reil-Held 2000; Voges 1996). The GSOEP not only allows researchers to make direct mortality estimations but also indirect mortality estimations of the respondents' parents (Klein 1993; indirect mortality estimation was also done by Becker 1998 and Abel et al. 1993 with different data sources).

East-West mortality comparisons are also possible using the Life Expectancy Survey provided by the Federal Institute for Population Research at the Federal Statistical Office (Bundesinstitut für Bevölkerungsforschung; Luy 2005).

The WHO MONICA projects (Multinational MONItoring of trends and determinants in CArdiovascular disease) ran from the 1980s to the 1990s and also incorporated a mortality follow-up. Study data come from a few selected cities or regions in East and West Germany (Breckenkamp et al. 2007; Helmert 2003a, b; Helmert and Voges 2002).

Health insurance providers are potentially useful sources of mortality data, even though their populations are usually not representative of the entire German population. The studies published so far, however, have not included regional differentiation (Geyer et al. 2001; Geyer and Peter 1999; Helmert 2005; Helmert et al. 2002).

Since 2004, the scientific public has had access to individual-level data on pensioners. These data are provided as scientific use files by the research data center of the German Federal Pension Fund (Deutsche Rentenversicherung Bund), and are suitable for old-age mortality analyses (Müller and Rehfeld 1985b; Rehfeld and Scheitl 1991; Shkolnikov et al. 2008; von Gaudecker and Scholz 2007).

2.3 Mortality in East and West Germany

This section focuses on mortality differences between East and West Germany. The East-West divide represents the crudest regional differentiation in Germany due to the decades-long division of Germany. Differences in mortality between these

[1] Theoretically, death counts and population are available via the Research Data Centers of the Federal Statistical Office and the Federal State Offices of Statistics in Germany as individual-level data, but this would not return more information than its aggregation to the regional level.

two parts of Germany have existed for decades, but East German excess mortality decreased after reunification. General mortality trends (Sect. 2.3.1) are complemented by cause-specific mortality trends (Sect. 2.3.2). Section 2.3.3 discusses the most frequently mentioned factors used to explain the East-West differences in mortality. It further elaborates on how East-West mortality differentials are placed into the current study on small-area mortality differentials.

2.3.1 General Mortality Trends

Large differences in life expectancy in East and West Germany existed from 1950 onward. The life expectancy of women in the West has been consistently higher than of women in the East since 1960, and for men from the mid-1970s onward. The life expectancy divergence between East and West Germany started in the mid-1970s, and reached its peak in the late 1980s. From 1989 to 1990, life expectancy decreased in East Germany. In the late 1980s, the life expectancy gap between the West and the East was 3 years among women and 2.5 years among men. While West Germans had experienced a steady decline in mortality, slower mortality improvements in the East led to the observed divergence (Luy 2004; Nolte et al. 2000a). This trend reversed in the late 1980s, and even grew stronger in the 1990s, when East Germany began to catch up after reunification. East German mortality declined rapidly, despite having started with a higher mortality level (Luy 2004; Nolte et al. 2000a, b). The gap between East and West has been diminishing ever since.

A growing mortality gap was observed not only between East and West Germany but also between Eastern and Western European states in general from the mid-1960s to the 1980s (Bobak and Marmot 1996b; Boys et al. 1991; Meslé and Vallin 2002; Okolski 1991).

Before 1990, West Germany had a mortality advantage over East Germany that was almost entirely determined by East German excess mortality above age 40. Among women, a large share of the life expectancy differences was due to excess mortality at even older ages (Nolte et al. 2000a). Men in East Germany exhibited higher mortality at almost all ages in each cohort born after 1900, while the female pattern was less pronounced (Dinkel 1992; Dinkel and Görtler 1994). Mortality rates in the East and the West did not show any major discontinuities over age and time. Unstable trends—mainly among men and elderly people—coincided with the years of the influenza epidemics (Diehl 2008; Luy 2004; Nolte et al. 2000a).

The temporary decrease in male life expectancy in 1989–1990 was determined by mortality below age 65. The sudden and drastic changes in the political and social landscapes caused economic shocks and psychosocial stress among men. Meanwhile, women were more affected than men by unemployment, but they probably had better compensation mechanisms, which resulted in a less pronounced decline in life expectancy in 1989–1990 (Bobak and Marmot 1996a; Watson 1995). Statistical artifacts, such as imprecise population counts due to unregistered migration, can be excluded as explanations (Häussler et al. 1995).

Three-quarters of the post-reunification improvements from the early to the late 1990s in eastern Germany's male life expectancy at birth were attributable to mortality improvements at age above 40, and one-third of all improvements were attributable to age above 65. For eastern German women, mortality at old age was even more important, since more than half of the increase in life expectancy at birth can be traced to age 65 and older. Eastern German young men of ages 15–39 years experienced a much steeper mortality decrease than young men in the West. This was probably due to their high mortality shortly after reunification, which is, therefore, an artificially elevated reference value (Nolte et al. 2000b).

During the 50 years from 1950 to 2000, mortality in all age groups greatly improved. The infant mortality rate (IMR) was 90% lower in 2000 than in 1950, making infants the age group that saw the greatest changes over time. Men experienced a decline of at least one-third across all age groups. Women's death rates at ages zero to 80 fell by at least 50%, while improvements above age 80 constituted at least 30% of the decline over the 50-year period. These sex-specific differences in mortality declines were also reflected in life expectancy. Women's life expectancy increase was almost linear over time. Men, on the other hand, initially experienced a slower life expectancy increase. From the late 1970s onward, male mortality declined faster in relative terms than female mortality (Luy 2004).

While at the beginning of the period, infant mortality contributed significantly to East-West differences, old age became much more important over time. Until the mid-1970s, the lower IMR and more rapid improvements in this rate in the GDR were responsible for part of the initial advantage of GDR in male life expectancy (Nolte et al. 2000a). The first few years after reunification, the IMR fell in both the East and the West, and the rates converged in 1997 (Nolte et al. 2000b, 2001).

The death rates of western Germans of very old age (80+) continued to decrease after reunification, whereas the death rates in eastern Germany began to decline faster than before. Even eastern Germans of very old age could profit from the improvements brought about by German reunification (Gjonça et al. 2000; Scholz and Maier 2003; Vaupel et al. 2003). This reflects the adaptation of "medical, social, and economic improvements associated with reunification" (Scholz and Maier 2003, p. 7) and demonstrates the importance of late-life events, the plasticity of old-age mortality, and the dominance of period effects on mortality (Vaupel et al. 2003). However, Gjonça et al. (2000) emphasized that the old-age death rates in East Germany had been declining before reunification. Reunification could have reinforced this development, although its effects on older men occurred with a time lag in both the East and the West.

Estimations of future mortality trends were made soon after German reunification. Chruscz (1992) hypothesized that, first, East-West differences in life expectancy were mainly determined by socioeconomic factors; second, the adjustment of economic, social, and psychological life conditions would largely eliminate differences in mortality; and, third, the reduction of old-age mortality would push up life expectancy in the West. According to Chruscz's optimistic scenario, the differences in life expectancy would be no more than 1 year in 2000, and, with the adjustment of medical care, within 5–7 years after 1992. This estimate has indeed proven to be correct for women, although for men, the East-West difference in life expectancy was still bigger than 1.5 years in 2000 (Luy 2004).

2.3.2 *Cause-Specific Mortality in East and West*

East-West differences in life expectancy are not only mirrored in the mortality level but also in cause-of-death structures. Given the different coding practices, cause-specific analyses for the period of the German division have to be interpreted with care. Direct East-West comparisons are problematic, but changes over time are informative within the coding systems. In the course of reunification, eastern Germany adopted the western German coding practice. For example, cancer mortality was seriously underreported in the GDR before 1990. The sudden increase in cancer mortality around 1990–1991 was related to this change (Brückner 1993; Kibele 2005; Luy 2004).

The remainder category of ill-defined causes was very small in GDR due to coding instructions that advised physicians to always complete the form with a cause. In cases of ambiguity, an autopsy was arranged. For political reasons, data on external, digestive, and ill-defined causes of death were not published separately after 1974, but in a summary category (Nolte et al. 2000a). Thus, important causes like traffic accidents, suicide, and liver cirrhosis were hidden.

In the following, East-West mortality differences are compared by causes of death for three time periods: before, around, and after reunification.

The diverging life expectancy gap between East and West in the mid-1970s to the mid-1980s can be mainly traced to East German excess mortality from cardiovascular and respiratory diseases and to a remainder group consisting of external, digestive, and ill-defined causes of death (Höhn and Pollard 1991). Between the mid-1970s and the late 1980s, West Germany experienced significant improvements in cardiovascular mortality, in line with other Western European countries (Nolte et al. 2000a; Vallin and Meslé 2004). This progress was most pronounced at older ages. Women in the GDR also experienced decreasing cardiovascular mortality, but men in the GDR did not exhibit such large declines.

Improvements in West Germany in the 1970s–1980s were also achieved in the area of cancer mortality, although the contribution of the decline in cancer deaths to life expectancy changes was small compared to the impact of declines in cardiovascular diseases (CVD). Women over age 40 benefited the most between the mid-1970s and the late 1980s (Nolte et al. 2000a). Before 1990, death rates due to neoplasms were considerably lower in the GDR than in the FRG (Höhn and Pollard 1991). Given the differing coding practices, real comparisons of cancer mortality can only be made for the period after reunification.

Alcohol consumption steadily increased in the GDR over time, leading to increases in liver cirrhosis mortality from 1970 to 1989. As liver cirrhosis mortality increased only during the 1970s in West Germany, the continued rise in the GDR contributed to the widening of the East-West life expectancy gap. Middle adult ages were most affected (Corrao et al. 1997; Nolte et al. 2002). From the 1960s to the late 1980s, suicide mortality in the two parts of Germany was decreasing. Nevertheless, by the end of the GDR, it was 70% higher in the East (Hoffmeister et al. 1990; Wiesner and Casper 1993).

It is difficult to assess the impact of cause-specific mortality on the temporary East German life expectancy decline. The different coding practices in East and West Germany prior to October 1990 must be taken into account when interpreting mortality changes. External causes—at least in sum—are thought to be the most reliable group of causes. A big part of the drop in East German life expectancy from 1988–1989 to 1990–1991 was due to external causes of death, especially among young men (Nolte et al. 2000b). Among the external causes, traffic-related mortality played an important role. This is because, after reunification, Western cars were suddenly available in East Germany, but the road conditions were bad. Traffic-related mortality underwent a fourfold increase between 1989 and 1991, especially among 18–24-year-olds (Winston et al. 1999). In addition to external mortality, most other causes also contributed to the decline in life expectancy among East Germans from 1988–1989 to 1990–1991. An increase in deaths from ill-defined conditions complicates the interpretation of the changing cause-specific pattern and of the life expectancy decline (Nolte et al. 2000b).

After reunification, cardiovascular diseases were responsible for most of the East-West mortality differences, especially among the elderly (Luy 2004). About two-thirds of the overall mortality decline in eastern and western Germany after reunification is attributable to a decline in cardiovascular diseases (Nolte et al. 2000b). While ischemic heart diseases (IHD) were most important (Luy 2004), cerebrovascular mortality was also higher in the East (Rossnagel et al. 2003). Other important causes were external causes, including traffic accidents, alcohol-related causes, and generally avoidable causes (Luy 2004; McKee et al. 1996; Nolte et al. 2000b; Riphahn 1999).

External mortality was responsible for a considerable share of the gap in life expectancy between East and West Germany, even though mortality rates from external causes declined during the 1990s. Men between the ages of 15 and 30 were mainly affected (Nolte et al. 2000b). After a peak in traffic accidents and related injuries in East Germany in 1991, mostly on rural roads, traffic accidents again decreased (Clark and Wildner 2000). It is possible that the East underwent a development similar to the one experienced in the West decades before. However, the process of adaptation appears to have been shorter in the East (Dinkel 1999).

Alcohol-related mortality contributed greatly to elevated mortality in East Germany and to the existing East-West life expectancy gap during the 1990s. Differences were greater for men (Nolte et al. 2003).

In the 1990s, cancer mortality did not contribute substantially to the differences in life expectancy between East and West (Luy 2004). Respiratory mortality decreased over time in both East and West Germany, and eastern Germany reached the lower western German level soon after reunification. This disease group hence contributed little to the East-West life expectancy gap (Kibele 2005; Luy 2004). Suicide rates in eastern and western Germany were declining, with male rates converging by the end of the 1990s, and female rates converging a few years previously (Kibele 2005).

It thus becomes obvious that most of the eastern German excess mortality could be considered “avoidable” (cf. Nolte and McKee 2004). Indeed, several studies sought to explain East-West mortality differences using this concept (Kibele and Scholz 2008; Nolte et al. 2002; Resch 2001). While for women the life expectancy gap due to avoidable causes almost closed between the early 1990s and 2000s, the male gap was largely explicable by these causes, with the greatest differences seen at ages 40–60. More than a third of male excess mortality could be traced back to preventable mortality, or mortality related to health policy. This is mostly traffic accident- and alcohol-related mortality in eastern Germany. Great reductions in mortality amenable to medical care contributed to closing the gap for both sexes (Kibele and Scholz 2008; Nolte et al. 2002).

Less research has been devoted to mortality from other, less frequent causes of death. However, lower incidence and mortality in infectious diseases in the GDR were related to higher immunization rates and to low rates of international migration (Reintjes et al. 2001).

The same trends contributed to the life expectancy differences across European countries, and within the two parts of Germany. Constantly declining death rates in Western countries and stagnation in Eastern European countries were the reasons why a divergence occurred in mortality trends (Vallin and Meslé 2004). The causes that are amenable to health care declined more slowly in the East (Boys et al. 1991; Forster 1996). Between the 1950s and 1990s, mortality improvements in Europe, including West Germany, were slightly greater for avoidable causes of death. Of these causes, the ones related to treatment and medical care improved the most (Treurniet et al. 2004).

To the extent that comparisons are possible, it would appear that similar causes of death were responsible for the East-West mortality gap before and after reunification. Before 1990, significant East-West differences in respiratory mortality existed, but these differences lessened thereafter. Cardiovascular and external mortality were behind the vast majority of mortality differences. An increase in external mortality seems to have contributed considerably to the declining East German life expectancy in 1989–1990. East-West mortality differences were largely attributable to avoidable causes of death. Higher GDR suicide rates have been interpreted as an expression of social inequality (Hoffmeister et al. 1990). According to Dinkel (2000), it is likely that political pressure and psychosocial burdens led to elevated suicide rates in the GDR. Surprisingly, however, the disclosure of suicide data for the GDR, which had been kept secret prior to 1990, did not show high suicide death rates.

2.3.3 Factors Behind East-West Mortality Differentials

The possible factors behind the differential mortality trends in East and West Germany are now considered. East-West differentials have diverged considerably from general factors of regional mortality differentials within Germany, because structural and institutional features, with their direct and indirect effects on health and mortality, differed between the two German states. It is clear today that higher mortality in the GDR cannot be considered a mere statistical artifact. The factors that may have contributed to the emergence and existence of East-West mortality differentials are manifold, and the most important of these factors are described in the following (Diehl 2008; Dinkel 2000; Luy 2004).

First, three data-related issues should be mentioned. East and West Germany calculated *death rates* in different ways before 1990. This biasing factor can now be excluded, and cannot contribute to the explanation of current East-West mortality structures (Luy 2004). *Infant mortality rates* were not completely comparable during the division of Germany because of the differing live birth and stillbirth definitions. This could have led to an underestimation of infant deaths in the GDR, but the impact appears to have been small (Thara 1997). The FRG rules were adopted in East Germany in October 1990, and infant mortality in the two parts of the country has since then been comparable (Nolte et al. 2000a). *Different cause-of-death coding practices* in the GDR and the FRG could account for changing cause-specific mortality patterns, but not for overall mortality (Nolte et al. 2000a). The differences in the cause-of-death structure should have largely disappeared when the coding practice of the FRG was adopted in the new German *Länder*, the newly-founded eastern German federal states. However, before reunification, some cause-specific differences had been determined by coding, rather than by real differences in mortality (Dinkel 2000; Kibele 2005; Luy 2004).

Adverse *environmental conditions* could possibly contribute to higher mortality in East Germany, where the environmental burden—especially in the mining areas in the south—was greater than in West Germany (Cockerham 1999). Proving that environmental conditions led to elevated mortality is critical given the limitations in the GDR cause-of-death statistics. Furthermore, the more polluted southern part of the GDR experienced higher life expectancy than the north (Dinkel 2000; Luy 2004). This shows that the environmental burden cannot be considered as a single determinant, even though an elevated lung cancer risk among uranium miners in the southern part of the GDR has been found (Brüske-Hohlfeld et al. 2006).

Psychosocial stress has also been frequently cited as a contributing factor in higher mortality in East Germany. This stress is said to have arisen as a result of the living and working conditions in the GDR, and of the political repression in the country. A further source of stress may have been reunification and its accompanying social and political changes (Cockerham 1999; Diehl 2008; Dinkel 2000; Häussler et al. 1995; Riphahn 1999). This stress may have led to excess mortality from cardiovascular diseases, alcohol-related causes, or suicide. After 1990, eastern Germany indeed experienced elevated mortality rates from these causes (Häussler et al. 1995; Hoffmeister et al. 1990; Riphahn 1999). As suicide data were not published separately toward the end of the GDR, it was suggested that suicide mortality may have been significantly higher in East than in West Germany (Höhn and Pollard 1991). This speculation was, however, rejected when the data was made available after reunification (Dinkel 2000; Hoffmeister et al. 1990). It is, of course, possible to make the opposite argument, and to suggest that living in the GDR caused less stress. Both assumptions are indeed difficult to prove.

Differing *work and life conditions* are relevant factors due to the unfavorable conditions in industrial production in East Germany. Lüschen et al. (1997) found the presence of work-related health effects, but these did not extend to East-West differences. The more health-adverse lifestyles in the GDR were, for example, reflected in the high rates of cardiovascular mortality, lung cancer, and alcohol-related mortality at middle-adult ages (Cockerham 1999; Heinemann et al. 1996; Nolte et al. 2000a, b). Diet-related factors in East Germany improved with the greater availability of fresh fruit, vegetables, and vegetable oil, and likely contributed to the fall in cardiovascular mortality after reunification (Nolte and McKee 2000).

The different political systems in the GDR and the Federal Republic led to differences in *health care systems and health policies*. Whereas both systems followed the principle of "prevention is better than cure," the GDR prioritized the health of children and workers. The mortality advantage in East Germany in the years immediately after the division of Germany could, for example, be traced to an improvement in children's death rates in the GDR (Nolte et al. 2000a). GDR health policies could not, however, sustain initial successes, and the country fell behind Western standards. Support in the preventive and curative medical treatment of the elderly was stronger in the FRG. Furthermore, many facilities of the GDR health care system were substandard, and the infrastructure was old and decrepit (Swami 2002). The lack of medical technology became visible after reunification, and led to huge financial investments in East Germany (Dinkel 1999, 2000; Dinkel and Görtler 1994). In the course of reunification, the former GDR adopted the FRG health care system (Simon 2005).

Selective migration, and, in turn, healthy migrant effects, could strengthen East-West mortality differences in several respects. West Germany received emigrants from the GDR until 1961, and also took in massive flows of labor migrants (Dinkel 2000; Razum et al. 1998). However, the GDR, like the FRG, also received displaced persons from Eastern Europe after World War II. Other features related to migration address the correct and timely registration of migration flows. In addition to the selective migration of the young and healthy, East-West migration in the period 1989–1990 could have influenced mortality by biasing the population denominator. The incorrect registration of migration around reunification was likely due to fundamental documentation system changes that were made during the unification process (Häussler et al. 1995). However, East-West migration flows tended to lead to an overestimation of the population in the East, which would, in turn, lead to an underestimation of mortality (Nolte et al. 2000a).

Eastern Germany recovered quickly from the mortality peak in 1990, in contrast to the mortality increase or stagnation seen in most other Eastern European countries after the regime change. It remains unclear why East German excess mortality during and after reunification disproportionately affected men. Women seemingly adjusted more quickly and easily to the altered situation, and hence benefited to a greater extent (Cockerham 1999; Dinkel 1999; Häussler et al. 1995; Heinemann et al. 1996). Watson (1995) related the more problematic mortality situation of East German men to gender roles in communist societies that enabled women to better cope with adverse conditions.

It is likely that a combination of these diverse factors—including data problems, the environmental burden, psychosocial stress, working and living conditions, and health care and migration—are responsible for past and more recent East-West mortality differences. Along with strong economic gains, conditions improved in many spheres of life in East Germany after reunification. Referring to the period until around 1990, Bobak and Marmot (1996a) estimated that the effects of environmental pollution and medical care in the mortality gap between Eastern and Western Europe were responsible for 20% or less of the gap. In East Germany, improved health care and health policy conditions are crucial in explaining mortality reductions after reunification (Kibele and Scholz 2008; Nolte et al. 2000b, 2002). The improved health care and health policy conditions are not just related to medicine but also range from better nutrition to better transport safety. Having examined the effects of migration on the life expectancy decrease in 1989–1990, Rossa and Schott (1997) found that migration affected this drop by less than 10%. Hence, a combination of health care and policy conditions, together with the other factors mentioned above, seem to have determined past and recent East-West mortality differences. Disentangling the separate effects of individual factors seems impossible.

2.4 Mortality Across Regions in Germany

Turning from the crude regional division into East and West Germany, and toward mortality variation in smaller areas, this section summarizes observed mortality trends in the federal states and smaller areas. The studies on which the summary is based are rather heterogeneous in terms of geographical units, time periods (single years vs. longer time periods), and cause-specific vs. total mortality. The most important publication on this subject is "Regionale Sterblichkeit in Deutschland (Regional Mortality in Germany)," which includes mortality analyses of almost all German federal states. It is mostly based on data from the 1990s by territorial units of different levels: from neighborhoods of Berlin and Munich, to districts, to urban-rural differences, and, finally, to the state level (Cromm and Scholz 2002). There are few publications that provide regional mortality analyses of the GDR.

Substantial East-West mortality differences are not as clear-cut at the level of smaller geographical units as they are at the broader East-West level. Differences across the German federal states exist as well, with the most prominent division being a north-south gradient (cf. Luy and Caselli 2007). This rough regional mortality pattern has persisted for many decades (cf. Gatzweiler and Stiens 1982; Kern and Braun 1987; Paul 1992; Queste 2007).

In general, observed variation tends to be greater at the small-area level. In the sex-specific context, more variation has been observed among men than among women, whereas differentials after reunification were shown to have increased among men and decreased among women (Bucher 2002; Kuhn et al. 2006; Luy 2006). The causes of death that showed strong variation were cardiovascular and respiratory diseases and traffic-related deaths. Lung cancer was also found to vary considerably, though not mortality from cancer of all sites (European Communities 2009; Kern and Braun 1987).

In the following, mortality trends at the regional level—federal states and smaller areas—are illustrated (Sect. 2.4.1). Section 2.4.2 then summarizes mortality trends within the federal states, across smaller areas.

2.4.1 Mortality Differences Across Federal States and Smaller Areas

Prior to a discussion of cause-specific mortality trends, trends in life expectancy and all-cause mortality are illustrated.

Life expectancy at birth across the German federal states in the mid-1990s was high in Baden-Württemberg, Bavaria, and Hesse; but low in Mecklenburg-Western Pomerania, Brandenburg, Saxony-Anhalt, and Thuringia. While Saxony, Berlin, Bremen, and Saarland also belonged to the low-life expectancy areas, the remaining (West) German states were above average. This pattern translated roughly to life expectancy at age 60. However, Hamburg, which belonged to the upper half in life expectancy at birth, was among the three best performers in life expectancy at age 60 (Sommer 1998). Over time, the crude ranking among the West German federal states remained fairly stable. After reunification, the strong mortality decreases in eastern Germany led to a convergence toward West German levels. For example, women in Saxony now belong to the upper third. In the European context, Germany is well within the average range (European Communities 2009).

During the 1980s, Berlin and southern East Germany experienced higher life expectancy than the north, even though the degree of industrialization and environmental burden was higher in the south of the GDR (Giersdorf and Lorenz 1986; Nowossadek 1994). Interestingly, urban-rural differences were not pronounced, and some rural *Bezirke* (regions approximately comparable to NUTS-2 level) experienced higher life expectancy, which may have been related to environmental pollution in several urban areas of the GDR (Nowossadek 1994).

The extent of regional mortality variation was greater in the West than in the East, and it was more pronounced among men than among women. After the fall of the Berlin Wall, life expectancy increases were stronger among women. Existing urban-rural discrepancies remained. Especially the south of eastern Germany experienced substantial in mortality gains during the 1990s (Mai 2004).

Generally, regional deviations from the average leveled off with age, starting in the mid-30s. Several other age-specific peculiarities were found to exist. For example, Bavaria, having high life expectancy at birth, experienced mortality rates above the average in the age range 15–25 years due to traffic accidents. At older ages, those states with high mortality at young adult ages approached the average, and therefore experienced a relative improvement, and vice versa. Infant mortality was low in the federal states with high life expectancy, that is, in Baden-Württemberg, Bavaria, and Hesse, but also in Schleswig-Holstein (Kvasnicka et al. 1993a; Sommer 1998).

The following examines regional mortality differences in Germany from a cause-specific perspective.

Naturally, cardiovascular mortality determines the all-cause mortality pattern. Cardiovascular mortality followed the clear north-south and East-West gradients, with higher mortality seen in the north and the East, as was observed in all-cause mortality. In addition, Saarland suffered from high cardiovascular mortality (European Communities 2009; Müller-Nordhorn et al. 2004, 2008; Willich et al. 1999). A study from the 1970s of the small-area situation in West Germany revealed excess cardiovascular mortality in the highly industrialized Rhine-Ruhr area. Mortality rates from ischemic heart diseases (IHD) rates tended to be higher in the northern part of West Germany. A cluster of high stroke mortality was found in North Rhine-Westphalia, Saarland, and Rhineland-Palatinate, and relatively high rates were also observed in the Bavarian districts along the eastern border (Jöckel 1989).

North Rhine-Westphalia experienced particularly low external mortality, partly due to low traffic-related mortality. Mortality related to traffic accidents was also low in the city-states of Bremen, Hamburg, and Berlin. Alcohol-related mortality among women was especially high in the East and in the city-states, and also in all of the regions of North Rhine-Westphalia. Mortality from infectious and parasitic diseases roughly reproduced the regional pattern of population density, with higher mortality seen in the more densely populated areas (NUTS-2 level *Regierungsbezirke*; 2002–2004; European Communities 2009).

The level of knowledge about the regional distribution of cancer mortality is more detailed than for any other cause of death. As in other countries, a cancer atlas exists for Germany, and provides information about 24 cancer sites. Detailed district-level information is available for 1981–1990 (Becker and Wahrendorf 1998). Cancers with large regional variation, such as lung or stomach cancer, are primarily behavior-related (smoking, alcohol consumption, nutrition), but they are also caused in part by occupational and environmental exposure (Albrecht et al. 1998; Becker and Wahrendorf 1998). The German cancer atlas also includes the regional distribution of cancer mortality in the GDR (Becker and Wahrendorf 1998). Even though cancer mortality appears to have been underestimated in the GDR, regional comparisons in this area are plausible.

While cancer mortality in West Germany was low in Baden-Württemberg, it was high in Saarland, the Ruhr area, West Berlin, and northeastern Bavaria (Becker and Wahrendorf 1998; Kvasnicka et al. 1993b). While cancer mortality in West Germany had been decreasing for several decades among women, it did not start to decrease among men until the early 1990s (Becker and Wahrendorf 1998). Research on lung cancer in West German federal states showed that mortality was higher in the city-states, while the lowest values were in the less industrialized areas, particularly in the south. Some of these differences could be related to the urban-rural divide, but the high lung cancer death rates in Saarland and North Rhine-Westphalia, with their high concentrations of heavy industry, suggest that an occupational burden may have played a role (Becker and Wahrendorf 1998; European Communities 2009; Neumann 1975). The regional cancer pattern in West Germany showed higher stomach cancer mortality in the northern part of Bavaria. Breast cancer was low in the south, and high in the north and west (Becker and Wahrendorf 1998; Böing et al. 1985;

European Communities 2009). Thyroid cancer was an exception to the prevailing regional mortality pattern, and showed a strong south-north gradient. However, the number of cases was very small.

An examination of the regional distribution of cancer mortality in the GDR demonstrates that the north of the GDR suffered high cancer mortality, as did the center-south. A similar pattern was also found in stomach or urinary bladder cancer. Lip cancer and cancer of the esophagus were high only in the north, while mortality from intestine and thyroid cancer was higher in the south. Lung cancer was particularly high in the north of East Germany, but it was also high in the center-south among men (Becker and Wahrendorf 1998).

A study analyzing GDR cancer data from the 1960s revealed a social pattern across the GDR *Bezirke*: stomach and rectum cancer were more prevalent among lower social classes, whereas colon and mammary gland cancer were higher in places with greater wealth, and especially in those with greater industrial development. Environmental factors were thought to explain this pattern of regional variation (Berndt and Gregor 1975).

2.4.2 Mortality Differences Within Federal States

This section gives a brief overview of mortality variation within the German federal states. Although these studies are heterogeneous in their setup, a summary of their results provides an overall impression of the mortality differentials from a small-area perspective. The spatial mortality differences in Baden-Württemberg, Bavaria, North Rhine-Westphalia, and Mecklenburg-Western Pomerania were the most frequently investigated. A detailed regional mortality study also exists for Hesse.

The description for each federal state starts with a rough overview of the federal states' socioeconomic conditions. A description follows of the small-area mortality patterns, and—where available—their associations with regional context factors. First, the mortality trends in the West German federal states and their subordinated regions are described. Second, the trends for the East German states and their respective small areas are outlined.

Baden-Württemberg (BW) is the wealthiest of all the German federal states currently. Baden-Württemberg has very low unemployment rates, and is home to a number of important companies in the high-tech and research and development industries, including in the areas of engine construction, automobile manufacturing, and metalworking.

While Baden-Württemberg has had the highest life expectancy in Germany, life expectancy differentials of up to 3 years can be found across its 44 districts, with mortality both decreasing and converging with regard to minimum and maximum values, relative to the late 1980s (Luy 2006; von Gaudecker 2004). High life expectancy was clustered around Stuttgart, Freiburg, and the region around Lake Constance (Bodenseekreis) (Gröner 2002; Paulus 1983; von Gaudecker 2004). The existence of small-area differentials becomes evident when the high-life expectancy region

Bodenseekreis is considered. The lake is surrounded by five districts. While mortality in this area was not found to be consistently below the average of Baden-Württemberg, it was shown to vary by age and cause-of-death group (Szagun 2001).

Since regional differences exist to almost the same extent in life expectancy at birth and at age 30, traffic accident mortality among young adults cannot explain these regional differences (Wolf 1991). Elevated mortality of young people was found to exist in rural areas, but this does not apply to all urban and rural districts (Gröner 1997; Wolf 1992). Lower mortality in the districts was associated with higher income, higher proportions of well-educated people, and migration intensity, but no relationship to environmental or health care factors was found (Cischinsky 2005; von Gaudecker 2004).

Bavaria (BY) is a large and wealthy federal state in southeastern Germany. The automobile and technology sectors are the most important industries. Unemployment is very low. The region around Munich is economically the most important, while the northeastern region (Upper Franconia and Upper Palatinate) that borders Thuringia and the Czech Republic are less developed regions, which suffered due to their geographical position during the division of Germany. Until the 1960s, most Bavarian regions were poor, except for Middle Franconia and the Munich area. Thereafter, economic development also started in Upper Bavaria and Nuremberg.

The 96 Bavarian districts (both in 1973–1982 and 2000–2002) experienced a mortality gradient from the northeast to the southwest with the highest mortality seen in the northeast (Kuhn et al. 2004, 2006; Neubauer and Frommholz 1986; Neubauer and Sonnenholzner-Roche 1986). The largest differences in life expectancy in the districts of Bavaria are around 5 years (Kuhn et al. 2004; Luy 2004). This is 2 years more than in Baden-Württemberg. However, these findings should be interpreted with caution. The districts in Germany are very different in terms of population and geographical size. The average population in Bavarian districts is much smaller than in Baden-Württemberg.

Evidence suggests that the current mortality pattern in Bavaria emerged in the 1960s, possibly due to infrastructure and sociocultural causes that are difficult to alter (Kuhn et al. 2006). Regional mortality differentials within Bavaria decreased during the 1990s in absolute terms. Among men, the greatest relative differences were in car accidents and in respiratory and digestive diseases, whereas for women, the differences were largest in neoplasms and accidents (Kuhn et al. 2004, 2006). Cancers with behavior-related risk factors drove the regional mortality differences in cancer mortality. For example, stomach cancer and intestine and rectum cancer showed a strong northeast to south gradient (Meyer et al. 2006).

Mortality tended to be lower in regions of high in-migration in Bavaria. Income level, education, and employment also correlated with mortality. Socioeconomic factors explained about half of the spatial variation in 2000–2002 (Kuhn et al. 2004, 2006).

Hesse (HE), with its 21 districts, is located in the middle of (West) Germany. Frankfurt am Main is an important German and international stock exchange center, with banks and insurance companies. The city also has the largest airport in Germany. Other important sectors of the economy in Hesse include the chemical-pharmaceutical industry, engine construction, and automobile manufacturing.

The economy is strong and produces a high per capita GDP. However, there are clear economic differences between the north and the south.

Over time, mortality in Hesse has been below the German average (Wittwer-Backofen 1999). And, with the exception of elevated rates of death from CVD and respiratory diseases at young ages, Hesse has also had below-average mortality in most causes of death, at least in 1980–1985 (Grün 1987).

For Hesse, a comprehensive ecological study on regional mortality, with the focus on old-age mortality in the years 1987–1993, is available. Men and women in the densely populated urban centers, such as Frankfurt, Darmstadt, and Kassel, experienced the highest life expectancy at birth and at age 65. Around 1990, those Hessian districts with an initially higher mortality level experienced faster mortality decreases, which led to a reduction in the differences between the districts during the short period of 1987–1993. Mortality declined faster among men. Socioeconomic factors predicted life expectancy at ages 65 or 75 better than life expectancy at birth (net migration, economic prosperity, population density, household structure). The higher correlation of female mortality at advanced ages with socioeconomic factors was considered to be a methodological effect reflecting greater regional variation among women than among men. Urban-rural differences were also found to exist in Hesse. Those causes of death that are partly behavior-related, such as cardiovascular and respiratory deaths, showed the closest association with socio-economic determinants among men (Wittwer-Backofen 1999, 2002).

Hamburg (HH) is a large city-state, with about 1.8 million inhabitants, situated in the north of Germany. Hamburg is a growing region, with a wide range of important industries, such as aviation, engine construction, ports, logistics, services, and transport. Although the general level of wealth is high, as in the other German city-states, poverty levels are also significant, and thus economic inequality is pronounced. The population of Hamburg is multicultural and multiethnic, and includes many foreigners, some of whom are in the country illegally.

With respect to mortality, Hamburg takes an intermediate position in Germany. In 1994–1997, the districts within Hamburg showed a social gradient for overall mortality that was particularly pronounced among men. The social rank was low in the inner city, and higher toward the outskirts. Mortality from liver cirrhosis, for example, was high in the districts of Mitte and Nord, and was low in the districts of Eimsbüttel and Wandsbek. Similar patterns were found for other avoidable causes of death (Freie und Hansestadt Hamburg, Behörde für Arbeit, Gesundheit und Soziales 2001).

Bremen (HB) is a city-state in the northwest of Germany, and consists of two cities: Bremen and Bremerhaven. Import- and export-related economic activities around the harbor are central to the economy. Since the founding of a university in Bremen in the early 1970s, academic neighborhoods have evolved. Bremen is characterized by a high share of foreigners and a high degree of economic inequality.

Life expectancy at birth in Bremen is slightly below the national life expectancy average. Remaining life expectancy at age 60 tends to be slightly above average (Sommer 1998).

Mortality differences were observed within the city of Bremen from 1970 to 1989. The mortality gradient between the upper- and lower-class areas was found to be increasing, and mortality was decreasing faster in upper social class areas. The upper-class areas were situated in the center of Bremen, and the neighboring areas to the west of the center, while lower-class areas were clustered more toward the outskirts and the east of the center (Tempel and Witzko 1994).

Lower Saxony (NI) is situated in northern Germany and has both economically underdeveloped and well-developed regions, like the area around Hannover, including the important Volkswagen automobile plant in Wolfsburg. Large parts of Lower Saxony were once adjacent to the former GDR (the so-called *Zonenrandgebiet*). These peripheral areas of Lower Saxony received special monetary grants from the FRG to compensate for disruptions in trade and industry as a result of the division. These subsidies ended with the fall of the Berlin Wall.

Mortality in Lower Saxony showed a diverse pattern and little spatial contiguity in the 2000s. High mortality prevailed in the south and southeast, as well as in the northwest, which are regions with high unemployment. Low mortality was associated with a high average disposable income and low unemployment, and also with high immigration and population growth (Driefert et al. 2009). Causes of death varied between urban and rural areas. Lung cancer mortality was, for example, found to increase with a rising degree of urbanization (1975–1977; men 45+, women 65+; Buser et al. 1986). In the late 1960s in the city of Hannover, population density was found to be highly correlated to urban mortality variation within the city (Manton and Myers 1977; Myers and Manton 1977). In van der Veen's mortality comparison for the years 1980–1988 between several regions in three neighboring European countries (the Netherlands, Belgium, Germany), the four NUTS-2 regions in Lower Saxony were included. While Lower Saxony was found to have a less favorable position among the chosen regions, mainly due to high cardiovascular mortality, lung cancer mortality was found to be lower in the German state (van der Veen 1994).

Schleswig-Holstein (SH) borders both the North Sea and the Baltic Sea, and Denmark to the north. After 1945, the population of this state increased by more than 50% due to the arrival of displaced persons. It is a less densely populated state, with relatively little economic development. A comparatively high share of the population works in agriculture and in the sea-related economy. The affluent regions surrounding the city of Hamburg also play an important role.

Two small-area studies on cancer mortality are available for Schleswig-Holstein. The first one found that breast cancer mortality in Schleswig-Holstein in 1981–1995 was increasing until the late 1980s, and then decreased. Rates were found to be higher in the urban areas (Heitmann et al. 2001). Another study dealt with the distribution of stomach and colon cancer in the districts of Dithmarschen and Nordfriesland, which are subdivided into 33 smaller areas. Cancer mortality in these sites was shown to have decreased over time, but some smaller rural areas still exhibited high stomach cancer mortality rates among men. The opposite was found to be true for colon cancer (Pröhl et al. 1995).

North Rhine-Westphalia (NW) is situated in the west of Germany, bordering the Netherlands. It is the most populous federal state of Germany, with 18 million people living in 54 districts as of 2006. The coal, iron, and steel industries gave rise to the region and the whole of Germany after World War II. The demand for labor brought many foreign labor migrants to North Rhine-Westphalia, many of whom are present in today's population. North Rhine-Westphalia has been very much affected by the industrial change in recent decades. Some of its regions have coped well with this change, and are now engaged in the electricity and water supply sectors.

Mortality in North Rhine-Westphalia has been at medium levels relative to Germany as a whole, and has been characterized by small-area mortality variation (van der Veen 1994). North Rhine-Westphalia has been the subject of several regional mortality studies since the 1980s. Mortality was found to be high in the central Ruhr area, while it was shown to be lower toward the edges of the state, such as in Münsterland in the north or in Bonn in the south. Excess mortality in the Ruhr area was most pronounced in the age group 35–54 (Klapper et al. 2007).

Regions of low mortality were largely determined by low cardiovascular mortality. Mortality in the Ruhr area was elevated not only due to high cardiovascular mortality but also due to respiratory diseases, lung cancer, and alcohol-related causes. While external mortality was low here, rural areas surrounding the dense center suffered higher external mortality, mainly because of transport accidents (Heins 1985; Heins and Stiens 1984; Limbacher 1986; Strohmeier et al. 2007). Traffic-related mortality in NW was, however, shown to be below the German average. Cancer mortality tended to be lower in the east of NW (European Communities 2009; Heins 1985; Heins and Stiens 1984; Limbacher 1986).

Mortality data on all causes of death, traffic accidents, and lung cancer for 1979–1981 were used for ecological regression analyses in North Rhine-Westphalia and Rhineland-Palatinate. While the mobility indicators were found to be only weakly associated with mortality, densely populated regions were shown to have high lung cancer and all-cause mortality, but low external mortality (Heins 1991; Heins and Stiens 1984). In general, high mortality in the Ruhr area—and even more so in its central agglomeration—was associated with adverse socioeconomic conditions (Klapper et al. 2007; Strohmeier et al. 2007).

The studies reflect a heterogeneous mortality structure in NW and the importance of behavior-related mortality. Klapper et al. (2007) noted that, without the Ruhr area, North Rhine-Westphalia would have the second-highest male life expectancy in Germany after Baden-Würtemberg.

Rhineland-Palatinate (RP) is situated in the southwest of Germany, and has a population of four million. Medium-sized businesses are the foundation of its economy. Besides industry, viniculture and tourism are important.

Rhineland-Palatinate and its regions have medium levels of mortality relative to West Germany as a whole (van der Veen 1994). Regional patterns are not clear-cut, although mortality has been found to be lower in the southeast and the northeast, and higher in the center-east (Henke and Müller 2002; Ickler 1984, 2008). Mortality from traffic accidents was above the West German average, especially in the south, while IHD mortality was about average relative to the West German level.

Among men, alcohol-related mortality was high in the southeast of Rhineland-Palatinate (Heins 1985; Heins and Stiens 1984; Ickler 2008).

Several sociostructural indicators, such as unemployment or education, were identified as explanatory factors of regional mortality variation (see description for NW; Heins 1991; Heins and Stiens 1984; Henke and Müller 2002).

Saarland (SL) is a relatively small federal state in the southwest of Germany, with one million inhabitants living in six districts (in 2006). It neighbors France and Luxemburg. Mining is no longer important, though the automobile industry continues to play a role in the Saarland economy. It has a low GDP by West German standards. Information technology is growing in Saarland.

Excess mortality has been found in Saarland's districts (Gatzweiler and Stiens 1982). A detailed ecological mortality analysis of colorectal cancer in the 50 communities of Saarland showed that people aged 45–74 years at diagnosis in 1974–1983 experienced lower mortality rates if they lived in communities with higher socioeconomic status (SES) (Brenner et al. 1991).

Berlin (BE) has been the capital of reunified Germany since 1990, and it is the only German state that was separated by the Berlin Wall. About 3.4 million people live in this city-state (in 2006). Service sector activities are important to the economy, as are politics, tourism, and the media.

Life expectancy in Berlin has been below the German average. It was at similar levels in East and West Berlin before reunification, with a small advantage seen in West Berlin. Even as East Berlin experienced a short-term life expectancy decrease from 1990 to 1991, West Berlin experienced a slight decline among men. This is exceptional, as no other West German state has undergone such a change.

Within Berlin, the central neighborhoods have tended to have the lowest life expectancy, while the outskirts have had the highest values. This pattern is in line with the socioeconomic positions of the areas (Kemper 2002; Meinlschmidt 2008; Scholz and Thoelke 2002). A similar pattern exists in several avoidable causes of death (Meinlschmidt 2008). Traffic-related mortality in Berlin is below the German average (European Communities 2009). However, there is small-area variation, and a cluster of higher mortality from car accidents was found in Berlin Mitte (Ebel 2004).

In the 12 neighborhoods of the former West Berlin, infant mortality was high in the east and low in southwest, which is in line with the socioeconomic situation in the neighborhoods. The infants of migrants experienced higher mortality, and this contributed to higher mortality in the disadvantaged neighborhoods, where the share of newborns to foreign families was high (1970–1985; Elkeles et al. 1994).

Brandenburg (BB) surrounds Berlin, and the areas along the borders of the capital clearly benefit from Berlin's infrastructure. Those surrounding areas, including Potsdam, have attracted residents from Berlin since reunification, as well as from West Germany. The peripheral parts of the state situated along the eastern border with Poland are less economically developed.

Brandenburg has a medium rank in life expectancy relative to eastern Germany, but scores low in comparison to the whole of Germany. The districts around Berlin, especially the Potsdam region, experienced lower mortality than the more rural areas located farther from Berlin (Queste 2007).

Mecklenburg-Western Pomerania (MV) is the most northeastern state in Germany, with the agriculture and tourism industries that fuel its economy clustered along the Baltic Sea coast and around the many lakes in the region. The regional economy is relatively weak, and unemployment is high. Mecklenburg-Western Pomerania took in a large number of displaced persons after World War II.

Mortality in Mecklenburg Western-Pomerania has remained above the East German average for decades, even though life expectancy in the 1960s was about the GDR average (Dinkel 2000). The temporary life expectancy decrease in 1989–1990 was mainly produced by the active male population, while the subsequent increase was mainly attributable to retired people (Kück and Müller 1997).

Excess mortality mostly affected young adults—especially men—aged 35–50, who died in car accidents (Dinkel 2000; Karpinski 1994; Kibele 2005). In rural districts, Mecklenburg-Western Pomerania experienced the highest car accident fatality rate among all of the federal states (Dinkel 2000). Apart from the urban-rural mortality gap, districts situated in eastern Mecklenburg-Western Pomerania had lower life expectancy (Kibele 2005; Müller and Kück 1998). Small-area differences within Mecklenburg-Western Pomerania were found to be much greater for men than for women (Müller and Kück 1998). High alcohol-related and avoidable mortality was found for Mecklenburg-Western Pomerania (Gabka 2003; Kibele 2005). Risky alcohol consumption was widespread in Pomerania, the eastern part of the federal state (Baumeister et al. 2005).

Saxony (SN) is a southern state in eastern Germany with a favorable mortality position. The area was economically strong even before 1945. Structural changes in the economy after 1990 brought real progress to the region: science and technology, chemical, automobile manufacturing, engine construction, and information technology are among the state's major industries. However, this economic boom mainly took place in a few big cities, while other parts of Saxony have remained much less developed. Mining, which had been an important industry in the GDR, has been reduced since reunification.

Mortality in Saxony is now the lowest among all of the eastern German states, and has converged with West German levels. Saxony experienced a decline in male life expectancy from 1990 to 1991, due to accidents, digestive diseases, cancer, and mental diseases (Schott 2002). Within Saxony, Dresden and its surrounding districts have the lowest mortality, and this area is also the most economically developed (Queste 2007).

Saxony-Anhalt (ST) has faced many economic problems related to restructuring after reunification, which resulted in a loss of some of its population, and in high levels of unemployment. The state has long been a center of the chemical and oil industries. The famous Leuna plant, situated in the south, was the biggest chemical enterprise in the GDR.

Saxony-Anhalt is among the regions with the highest mortality in Germany. In the early 2000s, life expectancy of males in Saxony-Anhalt was 2 years below the German average, while a decade earlier, the gap was as big as 3 years. The differences among women were 0.7 years and 2.2 years, respectively (Streufert 2005).

At the district level, mortality was lowest in the three cities and in the west of Saxony-Anhalt in 1994. The southeast of Saxony-Anhalt held a medium position. The center-north, which was most affected by the transformation, exhibited the highest mortality. The spatial pattern of cardiovascular mortality resembled this pattern (Mey 2002).

Thuringia (TH) is situated in the southeast of the former GDR, and also underwent substantial changes during the transition from a planned to a social market economy. Formerly important heavy industries lost their central roles. At present, the range of economic activities is more diverse, and includes not only mining and agriculture but also microelectronics, education, and science and technology development.

Thuringia also has the highest mortality in Germany after Saxony-Anhalt and Mecklenburg-Western Pomerania. The cities of Thuringia—including Erfurt, Weimar, Jena, and Suhl—have higher life expectancy than the rural areas (Mey 2002; Queste 2007).

2.5 Factors Behind Regional Mortality Variation

The relationship between place and health is complex. Although space is formally connected with geographical units, it in fact reflects multifaceted and changing structures (Curtis 2007; Gatrell 2002; Spijker 2004; Tunstall et al. 2004). The preceding review of mortality patterns and trends at the subnational level in Germany looked at some of the factors that might cause these variations. General mortality determinants—such as age, time, sex, income, health care, social class, and environment—vary across space, and have the potential to explain regional mortality differences.

Several frameworks that seek to explain regional health variation can be traced back to the "health field concept" developed by Lalonde in 1974. This concept breaks down the determinants of health variation into the four categories of human biology, environment, lifestyle, and health care organization, thereby extending determinants to nonmedical factors. Lalonde claimed that "[a]ny health problem can be traced to one, or a combination of the four elements" (Lalonde 1974, 1981). This concept, together with subsequent elaborations, still provides the basis for many regional mortality studies (Curtis 2007; Howe 1986; Raeburn and Rootman 1989; van der Veen 1994).

Despite the importance of the health field concept in mortality research, the factor of human biology as an individual characteristic has so far not been directly addressed in regional mortality studies in Germany. However, aging is a biological mortality determinant, and is usually controlled for. The factor of lifestyle has also attracted little attention. Studies incorporating lifestyle factors like nutrition or smoking are scarce at the regional level, but living arrangements are included in a few studies. While general indicators of health care organization appear to have little explanatory power, specific indicators appear to be more appropriate. Indicators of physical environment have little power in explaining mortality differentials at a regional level. The social environment appears to be more effective.

Economic conditions are an important factor that influences health variation not directly captured by the health field concept. The influence of economic conditions on mortality is partly mediated through lifestyle factors. Most studies have found that regional mortality differentials are largely determined by (socio)economic structures (Albrecht et al. 1998; Brzoska and Razum 2008; Cischinsky 2005; Gatzweiler and Stiens 1982; Heins 1985, 1991; Heins and Stiens 1984; Kemper and Thieme 1991; Kuhn et al. 2004, 2006; Lhachimi 2008; Neubauer 1988; Queste 2007; Spijker 2004; van Kevelaer 1982; von Gaudecker 2004; Wittwer-Backofen 1999).

Two more recent studies also included spatial trends and spatial associations as explanatory factors, proving that high- and low-mortality regions are not randomly distributed in Germany, but are clustered in space. Due to the prevailing northeast to southwest gradient, longitude and latitude can explain few if any of the regional mortality differences (Lhachimi 2008; Queste 2007).

Changes in the regional distribution of mortality over time appear to be more difficult to explain than cross-sectional differences, and few studies have addressed them so far (Schwierz and Wübker 2009; von Gaudecker 2004).

The factors that determine the regional mortality variation can be broken down into micro- and macro-level factors, that is, individual-level and regional-level factors that act on mortality, and interact with each other (e.g., Birg 1982; Curtis 2007). None of the aforementioned studies distinguished between these different levels. Modern analytical instruments make it possible to fully implement such an approach (Luy and Caselli 2007).

In the following sections, the factors that may be responsible for regional mortality differentials are discussed, and are traced back to the health field concept. Mortality determinants are thus divided into micro-level factors (Sect. 2.5.1) and macro-level factors (Sect. 2.5.2). Section 2.5.3 discusses aspects of the interplay between micro- and macro-level factors. The empirical focus is on German studies. Because of the restrictions on access to individual-level mortality data in Germany, evidence from other countries with greater data availability is used to complement German data.

2.5.1 Micro-level Mortality Factors

Mortality differs between populations, that is, between micro-level or individual-level mortality factors. Because such micro-level factors can be spread differently across regions, regional mortality differentials are also determined by population composition and not only by the regional context. Micro-level mortality factors are therefore as important as macro-level mortality factors in the study of regional mortality differences. It should also be noted that the mortality effect of individual-level factors can differ according to the regional context (Diez-Roux 2001, 2002).

The individual-level factors that figure prominently in mortality differentials include socioeconomic status, lifestyle, living conditions, human biology, and genetic factors. The mortality effects of these factors are presented in the following parts (Sects. 2.5.1.1, 2.5.1.2, 2.5.1.3, and 2.5.1.4). The question of to what extent these micro factors can cause or contribute to regional mortality differentials is addressed.

2.5.1.1 Socioeconomic Status

It has been shown that mortality differences can be greater between social groups than between countries (WHO Commission on Social Determinants of Health 2008). For a long time, it has been known that mortality strongly differs by SES, and that people with higher SES experience lower mortality risks (Antonovsky 1967). Socioeconomic status is a construct containing income, education, and occupational status. The single factors are naturally highly correlated. Socioeconomic status better reflects men's than women's positions. This is because women are less involved in employment and careers, and depend more on their husbands for their socioeconomic status than men do on their wives (Hoffmann 2006; Luy 2006).

Two causation mechanisms in the relationship between health and socioeconomic status are discussed in the literature, namely, that socioeconomic status influences health (causation mechanism), and that health influences socioeconomic status (selection into SES groups or social selection or reverse causation). Social selection has attracted less attention from researchers than the causation hypothesis, and has been shown to be of lesser importance (Goldman 2001; Hoffmann 2006; Mielck 2005). Distal and proximate (indirect and direct) factors mediate between socioeconomic status and health. The relationship between social status and health is more pronounced in western than in eastern Germany (differentiated by sex, the relationship is stronger for females in eastern Germany and for males in western Germany; Müller and Heinzel-Gutenbrunner 2005).

Mortality comparisons by German regions that incorporate socioeconomic status are extremely scarce due to the aforementioned lack of data. The German Socio-Economic Panel Study was used for several mortality studies that looked at socioeconomic status, but was only used for West Germany or for Germany as a whole, with no East-West distinction made. None of these studies attempted any further regional breakdown (cf. Unger 2003; Voges 1996). No mortality analyses by social class for the former GDR have been published, according to Abel et al. (1993).

In the following, health and mortality differentials by different indicators of social and economic conditions are considered: income, occupation, education, and marital status.

Studies have shown that, in many instances, income is strongly related to mortality and health. Having a lower income is generally associated with having a lower health status. In addition, groups with lower socioeconomic status tend to engage in more health-damaging individual behavior (Lampert and Kroll 2006). Life expectancy differences by income amount to 4–6 years between the poor and the rich, that is, those persons in the first and the fourth income quartiles. Greater differences are found to exist when more refined income groups are used. Income-related mortality differences tend to be greater among men (Lauterbach et al. 2006; Reil-Held 2000). Social gradients are usually highest in the working-age population and in the first year of life (Siegrist and Marmot 2004). Even though the social mortality gradient decreases with age, it still exists among pensioners, again amounting to several years of remaining life expectancy. Similarly, income-related mortality gradients have been shown to exist in eastern and western Germany (Shkolnikov et al. 2008; von Gaudecker and Scholz 2007).

Although income is probably the most important mortality-determining factor among all of the socioeconomic indicators, it is not a standalone factor. A low income is frequently the result of having less education and a job that requires lower qualifications.

People who are employed in occupations that require lower qualifications, and that have lower status, also have a higher mortality risk. The mortality risk among manual workers is four times higher than among professionals in Germany[2] (1987–1996; ages 30–70; Geyer and Peter 1999; Helmert 2005; Helmert et al. 2002). At retirement ages, the mortality of former manual workers is one-third higher than among salaried employees (Shkolnikov et al. 2008). Manual workers or members of lower occupational classes may be more exposed to occupational hazards, and their lifestyles may be unhealthier (Geyer and Peter 1999; Siegrist and Marmot 2004). Unemployment is also related to health. Unemployment is associated with declining health status, and mortality increases with the length of the preceding unemployment period. Evidence suggests that unemployment is causal in the development of health problems (Grobe and Schwartz 2003).

Generally, better-educated people live longer (Ross and Mirowksy 1999). However, less research has been done into the relationship between education and mortality than between mortality and other SES indicators. Among women in Germany, the education effect seems to be stronger than among men (Becker 1998). The educational gradient in mortality is, however, less pronounced in eastern Germany. Among the factors that may explain the smaller social class differences in the former GDR are the equal distributions of health-related behaviors, workloads, and medical resources. In addition, the GDR regime tried to suppress social differentiation by privileging working-class children in higher education. Better educated people in the GDR did not necessarily earn more (Abel et al. 1993; Becker 1998).

Several studies based their results on the relationship between socioeconomic status and mortality on combined indicators of socioeconomic status. Luy (2006) concluded that income has more resource-related social class effects on mortality, whereas education has more effects on health-related behavior. When other factors—such as self-rated health, health-related lifestyle, family status, and number of diseases—have been standardized, strong evidence has still been found for a social mortality gradient (Helmert 2003b).

While overall mortality clearly has a social gradient, research has also indicated that many specific diseases are unevenly distributed over social classes. Mielck (2005) summarized research in Germany on the major diseases and their occurrence across social classes. People in the lower social classes are generally more likely to get a certain disease than people in the higher social classes. Only for a few diseases, such

[2] Results were derived from health insurance data. Health insurance members are a selective, rather homogenous, group with regard to occupations and regions. As a result, the social gradient may be underestimated.

as allergies, is the prevalence lower than in the higher social classes. The risk factors of diseases or the mediating factors are distributed unequally across social classes, with a higher burden placed on the lower social classes (Heinrich et al. 2000; Mielck 2005). These patterns are likely to translate into the cause-of-death structure by socioeconomic group as is the case in other European countries (e.g., Erikson and Torssander 2008; Kunst et al. 1998; Rau et al. 2008; Saurel-Cubizolles et al. 2009).

Marital status is here considered as part of socioeconomic status, though its classification is ambiguous. There seems to be a protective effect of family related to its implied social support, and marriage is particularly protective for men. Two hypotheses address the mortality advantage of married people: the selection hypothesis and the marriage protection hypothesis. The first hypothesis claims that people in good health have better chances on the marriage market. The marriage protection effect emerges through social support that may help in preventing and curing diseases. Health care utilization also differs by marital status (Goldman et al. 1995).

Moreover, in the German context, divorced, separated, or widowed people have significantly higher mortality risks than married people, particularly in West Germany (Becker 1998; Helmert 2005; Helmert and Voges 2002; Helmert et al. 2002). The protective effect of marriage seemed to have been lower in the GDR (Becker 1998; Klein 2000; Razum et al. 1999). Because it was promoted by the GDR regime, marriage was less meaningful, and different family structures emerged in East Germany that led to family structures that have a smaller impact on mortality risk than in the West (Klein 2000). Like in West Germany, being unmarried in East Germany after reunification is related to lower socioeconomic status. Evidence shows that, in eastern and in western Germany, there is a protective effect of marriage today (Brockmann and Klein 2002). Klein (2000) suggested that regional mortality patterns are partly overlaid by marital status effects.

There are structural economic differences across the regions in Germany. These are reflected, for example, in the predominance of certain economic branches, such as strong service sector activities in the city-states, or, historically, extensive mining activities in North Rhine-Westphalia, Saarland, and the south of the former GDR. These structural differences, together with a region's general economic prosperity, influence the region's income and unemployment levels. Regional differences in family structures may be mediated by family policies, as has been seen in the differing legislation between the FRG and the GDR, and by cultural values. In sum, there appears to be a large degree of variation in regional socioeconomic structures, and these differences may in turn have large effects on regional mortality structures.

2.5.1.2 Lifestyle

Morbidity is in line with mortality patterns, at least on a larger scale, such as East-West differentials. These patterns are related to lifestyle factors, which are the result of socioeconomic factors, as outlined in the previous section. Lifestyle consists of direct and indirect mortality risk factors. Indirect (also called distal) risk factors—like smoking, alcohol consumption, lack of exercise, or an unhealthy diet—cause diseases. Among the direct pathophysiological risk factors are blood pressure, cholesterol, and other diseases that may cause death in the long run. People have higher mortality risks the more risk factors they have (Helmert 2003a).

Lifestyle is mirrored in many largely behavior-related causes of death, like lung cancer, diabetes, or cardiovascular diseases, and in avoidable causes, such as traffic accidents and alcohol-related mortality. East-West differences are easier to distinguish than other regional patterns, since they evolve from different structural backgrounds.

Most cardiovascular risk factors were more common in the East German population before reunification. During the 1990s, cardiovascular risk factors converged in the East and in the West. Smoking was an exception among the risk factors, with a higher prevalence seen among men in the GDR, but a lower prevalence seen among women. However, young eastern German women are now smoking more than their West German counterparts (Luy 2005; Mensink and Beitz 2004; Müller-Nordhorn et al. 2004). Higher cholesterol concentrations were observed for both sexes before reunification in East Germany, but became comparable to West German levels thereafter. Blood pressure and obesity were consistently higher in the East. Rates of diabetes were higher, at least in the 1990s (Mensink and Beitz 2004; Müller-Nordhorn et al. 2004).

A comparison of smoking, overweight, hypertension, inactivity, and regular alcohol consumption as mortality risk factors did not show significantly different patterns in East (1991–1998) and West Germany (1986–1992) (Helmert 2003a). Supposedly, the different time periods have an impact on the comparison between East and West Germany, since other studies reveal significant differences.

The diets of GDR citizens tended to be less healthy than those of West Germans, partly due to limited food availability, including shortages of fresh fruit, vegetables, and vegetable oil in the East. Differences in the diets of East and West Germans diminished during the 1990s. It is likely that these changes are also related to the fall in cardiovascular deaths throughout the 1990s (Mensink and Beitz 2004; Müller-Nordhorn et al. 2004; Nolte and McKee 2000; Thiel and Heinemann 1996).

Patterns of alcohol consumption differ regionally, with higher beer and wine consumption seen in the West. Alcohol-related mortality also differs regionally, and still contributes to the mortality differences between the East and the West. Eastern Germans have higher levels of alcohol consumption, and display riskier alcohol consumption patterns (Mensink and Beitz 2004; Robert Koch-Institut 2009). After taking the protective effect of alcohol into account, the alcohol-related East-West mortality gap was found to have diminished over the 1990s (Nolte et al. 2003). From a regional perspective, alcoholism was shown to be more common in the north of the GDR than in the south prior to 1990. Schwerin, Neubrandenburg, and Rostock were the *Bezirke* with the highest number of medical interventions related to alcoholism, while Dresden had the lowest incidence (Sieber et al. 1998). Northeastern Germans continue to consume more alcohol than other Germans (Baumeister et al. 2005).

Small-area differences in cardiovascular risk factors (hypertension, serum cholesterol, cigarette smoking, and obesity) were also found between two cities in the GDR.

In the mid-1970s, a higher incidence of cardiovascular risk factors was found among residents (especially men) of the eastern city of Schwedt than among residents of the southern city of Erfurt. This gap has been attributed to regional dietary patterns and different ways of life in Schwedt, which was a newly built city at that time (Gräfner et al. 1981). These findings are also relevant for this study, because they address the issues of the north-south gradient and the different population compositions.

An examination of direct risk factors shows that the lifetime prevalence of myocardial infarction decreased in western Germany in the 1990s, but increased in eastern Germany (Wiesner et al. 1999b). Stroke prevalence did not significantly differ between eastern and western Germany (Wiesner et al. 1999a). Hypertension was more prevalent for men than for women, and was higher in eastern than in western Germany. A decline in the East coupled with an increase in the West led to a convergence at a high level during the 1990s (Thamm 1999). A regional comparison revealed greater hypertension prevalence in the northeast than in the southwest (Meisinger et al. 2006).

The regional mortality effects of lifestyle factors largely depend on the population structure, as risk factors reflect different lifestyles in different socioeconomic environments. It is certainly possible that lifestyle factors, such as eating habits or outdoor sport activities, vary regionally.

2.5.1.3 Living Conditions

Living conditions have seldom been taken into account in studies on health and mortality in Germany. Living conditions include the location of a person's home, the size and the furnishings of the home, the household composition, the environmental conditions in the home and in the surroundings, the type of heating, and the neighborhood. Living conditions could also be regarded as a macro-level factor, as they usually affect several people. Urbanization is, for example, an aspect of living conditions on the aggregate level. The classification of living conditions under micro-level factors is more appropriate here, as macro-level factors in this study refer to regional factors.

A major aspect of living conditions is housing, which is also related to health. Dwellings differ not only in their living spaces but also in their health-related features. For example, the type of heating, the levels of dampness and dust, and the concentration of heavy metals differ considerably between houses (Heinrich et al. 2000). Members of the lower social classes are more likely to suffer from adverse housing conditions, and from greater negative environmental burdens, including more noise and air pollution (Heinrich et al. 2000; Mielck 2005). Both the interior of the home and the home's location affect health (Heinrich et al. 2000). Furthermore, home owners tend to be healthier than renters. Home owners generally are of higher socioeconomic status, but even after controlling for financial and occupational status, home owners have been found to have better self-rated health than renters (Pollack et al. 2004). It has been suggested that the better health seen among home owners is attributable to their social and physical environments, which may, for example, foster a feeling of security.

Differences in living conditions are especially pronounced between East and West Germany. These differences have been diminishing since reunification through accelerated improvements in the East (Nolte and McKee 2000; Schmitt and Maes 1998). Exposure to pollution in dwellings used to be higher in East Germany, but was reduced after reunification, especially due to a shift from coal to central heating (Heinrich et al. 1999; Müller-Nordhorn et al. 2004). The improved housing conditions for East Germans after reunification were associated with increased living space and a rising share of home-ownership. The furnishings and fixtures of the dwellings also improved greatly. These improvements were, however, accompanied by rising prices, as rents during the 1990s rose faster than income (Hinrichs 1999).

Small-area differences in living conditions, mainly triggered by social and economic structures, are likely to exist.

2.5.1.4 Human Biology and Genetic Factors

Genetic makeup varies greatly between individuals, with some people being more susceptible to developing certain diseases than others. Genetics play an important role in diseases known to have a strong hereditary component, such as certain types of cancer, cardiovascular diseases, diabetes, or mental illnesses (Curtis 2007, p. 156). About 5% of all malignant neoplasms are due to a genetic predisposition, mainly cancer of the colon, breasts, ovaries, and eyes (Becker and Wahrendorf 1998). Generally, around one-quarter of variation in lifespan is attributable to individual genetic makeup (Christensen and Vaupel 1996). It is also highly likely that some people are more susceptible than others to environmental disturbances. How such mechanisms work is largely unclear.

One way to find out about spatial differences in genetics is to analyze migrants' health patterns. In Amsterdam, for example, there are only a few diseases that tend to affect migrant groups more than the native population, including diabetes and heart diseases among immigrants from South Asia (Uitenbroek and Verhoeff 2002).

Regional clustering of genetic traits is possible, though unlikely, in a mobile modern society. It may be assumed that genetic differences within Germany cannot explain regional mortality differentials (Curtis 2007; Heins and Stiens 1984; Kemper and Thieme 1991).

2.5.2 Macro-level Mortality Factors

Contextual factors or group-level variables are macro-level factors that act from a higher level on all lower-level units. There are two types of contextual factors. The first type is a derivative of individual-level variables (derived or aggregate variables). All individual-level factors can also be turned into group-level factors, whether as a mean, a proportion, or another statistical form calculated for groups of individuals. The second type of contextual factor does not have a straightforward connection with the individual level. These factors can be integral variables (group-level variables that have no individual-level equivalent, such as legislation), environmental variables (not derived from individual-level variables, but with analogues on the group and individual levels, such as sunlight exposure among individuals and in a region), or structural variables that constitute interactions between group members (Diez-Roux 2002).

In the following, the mortality impact of demographic structure, socioeconomic conditions, and changes in these conditions as well as the degree of inequality, medical care provision, and environmental conditions are discussed.

2.5.2.1 Demographic Structures and Population Composition

The influence of basic demographic factors reflecting the age and sex composition of the population can be easily standardized. Important aspects of demographic differences include the population composition by marital status, nationality, population density, and migration patterns.

Population density can be of importance for mortality, since it is related to the availability of general infrastructure, such as health care services and schools. At the same time, the spread of diseases can be higher in urban centers with higher population densities and more frequent inter-individual contacts (cf. European Communities 2009). In western Germany, urban mortality is higher than rural mortality. In eastern Germany, mortality is considerably higher in the more remote rural areas (Mai 2004; Queste 2007).

Migration flows affect mortality because the migrant populations differ from the host population with respect to health, education, occupation, and behavioral and cultural patterns. The term “healthy migrant effect” refers to the higher levels of health among migrants than among the receiving population, due to the health selection effect associated with migration. However, this initial health selection effect diminishes with time following the move (Lechner and Mielck 1998; Raymond et al. 1996; Razum et al. 1998; Uitenbroek and Verhoeff 2002).

Immigration and emigration areas are more affected by structural changes to sociodemographic patterns. In general, areas that attract immigrants tend to have a younger population age structure, slower rates of aging, and more prosperous economies. The opposite holds for emigration areas, which lose the most educated and active people.

The more industrialized areas in West Germany were receiving regions of mostly Southern European labor migrants during the 1950s up to the early 1970s, with more migrants arriving in subsequent years due to family reunion. The labor migrants were mostly employed in the automobile, coal, iron, and steel industries. This major in-migration flow is still reflected in today’s distribution of foreigners. The largest group of labor migrants in the GDR was from Vietnam, followed by migrants from other communist countries.

Over the 1990s, high levels of out-migration and low levels of in-migration were observed in eastern Germany, while the reverse occurred in West Germany, especially in southern Germany. These migration trends were driven by young people in vocational training and young professionals. Even before reunification, migration flows occurred from East to West Germany. This resulted in a loss of human capital that accumulated over the years (Schneider 2005). Luy and Caselli (2007) found evidence that these structural changes have indeed resulted in unfavorable mortality structures in northeastern Germany. Further studies have linked regional mortality variation in Germany to migration flows, and have shown low mortality in areas of migration in-flows. These low death rates may be related to the strong economic performance of these areas (Cischinsky 2005; Kuhn et al. 2006; Lhachimi 2008).

Marriage patterns furthermore contribute to the demographic structure of a population. At the individual level, marriage has a positive effect on health (see Sect. 2.5.1.1 for the individual-level effect). The differential regional impact of marital status on mortality could be seen in the course of reunification. The mortality differences between the married and the unmarried were small in the GDR, but married people had a significant mortality advantage in both East and West Germany (Becker 1998; Brockmann and Klein 2002; Razum et al. 1999; Watson 1995). This may have been an expression of the effect of social capital on health but also may have reflected differential selection processes (cf. Watson 1995). Regional variation in marriage rates and the meaning of marriage for health can be related to changing trends in selection into marriage, and to cultural and religious values in Germany.

In sum, all of these factors related to demographic structure and population composition appear to be relevant in regional mortality research. However, through various mechanisms, the effects of migration flows seem to have the greatest impact on regional mortality differences.

2.5.2.2 Socioeconomic Conditions

A region's socioeconomic conditions can also shape mortality structures. Economic wealth increases living standards, and the regional governments can implement health and education policies or improve general conditions at the local level. The clear association between high levels of life expectancy and prosperity support the argument that better health care, better living conditions, and safer environments lead to lower mortality and steeper mortality improvements. Local industries determine the predominant types of occupations.

An association between countries' economic performance and mortality has been established. It has been shown that life expectancy tends to be higher in countries where the income level is higher. Preston (1976) showed the relationship between increasing life expectancy and increasing national wealth with a curve of life expectancy that strongly rises with increases at lower wealth levels (low income countries), but then levels off at higher wealth levels. Hence, poorer regions benefit more from rising wealth.

It has also been suggested that, in addition to the general link between income and mortality, lower levels of income inequality may lead to lower mortality. Income inequality has been found to play a less important role in predicting life expectancy in high-income than in low-income countries in the cross-section (Moore 2006; Wilkinson 1992, 1998). Marmot (1994) gave two explanations for the health effect of income inequality. First, inequality is associated with a greater proportion of poor people with worse health. Second, inequality itself (and not just poverty) causes mortality deprivation. Inequality traces back to the relative standing of a population subgroup relative to another. Some evidence suggests that the relationship between life expectancy and income inequality is even closer than to income level, that is, relative deprivation, rather than absolute deprivation, matters due to certain psychosocial mechanisms (Marmot 1994; Siegrist 2000; Wilkinson 1992, 1998). It should, however, also be noted that when the income of the poorest segments of the population increase, income inequality decreases.

However, it has also been shown that the association between mortality and income inequality has not been equally significant in all countries, time periods, and age groups (Lynch et al. 2004). Several authors have stressed, for example, that such an association is stronger in low-income countries. Furthermore, it is not clear that increases in income necessarily lead to increases in life expectancy (Deaton 2003; Lynch et al. 2004; Preston 1976; Shkolnikov et al. 2011).

On the macro level, the effects on mortality of an area's income and income inequality level, and the relationship between these two factors over time, were mostly analyzed in the international context. Several of these cross-country studies included Germany. For Germany, it has been proven that, at the individual level, wealthier people have lower mortality (Klein and Unger 2006; Lampert and Kroll 2006; Lauterbach et al. 2006; Reil-Held 2000; Shkolnikov et al. 2008; von Gaudecker and Scholz 2007). At the regional level in Germany, a strong association between mortality and economic wealth has been demonstrated by several studies, including studies that looked at the districts of Bavaria and Baden-Württemberg (Kuhn et al. 2006; von Gaudecker 2004) and at all German districts (Brzoska and Razum 2008). Other indicators of economic wealth were connected to mortality and health outcomes as well. The most important of these, unemployment and the type of occupation, were examined at the individual and at the macro levels (see, e.g., Albrecht et al. 1998; Grobe and Schwartz 2003; Queste 2007). It has been shown that the federal states with lower unemployment levels exhibited lower postneonatal mortality, apart from all-cause mortality (Nolte et al. 2001).

In addition to income and income inequality, a region's economic trends may influence the psychological well-being of the residents, as people with better career prospects have a greater feeling of job security and economic stability (Siegrist 2000).

The regional clustering of certain occupational branches with their specific occupational risks can lead to regional excess mortality. For example, while cancer caused by occupational exposure account for only 4–8% of all cancers, highly industrialized regions may have much higher rates of work-related cancers (Becker and Wahrendorf 1998).

Regional differences in income and occupation reflect prevailing economic and structural conditions, like more agricultural workers in the countryside. Educational differences are less comparable across the German states, since the educational system is administered by the federal states. Bavaria, for example, has a low share of high school graduates, which is caused by a less permeable school system. Hence, educational levels can differ regionally, and this can be reinforced by selective migration. Educational differences may, however, determine individual mortality risk factors (see Sect. 2.5.1.1).

In a comparison of East and West German mortality trends, income level appears to be a more plausible explanation of differences than income inequality. In more egalitarian societies like the GDR, income inequality is less pronounced. In the years immediately following German reunification, income inequality increased in East Germany, but was accompanied by high GDP increases in East Germany (Goebel et al. 2004). A move toward a capitalist system brings increasing income inequality, which can cause extra pressure. As a legacy of GDR times, eastern German federal states generally still experience lower levels of income inequality (Berlinpolis e.V. 2006). However, mortality has been greater in the eastern German federal states. Even though the GDR was, at least in theory, a more egalitarian society than West Germany, social differences existed, and were also reflected in mortality (cf. Berndt and Gregor 1975). The GDR tried to level social differences by providing special advantages to the children of workers, while discriminating against the children of university graduates.

Germany exhibits substantial regional differences in the areas of income and income inequality, occupational branches, and educational levels (Statistisches Bundesamt 2006). Education and income inequality levels are not necessarily comparable at a regional level, but income and occupational composition are.

2.5.2.3 Medical Care Provision

The German health care system has long been seen as a classic example of systems that provide (nearly) universal medical care (Iglehart 1991). Health care is governed by the state. The state is responsible for most of the hospitals, but all other forms of health care are provided by the private market. Financing takes place via the social security system. About 90% of the population are covered by compulsory health insurance (CHI), and the rest have private insurance (Swami 2002). Because residents of Germany are legally required to be insured, only a negligible share of the population are not covered by any form of health insurance. Insurance coverage includes all medically necessary treatments for both insurance types, independent of the income of patients. Patients have been required to make co-payments since the German health care reform of 2004. An association of CHI physicians issues authorizations for practices according to the population's need for physicians, in an effort to avoid under- and oversupply. It would appear that this health care system provides good access to medical care for the whole population (Rosenbrock and Gerlinger 2004).

Given this universal coverage, how can medical care contribute to regional disparities in health and mortality? Distinctions can be made between the factors of the provision or availability of medical care, access to and utilization of medical care, and the quality of medical care (Curtis 2007).

Regarding the availability of medical care in the German regions, regulations on the education of medical students and the ongoing demographic change lead to lower replacement rates of physicians in certain regions. In the GDR, the government paid special attention to an equal distribution of health care and had a special policy for sending physicians to the countryside (Hilbk 2002). Today, the average age of physicians is steadily increasing, and the share of young physicians is decreasing, especially in eastern German rural areas. Eastern Germany's physician density is lower, and it faces a particularly serious problem of undersupply of general practitioners (Kopetsch 2004). Financial rewards are lower in the East, even for the same services, and the workload is heavier (Brenner 2001; Hilbk 2002). In addition to these regional differences in physician density, the equipment with specialized medical facilities tends to be concentrated in urban areas, for example in university hospitals.

Given the legal obligation to have health insurance, individual access to health care is almost universal. But access to medical care can potentially produce regional differences in health due to, for example, differences in the mean admission time to hospitals following emergencies like strokes, acute myocardial infarctions, or accidents. The access to emergency medicine can be especially problematic in the rural areas of regions like Mecklenburg-Western Pomerania.

On the individual level, it has been observed that poor people pay less attention to their health, and go to the doctor less frequently. People with private medical insurance—mainly wealthier people—appear to have better access to the health care system (Lampert and Kroll 2006; Mielck 2005). Migrants have worse access to the health care system (Razum 2004). It is plausible that an area-specific accumulation of such risk groups may lead to mortality differences in the long run.

The quality of health care can be assessed by health care outcomes. Medical care can be particularly effective in reducing mortality from the so-called avoidable causes, such as deaths from infectious diseases at young ages or cardiovascular diseases at ages under 75 (Holland 1988; Nolte and McKee 2004; Rutstein et al. 1976).

The East-West life expectancy gap in the 1980s and 1990s was partly due to avoidable causes of death. A rapid decline in avoidable causes over the 1990s took place in eastern Germany. The availability of high-quality health care and the steady improvement of this care seem to be the preconditions of declining mortality. This also depends on mediators such as personal financial resources, which influence the pace of the implementation of improvements. In the East-West comparison, room for improvement has been noted for some causes that are likely to respond to health policy, like alcohol-related diseases and accidents (Kibele and Scholz 2008; Nolte et al. 2002).

Several studies have sought to explain regional mortality differences by indicators of health care. They have shown, however, that the associations between the level of mortality and indicators of health care service are frequently nonexistent or counterintuitive (Albrecht et al. 1998; Cischinsky 2005; Kuhn et al. 2006; Lhachimi 2008; von Gaudecker 2004; Young 2001). Socioeconomic predictors work better in explaining mortality declines and geographical disparities. Health care indicators used in studies on avoidable mortality are often crude, and socioeconomic differences may indirectly "reflect differences in the timely access to effective care" (Nolte and

McKee 2004, p. 36; Mackenbach et al. 1990). This is related to the meaning of density of health care resources, like the number of physicians or hospital beds, which cannot be clearly determined at the regional level. While a good supply of medical care should result in better health status and lower mortality, the presence of a large number of physicians may also be a response to a sick population. At the same time, the transfer of seriously ill persons to places with better medical care can be another biasing factor (Young 2001).

In short, the availability of medical care is good across Germany, but has been better in the West. Access to medical care may be worse in the countryside, but care still remains available to all population groups. The utilization of health care services depends on individual risk profiles, which may differ regionally. The quality of health care improved considerably in eastern Germany after reunification, and it is now comparable over all of the regions of Germany.

2.5.2.4 Environmental Conditions

Environmental pollution is a risk factor mostly for respiratory diseases and certain types of cancer. Contacts with health-damaging substances may occur through oral intake, skin contact, or inhalation, and long-term exposure may lead to chronic forms of diseases. However, short-term effects of exposure, like breathing difficulties, are also possible. Common examples of environmentally induced diseases are skin cancer, which is mainly caused by overexposure to sunlight; thyroid disorders, which may be caused by shortages of iodine; and lung cancer, which can result from asbestos exposure. Among the factors that may influence the development of an environmentally induced disease are behavioral factors, genetic predisposition, and occupational exposure (Curtis 2007).

In addition to lifestyle factors like nutrition and smoking, the environmental burden can—albeit with long latency periods—play an important role in the development of cancer. In the 1980s, it was thought that, in the broader sense, about 80% of all cancers were environmentally induced (Howe 1986), but this view has shifted toward a more complex interplay between lifestyle, genetics, and environmental factors. According to current estimates, just 2% of cancers are related to the environment in the narrower sense (Becker and Wahrendorf 1998). A study from the 1980s that looked at overall mortality in Germany tied 16% of deaths directly or indirectly to environmental factors (Heins and Stiens 1984).

Environmental pollution as an agent for respiratory diseases is spread differently throughout Germany, and distinct East-West differences exist. In the late 1980s and early 1990s, air pollution was worse in the East than in the West, largely due to brown coal heating and energy production (Heinrich et al. 1999; Wichmann and Heinrich 1995). In the West, heavy industries were in the process of being dismantled by the 1980s. Generally, initiatives to protect the environment were more prevalent in the West than in the East. After reunification, pollution caused by particulates, sulfur dioxides, and lead was reduced through, for example, the introduction of central heating and the shutting down of old industries (Müller-Nordhorn et al. 2004; Schulz et al. 2007). From an international perspective, Germany has a relatively small environmental burden (Schulz et al. 2007). As mentioned in Sect. 2.3.3, the higher environmental burden in the southern part of the GDR cannot be directly related to mortality, which was lower in the south of the GDR than in the north (Dinkel 2000; Luy 2004). Although mortality at the area level is not elevated, there is evidence that former miners have an increased lung cancer risk (Brüske-Hohlfeld et al. 2006).

The reflection of environmental burden in diseases is not always in the expected direction, and illustrates the degree of sensitivity to air pollution. Eastern Germans are more likely to suffer from respiratory diseases, lung function decrements, atopic skin disorders, and a higher concentration of IgE (an antibody which mediates allergies). On the other hand, western Germans have a higher prevalence of asthma, wheezing, and hay fever (Heinrich et al. 1999; Wichmann and Heinrich 1995; studies mostly on children). Small-area differences in disease patterns may reflect the regional variation in the burden due to air pollution (Heinrich et al. 1999).

The prevalence of respiratory diseases is not independent of socioeconomic status, with more frequent occurrences found in the higher social classes. People in the lower social classes are more often exposed to factors like noise pollution or the presence of harmful substances in the workplace (see Sect. 2.5.1.1; Curtis 2007).

At the regional level, mortality appears to be higher in areas with more air pollution, as measured by particulate matter concentration changes. However, no such effect on mortality has been found in less polluted areas (Gatzweiler and Stiens 1982; Peters et al. 2000). Ecological associations at the district level between alcohol and disaccharide consumption and stomach cancer, as well as between protein intake and pancreatic cancer, have been found (West Germany, 1976–1980; Böing et al. 1985). Other regional mortality studies in Germany have, however, found no significant effects of environmental pollution on mortality. This is possibly due to overlaps with adverse socioeconomic contexts, and severe measurement problems (Cischinsky 2005; Gatrell 2002; von Gaudecker 2004).

Seasonal mortality patterns, as well as links between the temperature and mortality, have been found in Germany. Mortality is lower in the summer than in the winter. Heat waves in the summer lead to higher mortality. Temperature changes over the course of the year lead to increasing death rates when the temperature is rising and vice versa (Laschewski and Jendritzky 2002). Between East and West Germany, the seasonal mortality pattern was slightly more pronounced in the East in the second half of the twentieth century (Dinkel and Kohls 2006). The East also tends to have greater temperature extremes in general due to the continental climate in the area.

The availability of faster cars and the steady improvement in road conditions in East Germany led to a sharp increase in traffic accidents in East Germany shortly after reunification. In addition, more road traffic led to more traffic pollution after reunification, a factor that is known to contribute to respiratory problems (Wichmann and Heinrich 1995). The amount of road traffic is a good indicator of air pollution, since cars are the biggest source of this type of pollution (Albrecht et al. 1998).

The adverse conditions of the physical environment may explain regional mortality differences, including the persistence of an urban-rural divide, and, to a decreasing extent, an East-West divide. The impact of environmentally induced diseases on regional mortality differences seems minor compared to other risk factors.

2.5.3 Interplay Between Micro- and Macro-level Mortality Factors

The preceding review of possible determinants of regional mortality differences at the micro and macro levels has shown that a large share of differential mortality appears to be directly or indirectly related to socioeconomic differentials in the population and between regions (cf. Leon 2001). Individuals are influenced by the social and built environments in which they live. Because the regional context is, to a certain extent, composed of the aggregation of individual-level characteristics, mortality determinants at the micro and the macro levels cannot be considered independently of each other.

Empirical studies have shown that independent context effects on mortality persist, even when individual-level risk factors are controlled for (Pickett and Pearl 2001; Riva et al. 2007). Theoretically, outcomes at the micro level can be influenced by conditions at the macro level and vice versa. Empirical evidence has proven that this is the case (Diez-Roux 2002; Riva et al. 2007). But how this interplay of individual- and regional-level contexts occurs—and the extent to which it occurs—remains unclear (Diez-Roux 2001; Tunstall et al. 2004). Thus, both further elaboration of and a more solid theoretical foundation for the causal pathways that demonstrate how micro- and macro-level factors interact and influence individuals' mortality risks are needed (Diez-Roux 2001; Pickett and Pearl 2001; Riva et al. 2007; Voigtländer et al. 2008).

It can be hypothesized that living in an advantageous environment has the greatest impact on individual health. Or, conversely, it can be argued that living in a deprived area has the greatest effect on individual health (Diez-Roux 2001). Empirical evidence suggests that people of lower SES groups suffer greater detrimental effects of adverse regional context (Riva et al. 2007). This issue will be picked up by the literature review on multilevel modeling in health statistics in Chap. 5.

Concepts used to explain regional mortality variations usually consider different area levels—such as nation-states, cities, and neighborhoods—that may be acting on the mortality risks of individuals (Dahlgren and Whitehead 2007; Valkonen 2001). Suitable definitions of an area may differ according to health outcome, such as cause-specific mortality. Additionally, while interactions between different levels are thought to exist, they are rarely specified (Diez-Roux 2001).

Generally, it is expected that individual-level and regional-level risk factors, as well as their interplay, determine an individual's mortality risk. Several factors, such as policies or cultural norms, may have effects on both individual- and regional-level factors.

2.6 Research Questions

Regional mortality differences reflect social inequalities in population health. However, the interplay between mortality and the social and built environments is not yet fully understood, and has not been adequately explored, especially in Germany.

The literature review provided a summary of regional mortality in Germany, and of the possible determining factors at the regional level. The literature review discussed the various studies but also demonstrated that research remains very scattered. East-West mortality differentials and their subsequent convergence after reunification attracted the most attention. Although East German regions underwent the greatest societal changes due to the regime shift, other German regions underwent structural changes too. These changes did not emerge suddenly, as in East Germany, but may also have had an impact on mortality.

Several weaknesses of the current research picture were mentioned in the literature review. Most studies looked at only certain regions instead of the entire country. In addition, in many studies, the longitudinal perspective was largely neglected, the East-West division was not refined through the inclusion of a small-area perspective, and objective measurements in the assessment of the spatial patterns were partly missing. Moreover, past research did not demonstrate to what extent the population composition is responsible for regional mortality variations.

This study seeks to explore the patterns of regional mortality variation in Germany and how they change over time, and to identify the factors that explain these structures and their changes. The role of population composition—that is, the differential spread of individual mortality risk factors on regional mortality variations—will also be assessed. The focus of this study is thus on small-area mortality differentials, and the research questions are addressed at different spatial scales, and are based on multidimensional data.

The following research questions will serve as a basis for the empirical analyses on regional mortality variations in Germany.

What mortality patterns can be observed at different levels of regional aggregation? With increasing life expectancy in Germany over time, how is the life expectancy increase distributed over the regions? Which regions modify the general regularities in regional patterns? Can meaningful aggregated regions with distinct mortality structures be identified?

In order to gain insight into the causes of these regional mortality patterns, the following questions are posed:

How do age- and cause-specific mortality contribute to these regional patterns, and to changes in these patterns? Are there different underlying age- and cause-specific distributions that produce the same overall mortality outcome?

What factors explain mortality variations between individuals and between regions? Are the determinants of mortality differences between regions different from the mortality determinants that drive the mortality change in the regions over time?

Specific factors that were thought to explain East-West differences in mortality before reunification, like health care factors, have by now been adjusted. Other factors—such as socioeconomic conditions, occupational structures, or environmental burdens—differ greatly within Germany, and not only between East and West. However, because an East-West life expectancy gap clearly existed after reunification, the following question arises:

What is the role of the East-West divide in the mortality variation across space and time?

Population compositions differ considerably between Germany's regions, that is, the prevalence of important individual characteristics varies by region (apart from the age- and sex-specific structures). The literature review noted the presence of significant mortality differences between population groups. The combination of the two levels implies that regional mortality differences are—at least in part—due to differences in population composition, and that establishing ecological associations between mortality patterns and their determinants is insufficient.

Once the differences in population composition across regions are accounted for, are there any remaining small-area mortality variations in Germany? What regional-level context factors explain the remaining small-area mortality variations? Is there evidence that the regional context alters the mortality impact of individual-level mortality risk factors?

Chapter 3
Mortality Differentials Across Germany's Federal States

3.1 Introduction

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

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

3.2 Data

3.2.1 Population and Death Counts

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

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

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

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

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

3.2.2 Cause-of-Death Statistics

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

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

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

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

3.2.2.1 Differences Between the GDR and the FRG

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

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

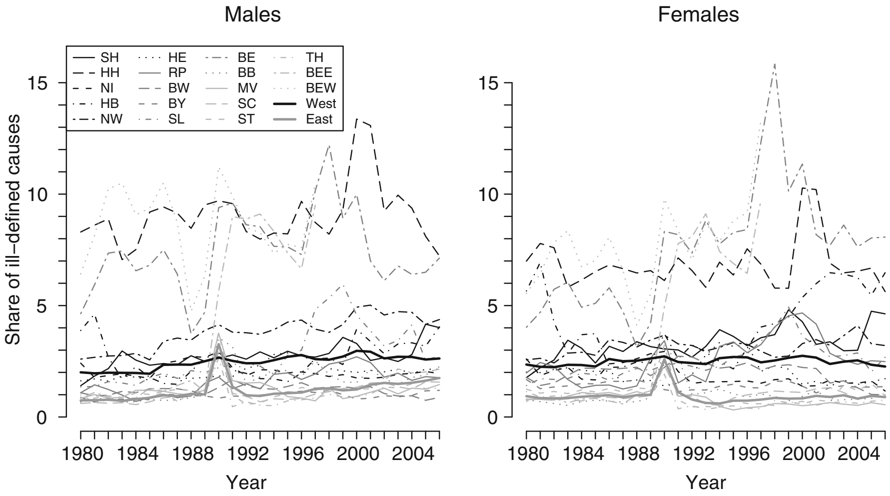

Fig. 3.1 Share of ill-defined causes in all deaths by federal state; 1980–2006. *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg,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

3.2.2.2 Ill-Defined Causes

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

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

3.2.2.3 ICD Classifications

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

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

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

3.2.2.4 Selection of Causes for Subsequent Analysis

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

3.3 Methods

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

3.3.1 Life Expectancy

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

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

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

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

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

3.3.2 Lifespan Disparity $e^\dagger$

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

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

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

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

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

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

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

3.3.3 Dispersion Measure of Mortality

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

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

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

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

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

3.3.4 Cause-of-Death Analysis

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.4 Life Expectancy and Its Variation Across Federal States

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

3.4.1 Life Expectancy in East and West Germany

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

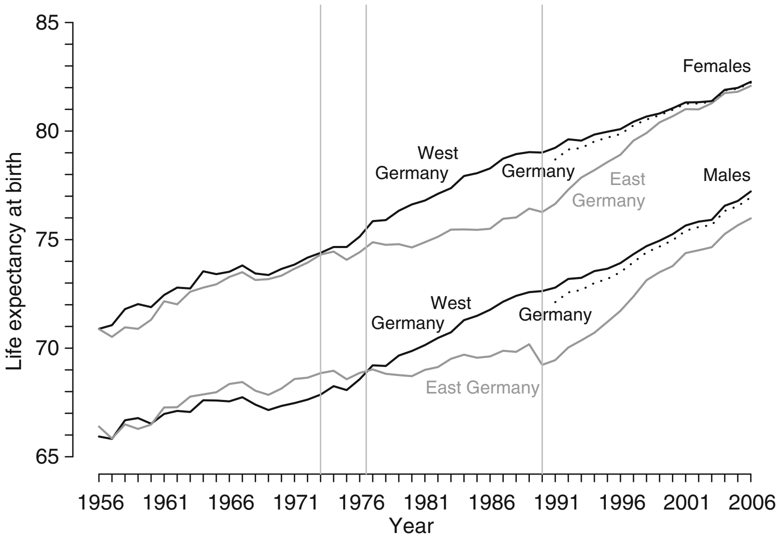

Fig. 3.2 Life expectancy in East and West Germany; 1956–2006. *Vertical lines* distinguish important time periods and indicate when East and West German life expectancies cross and 1990, the year of reunification. 1956–1972 (f) and 1956–1976 (m): life expectancy was higher in East Germany; 1973–1990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

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

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

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

3.4.1.1 Age-Specific Differences in Life Expectancy

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

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

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

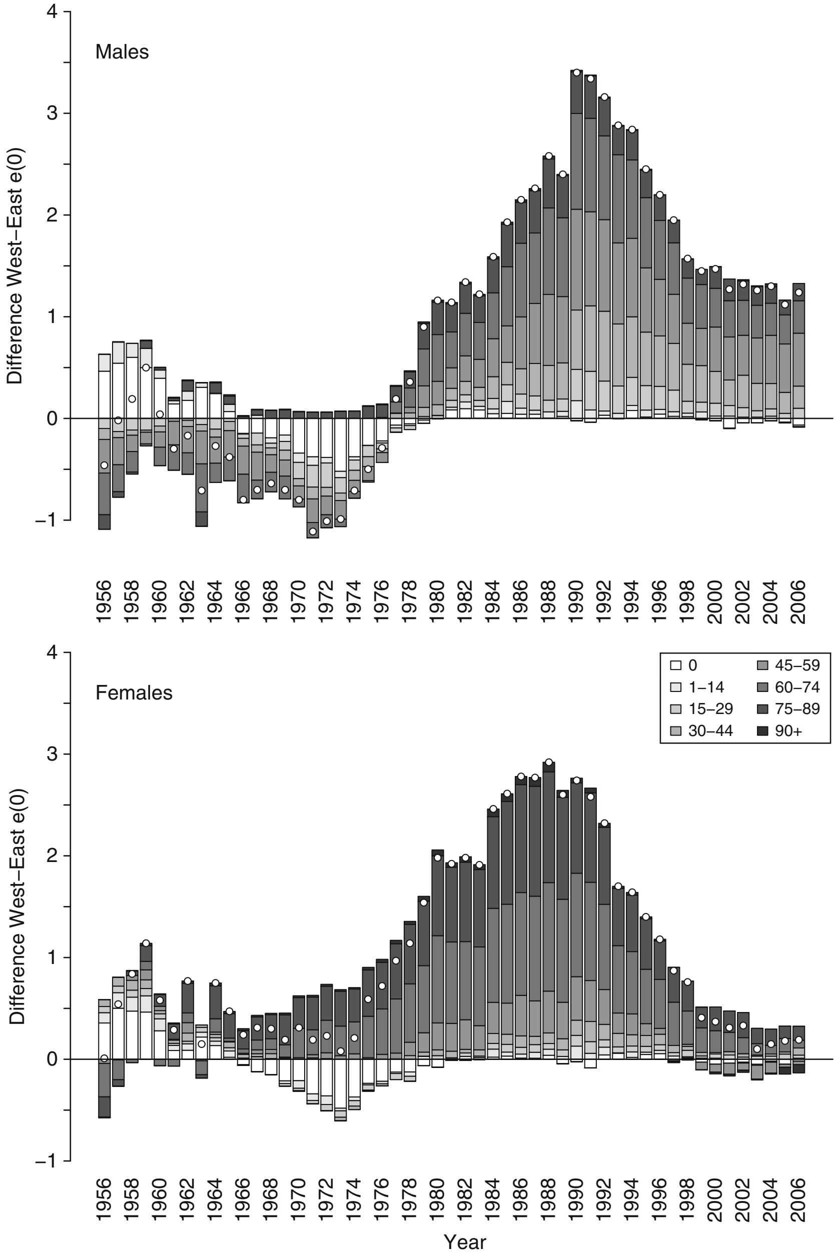

Fig. 3.3 Contribution of age-specific mortality to differences in life expectancy between West and East Germany; 1956–2006. *Circle* indicates total life expectancy difference (Data source: Human Mortality Database 2008c)

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

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

3.4.2 Life Expectancy by Federal State

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

3.4.2.1 Regional Pattern of Life Expectancy

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

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

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

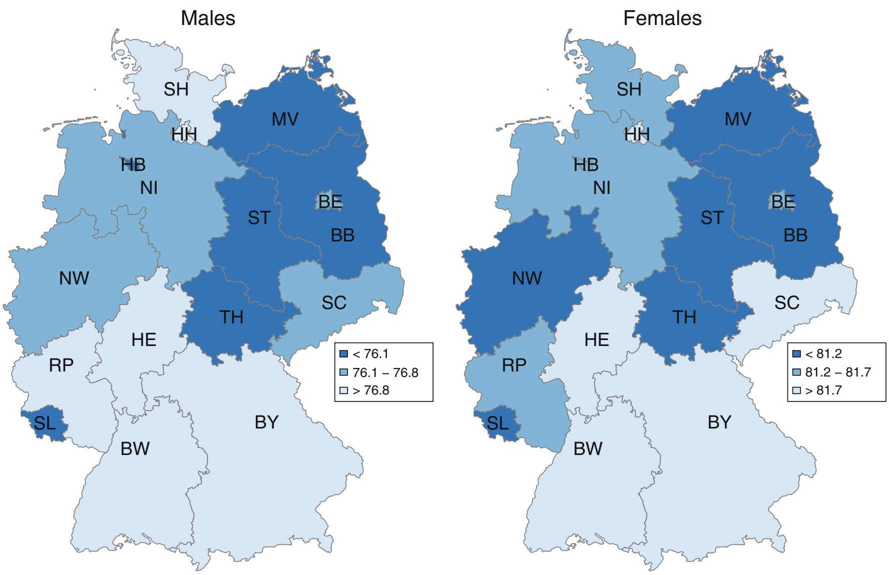

Fig. 3.4 Life expectancy by federal state; 2004–2006. *SH* Schleswig-Holstein (e_0 males 76.83 years, females 81.30 years), *HH* Hamburg (76.98, 81.35), *NI* Lower Saxony (76.64, 81.35), *HB* Bremen (76.09, 81.21), *NW* North Rhine-Westphalia (76.46, 81.18), *HE* Hesse (77.61, 81.95), *RP* Rhineland-Palatinate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

3.4.2.2 Trends in Life Expectancy

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

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

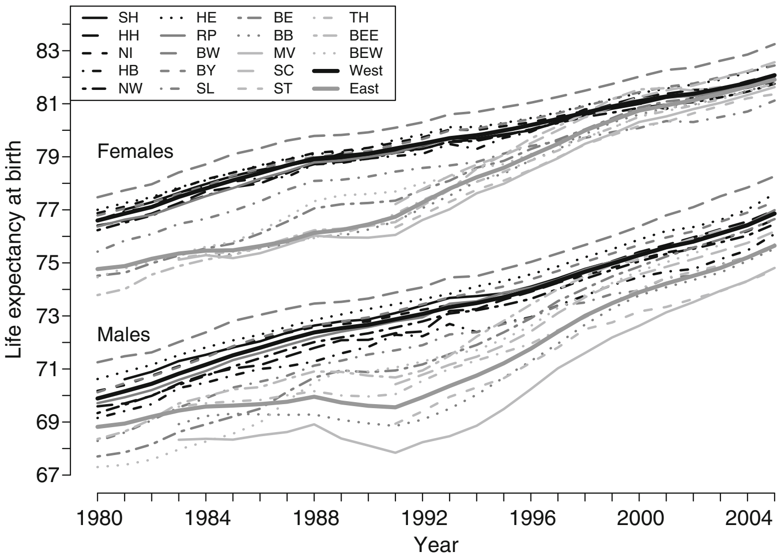

Fig. 3.5 Life expectancy by federal state; 1979–1981 to 2004–2006. *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.4.3 Dispersion of Life Expectancy Across Federal States

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

3.4.3.1 Dispersion Measures

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

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

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

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

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

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

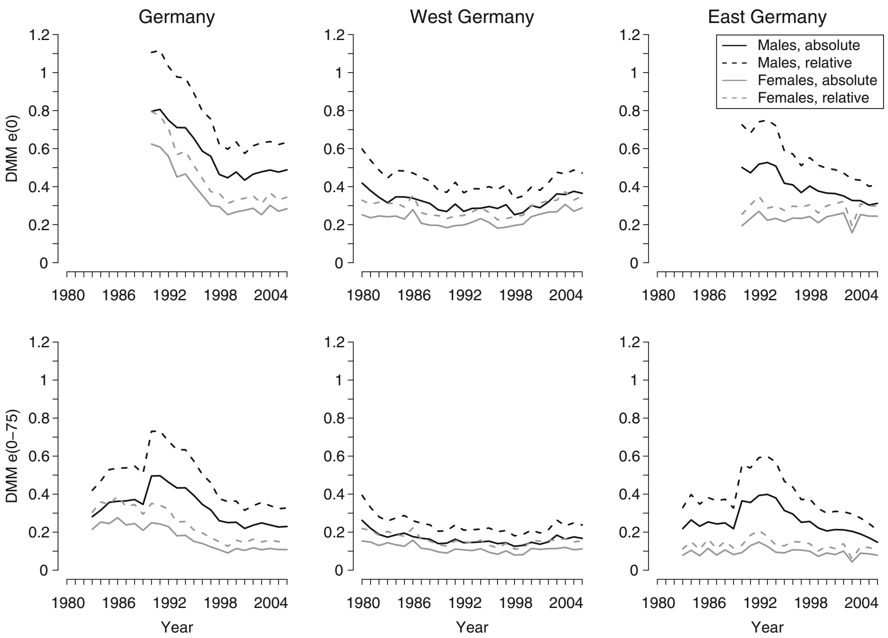

Fig. 3.6 DMM across federal states for life expectancy at birth (e_0) and temporary life expectancy (${}_{75}e_0$); 1980–2006. Absolute DMM in years, relative DMM in years relative to life expectancy. East and West Germany both excluding Berlin (Data source: Federal State Offices of Statistics, Germany)

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

3.4.3.2 Results

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

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

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

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

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

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

3.5 Lifespan Disparity and Its Variation Across Federal States

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

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

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

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

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

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

3.5.1 Lifespan Disparity in East and West Germany

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

3.5.1.1 Five Periods of Lifespan Disparity Changes

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

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

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

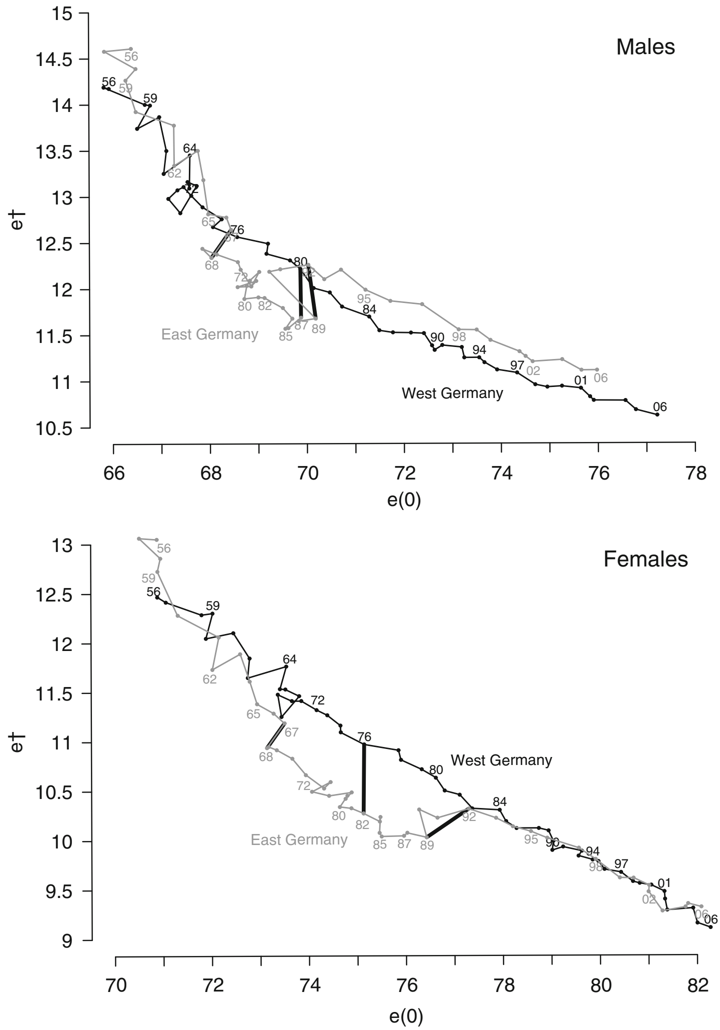

Fig. 3.7 Lifespan disparity $e^{\dagger}$ versus life expectancy e_0 in East and West Germany; 1956–2006. *Bold lines* indicate comparisons described in the text (Data source: Human Mortality Database 2008c)

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

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

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

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

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

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

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

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

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

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

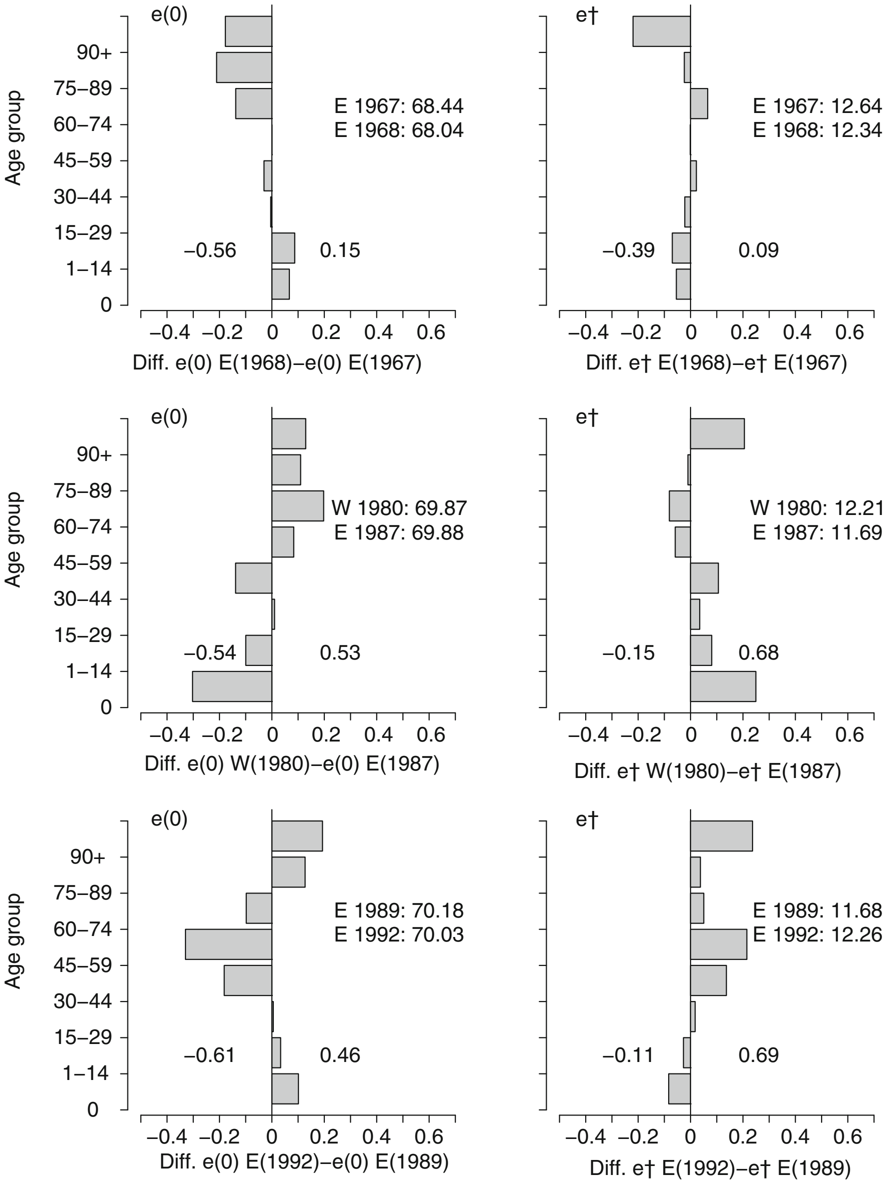

Fig. 3.8 Contribution of age-specific mortality to differences in e_0 (*left panel*) and $e^{\dagger}$ (*right panel*), males: comparison 1967–1968 in East Germany (Period 2, *upper panel*); comparison West Germany 1980 and East Germany 1987 (Period 3, *middle panel*); comparison 1989 and 1992 in East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

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

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

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

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

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

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

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

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

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

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

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

3.5.2 Lifespan Disparity by Federal State

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

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

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

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

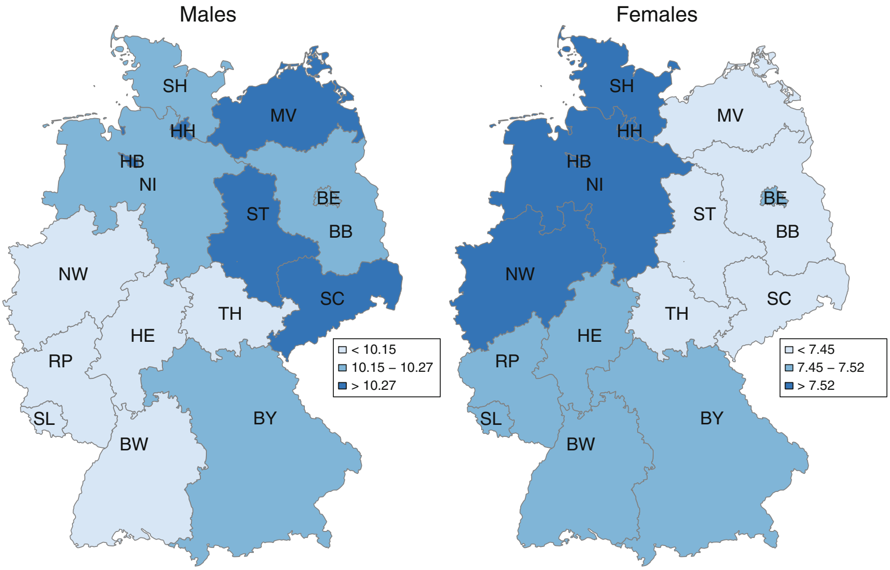

Fig. 3.9 Temporary lifespan disparity ${}_{90}e_0^{\dagger}$ at male temporary life expectancy ${}_{90}e_0$ of 74 years and female temporary life expectancy ${}_{90}e_0$ of 80 years; interpolated values of 3-year averages of ${}_{90}e_0^{\dagger}$ and ${}_{90}e_0$. *SH* Schleswig-Holstein (${}_{90}e_0^{\dagger}$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

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

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

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

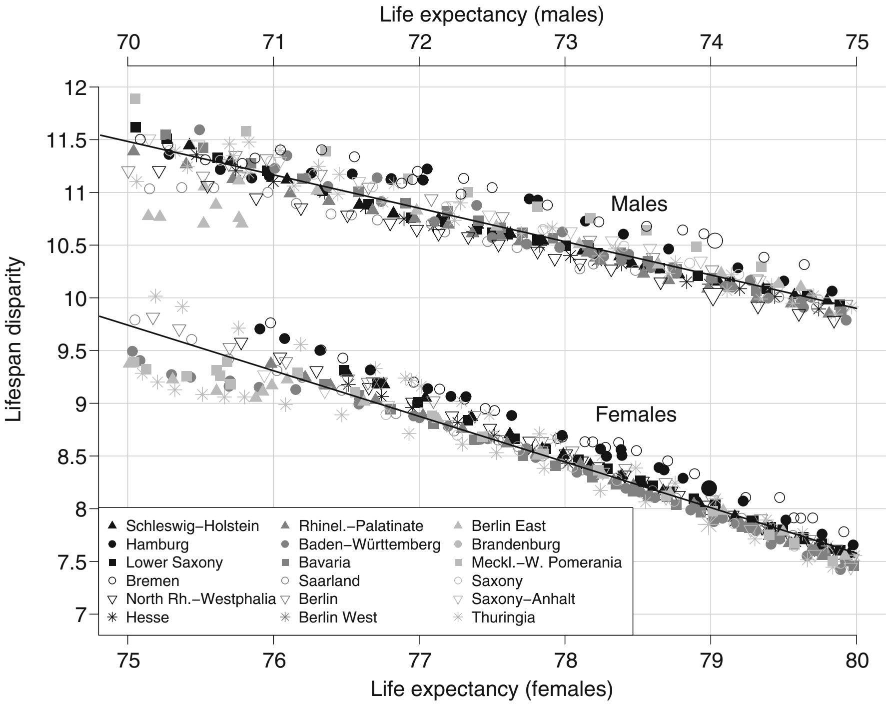

Fig. 3.10 Temporary lifespan disparity ${}_{90}e_0^\dagger$ versus temporary life expectancy ${}_{90}e_0^\dagger$ for ${}_{90}e_0$ between 70 and 75 years (m) and between 80 and 85 years (f); 1979–1981 to 2004–2006 ${}_{90}e_0^\dagger$ (m) = 33.7299 – 0.3177* ${}_{90}e_0$ (m), ${}_{90}e_0^\dagger$ (f)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

3.5.2.2 Changes Over Time

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

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

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

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

3.5.2.3 Lifespan Disparity and Age-Specific Mortality Profiles

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

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

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

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

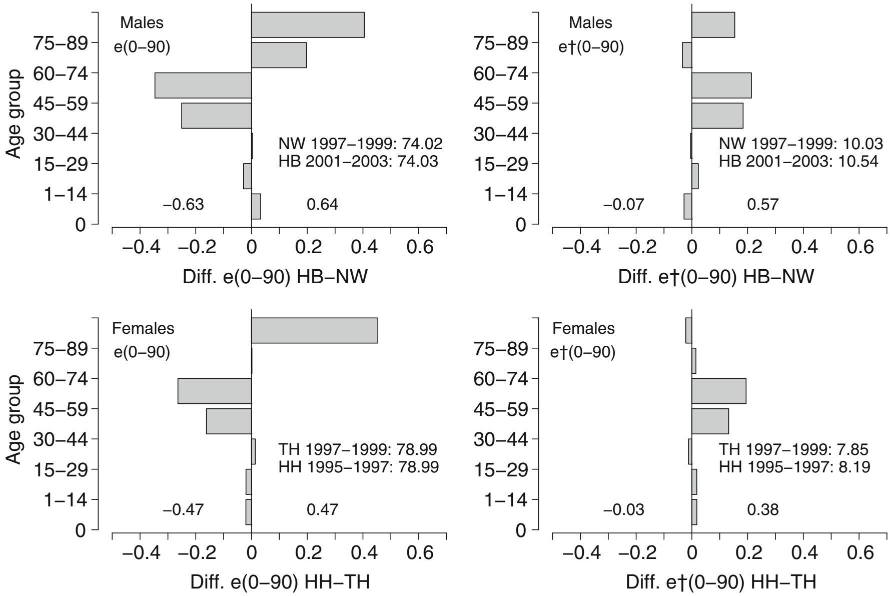

Fig. 3.11 Contribution of age-specific mortality to differences in temporary life expectancy ${}_{90}e_0$ and temporary lifespan disparity ${}_{90}e_0^\dagger$ in selected federal states when ${}_{90}e_0$ is equal; comparison between federal state with higher to federal state with lower ${}_{90}e_0^\dagger$.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

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

3.6 Cause-of-Death Patterns Across Federal States

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

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

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

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

Data source: Federal State Offices of Statistics, Germany

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

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

3.6.1 Model Comparison

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

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

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

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

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

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

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

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

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

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

3.6.2 Cause-Specific Mortality by Age and Over Time

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

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

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

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

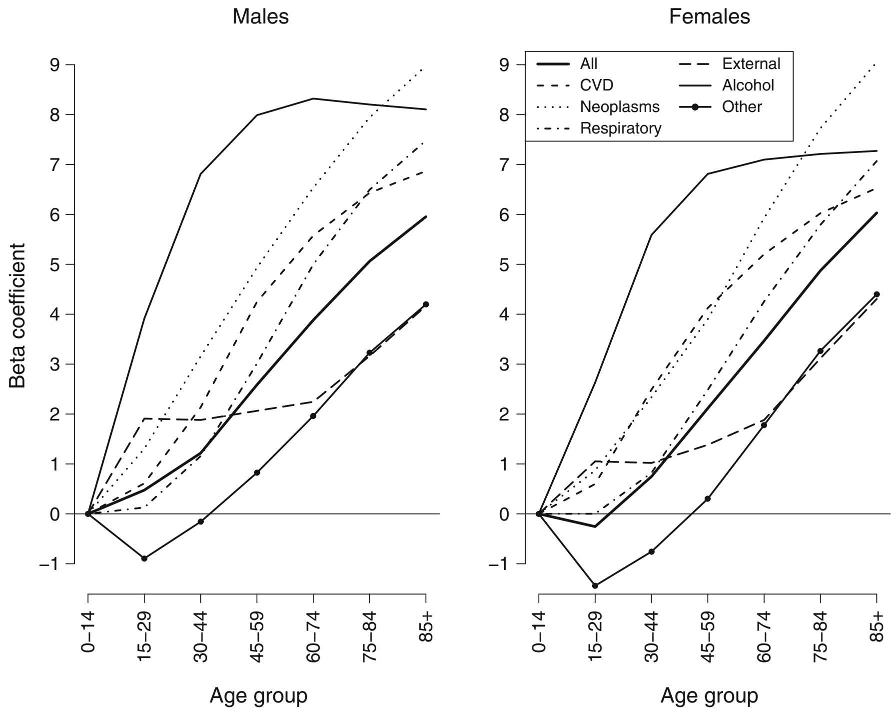

Fig. 3.12 Beta coefficients of cause-specific mortality by age group; 1991–2006 (age effect in Model 2: A + FS + T; reference age group 0–14) (Data source: Federal State Offices of Statistics, Germany)

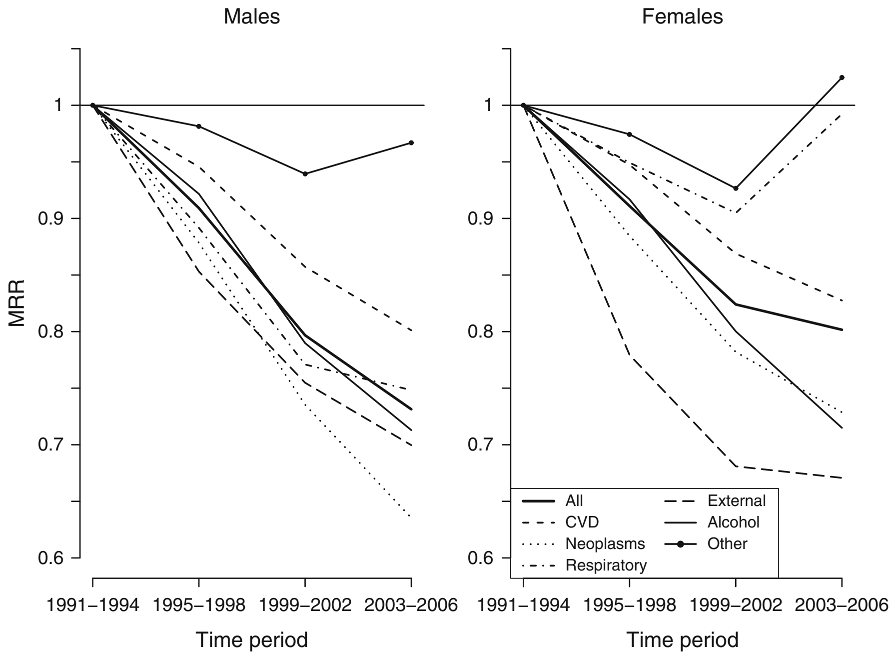

Fig. 3.13 MRR of cause-specific mortality by time period; 1991–2006 (time effect in Model 2: A + FS + T, reference time period 1991–1994) (Data source: Federal State Offices of Statistics, Germany)

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

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

3.6.3 Cause-Specific Mortality by Federal States

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

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

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

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

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

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

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

(continued)

Table 3.5 (continued)

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

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

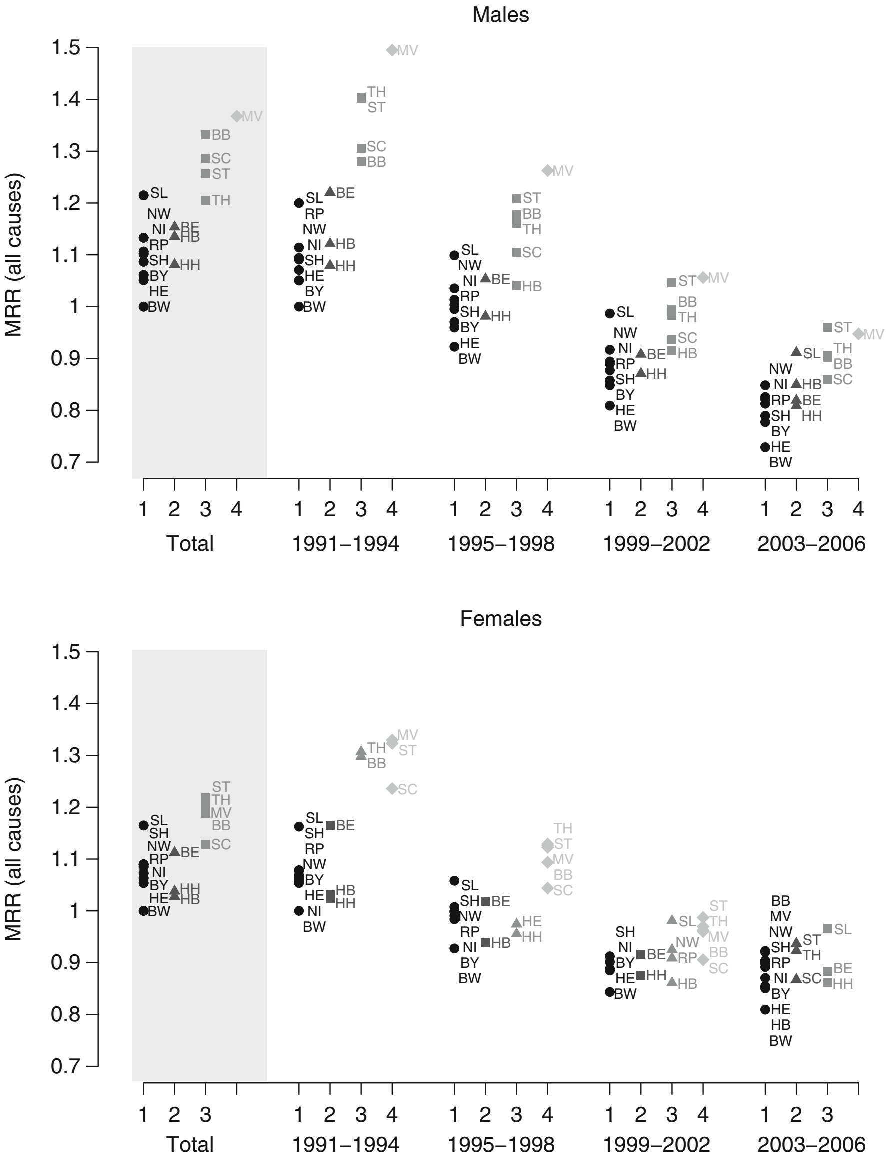

Fig. 3.14 Federal states clustered according to their cause-of-death structures by time period; plotted according to MRR in all-cause mortality; 1991–2006. Total (*highlighted in gray*): space effect from Model 2 clustered; time periods: time-space effect from Model 3c clustered. *SH* Schleswig-Holstein,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

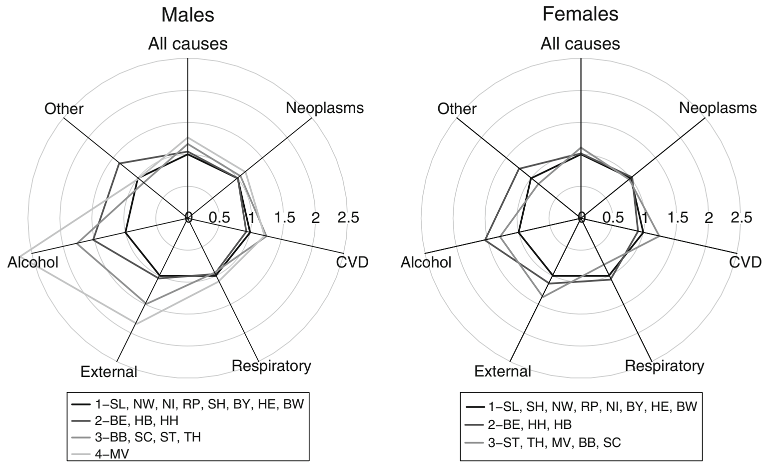

Fig. 3.15 MRR of federal state clusters by cause-of-death groups; 1991–2006 (model with A + T + cluster). *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE*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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.7 Summary

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

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

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

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

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

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

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

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

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

3.8 Discussion

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

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

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

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

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

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

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

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

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

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

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

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

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

			Population		Death counts	
Federal state	# districts in 2006	Territorial changes 1980–2006	75+	90+	75+	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+
∑	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

	Year												
Variable	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:

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

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).

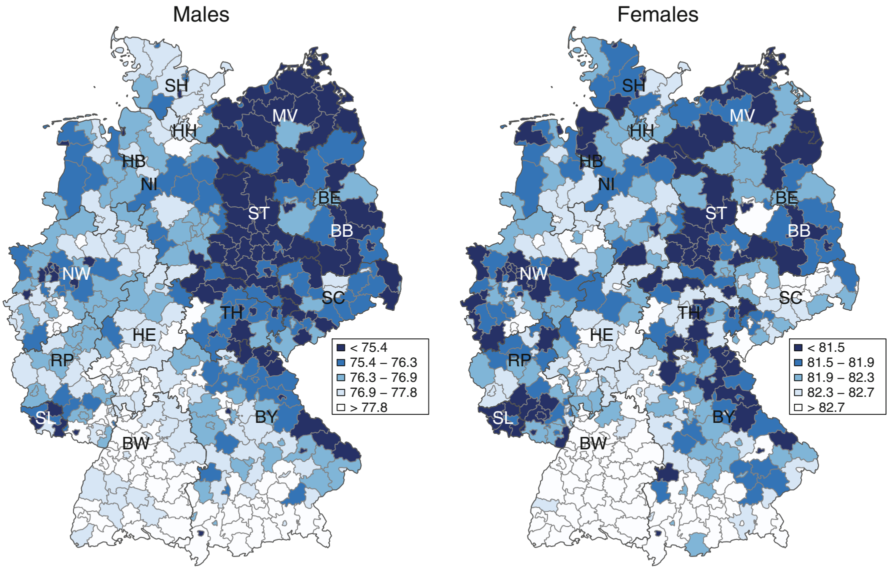

Fig. 4.2 Life expectancy by district; 2004–2006. *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western Pomerania, *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.

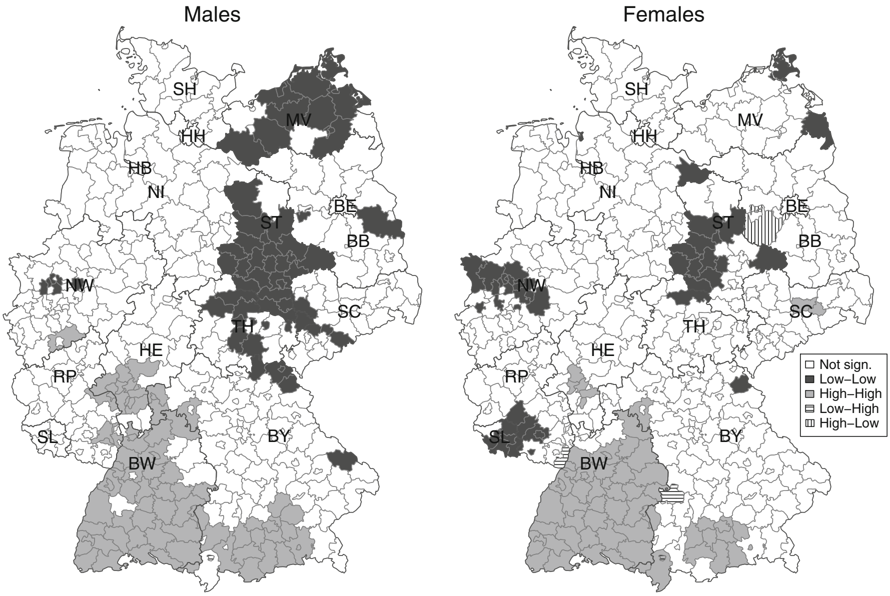

Fig. 4.3 Local Moran's I of life expectancy by district, only districts with significant autocorrelation ($p < 0.05$); 2004–2006. Legend description: Low-Low (*High-High*): Positive spatial autocorrelation; district with low (*high*) life expectancy surrounded by districts with low (*high*) life expectancy; 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

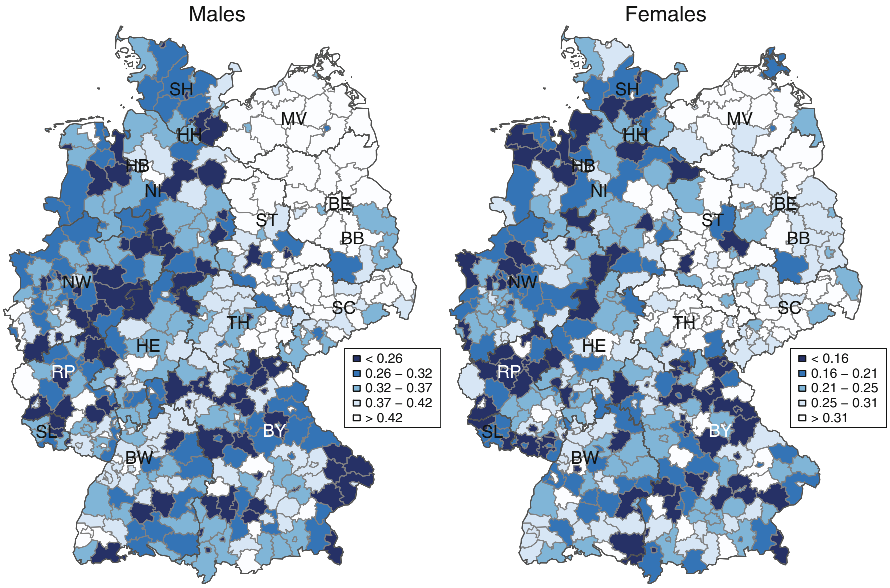

Fig. 4.4 Arithmetic mean of annual life expectancy changes; 1995–2006 by district. *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *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.

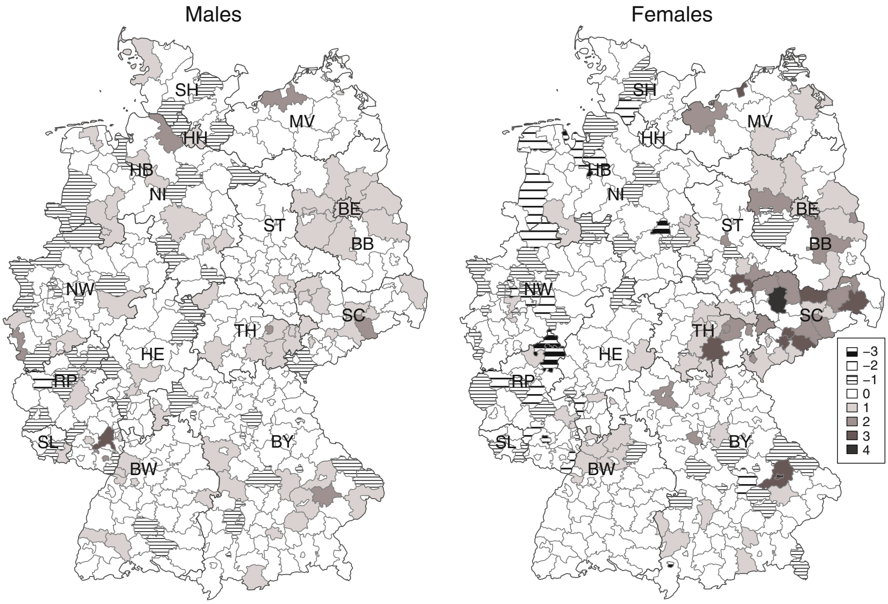

Fig. 4.5 Rank changes in life expectancy; 1995–1997 to 2004–2006 by district. *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *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

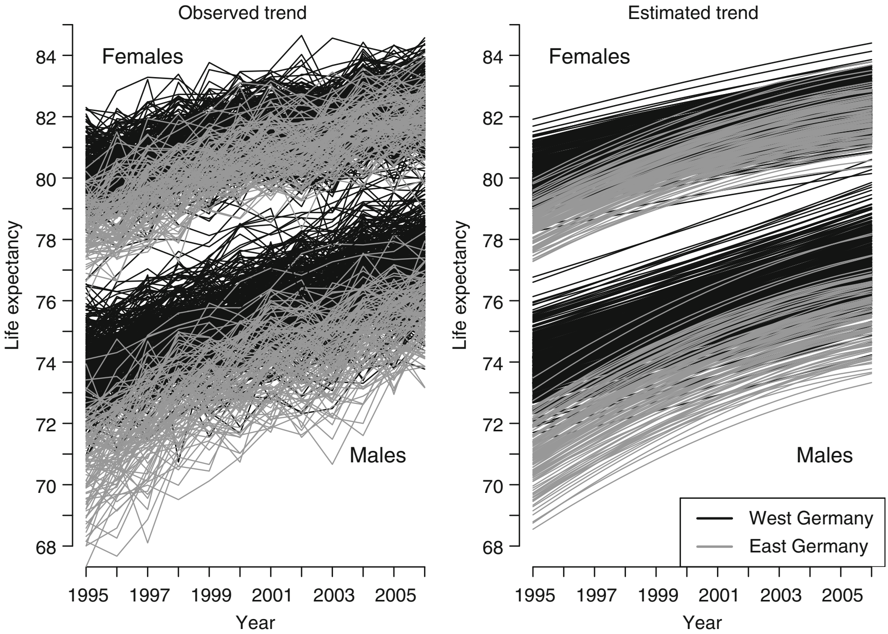

Fig. 4.6 Observed and estimated trend of life expectancy by district; 1995–2006 (Data source: Federal State Offices of Statistics, Germany)

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.

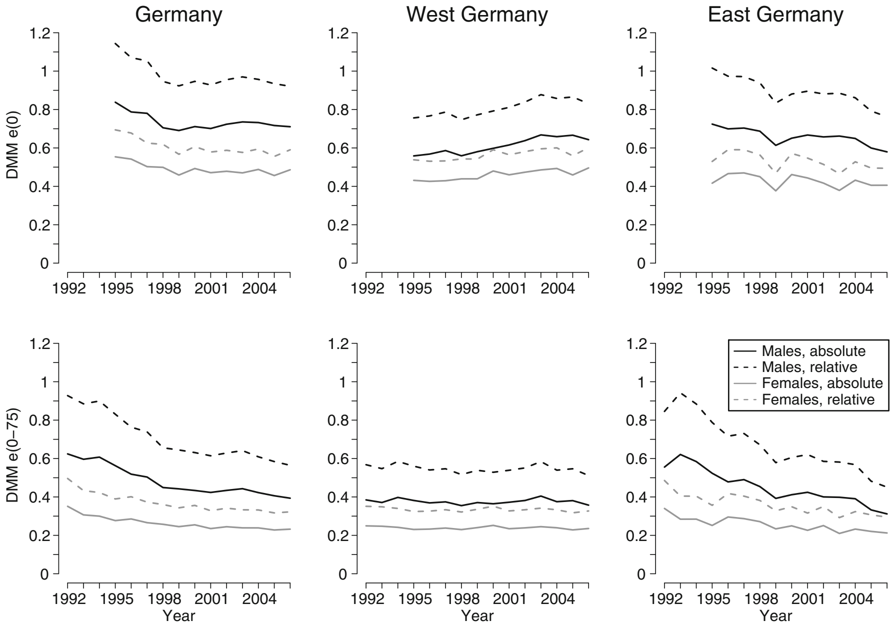

Fig. 4.7 DMM across districts for life expectancy at birth (e_0) and temporary life expectancy ($_{75}e_0$); 1992–2006. Absolute DMM in years, relative DMM in years relative to life expectancy; East Germany includes Berlin (Data source: Federal State Offices of Statistics, Germany)

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

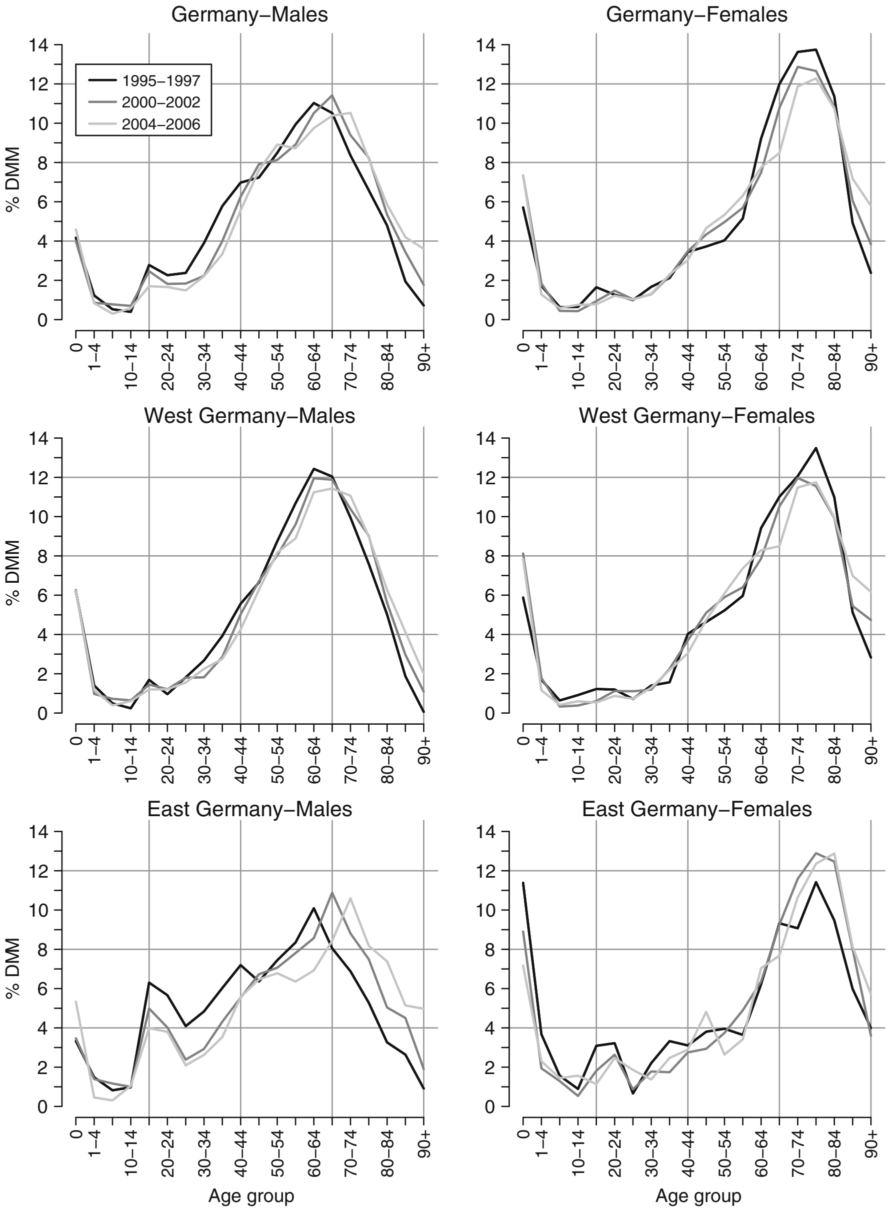

Fig. 4.8 Contribution of age-specific mortality to DMM of life expectancy at birth as percentage of total DMM; Germany, East and West Germany; 1995–1997, 2000–2002, 2004–2006. DMM Germany 0.77, 0.68, 0.69 (men), 0.49, 0.44, 0.44 (women). DMM West Germany 0.53, 0.58, 0.62 (men), 0.38, 0.43, 0.45 (women).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

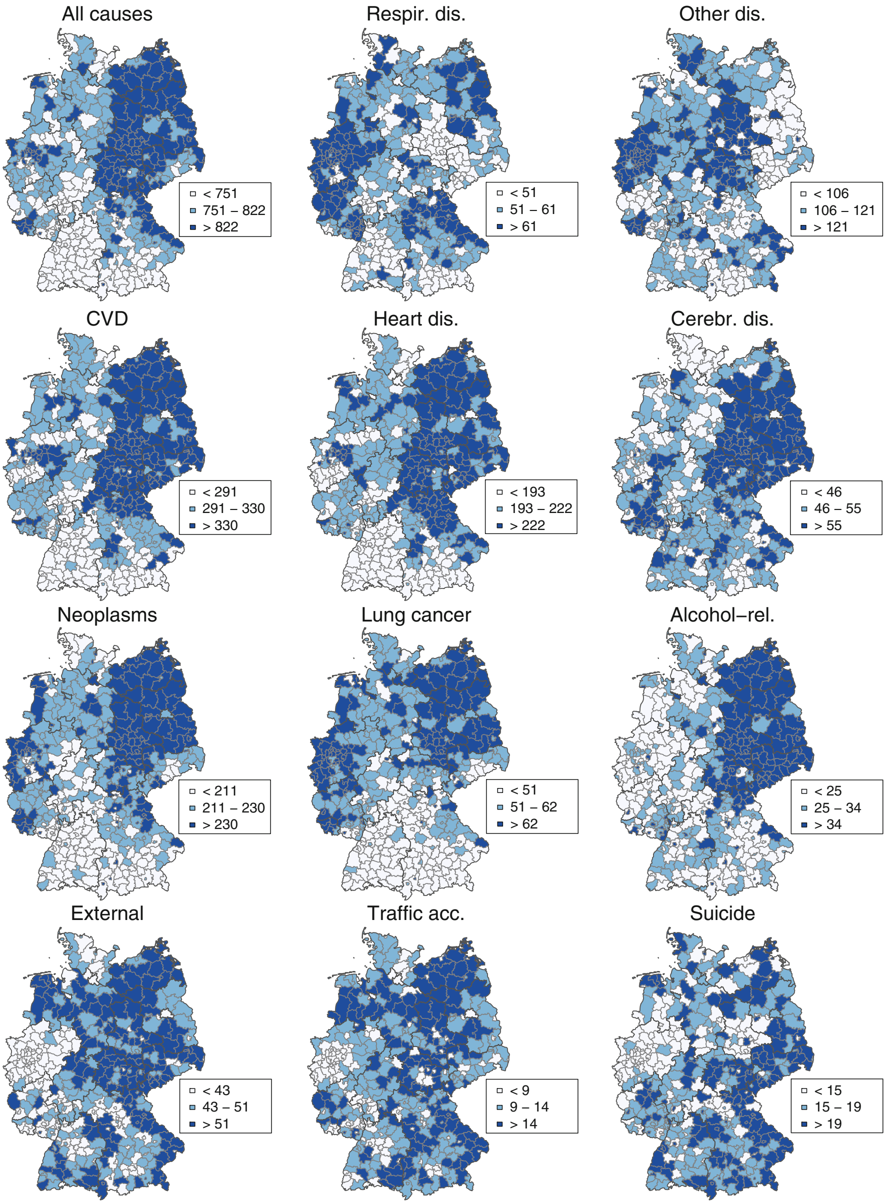

Fig. 4.9 SDR by leading causes of death by district, males; 2004–2006 (Data source: Federal State Offices of Statistics, Germany; Research Data Center of the Federal Statistical. Office and the Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy 2007)

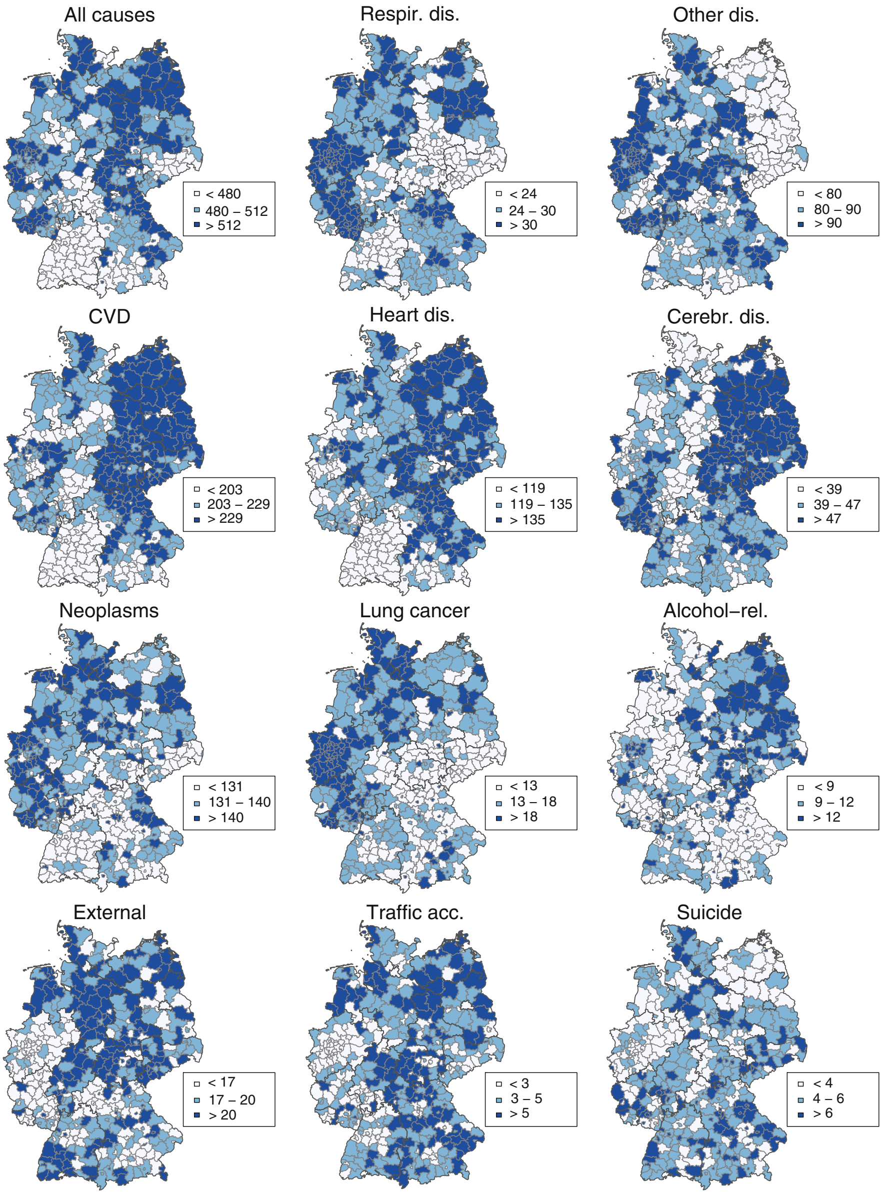

Fig. 4.10 SDR by leading causes of death by district, females; 2004–2006 (Data source: Federal State Offices of Statistics, Germany; Research Data Center of the Federal Statistical. Office and the Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy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

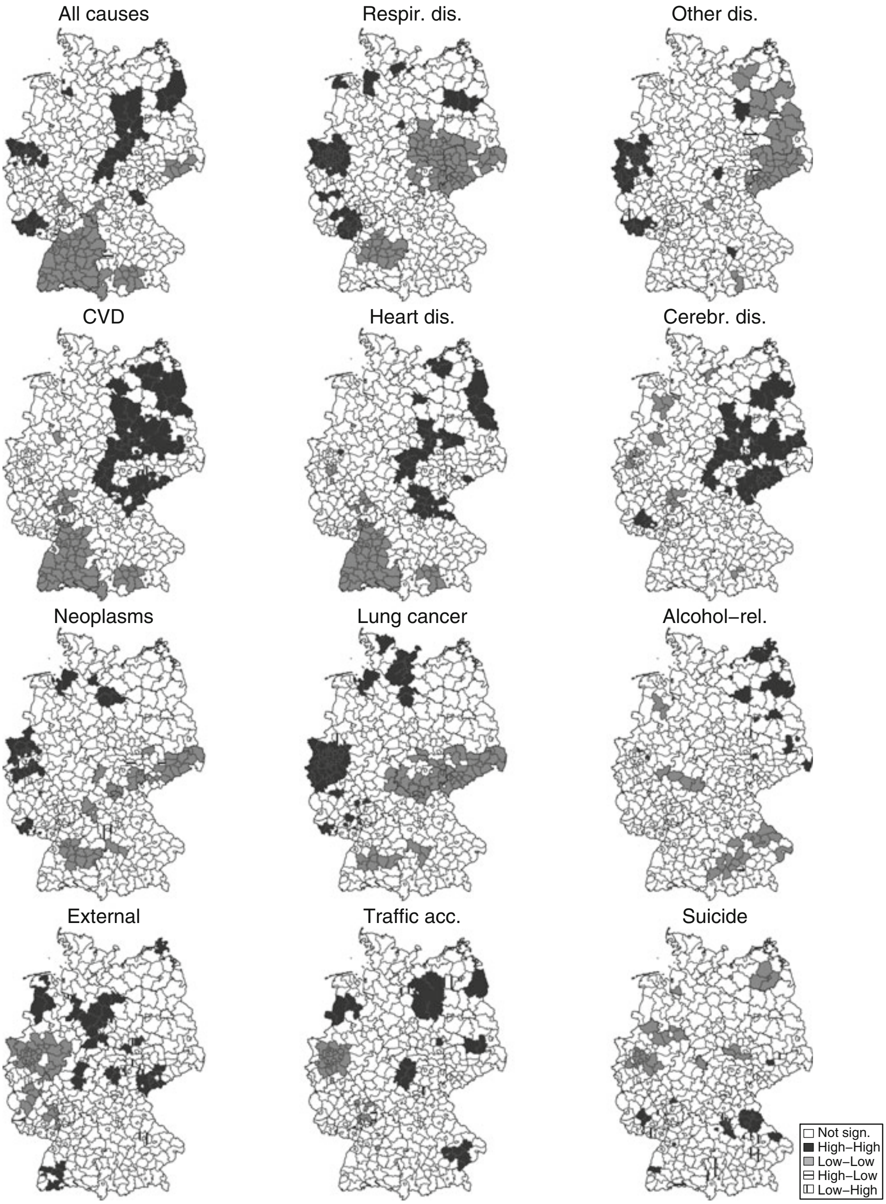

Fig. 4.12 Local Moran's I of SDR by leading causes of death by district, only districts with significant autocorrelation ($p < 0.05$), females; 2004–2006. Legend description: Low-Low (*High-High*): Positive spatial autocorrelation; district with low (*high*) life expectancy surrounded by districts with 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]

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[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.

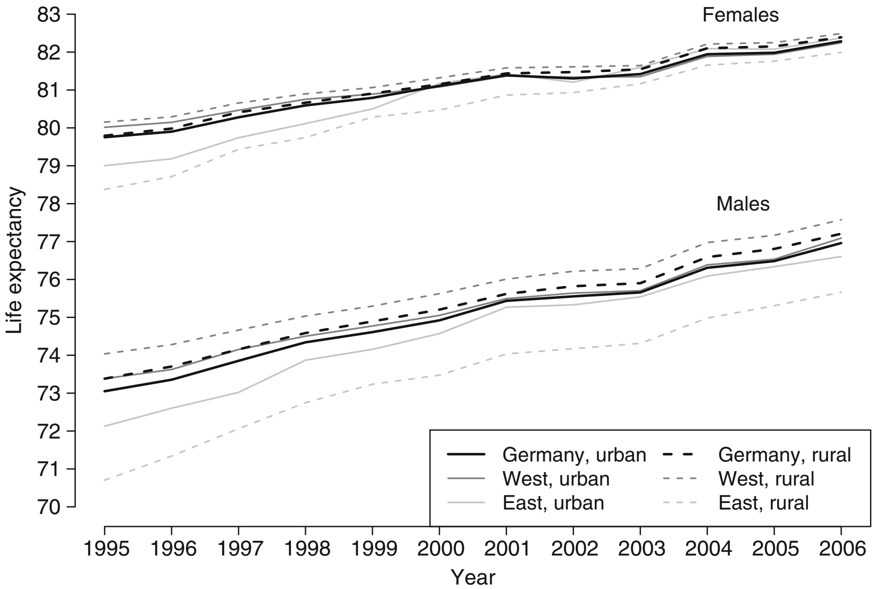

Fig. 4.13 Life expectancy in urban and rural regions of East and West Germany; 1995–2006 (Data source: Federal State Offices of Statistics, Germany)

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

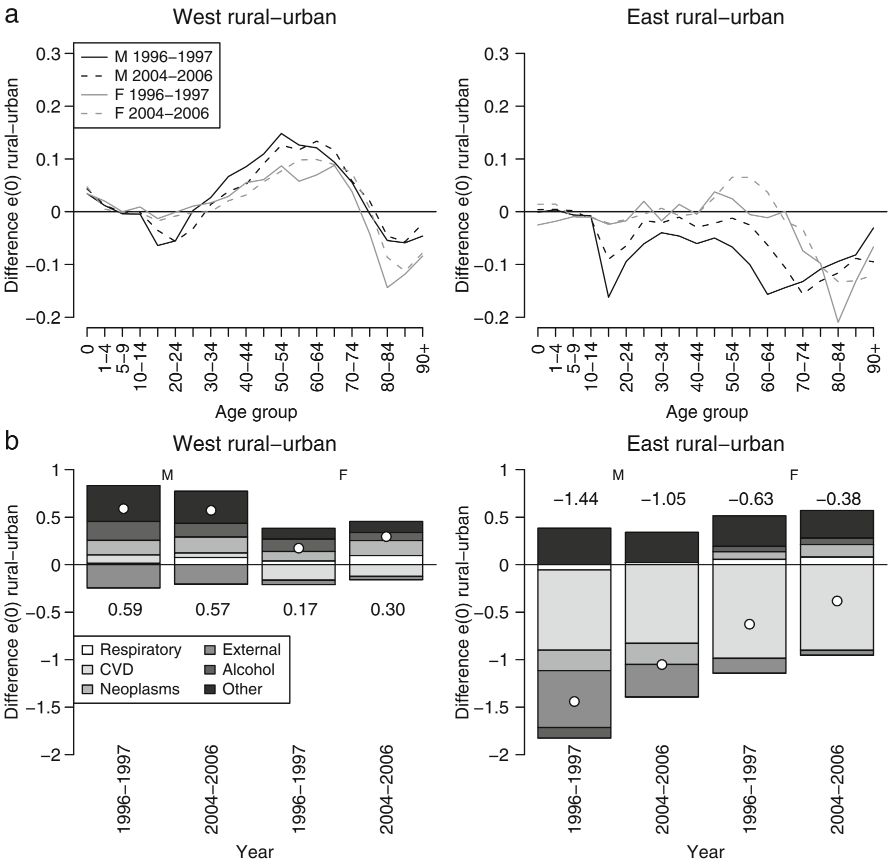

Fig. 4.14 Contribution of age- and cause-specific mortality to differences in life expectancy between rural and urban areas; 1996–1997 and 2004–2006. (**a**) Contribution of age-specific mortality to the total rural-urban life expectancy difference. (**b**) Contribution of cause-specific mortality to 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.

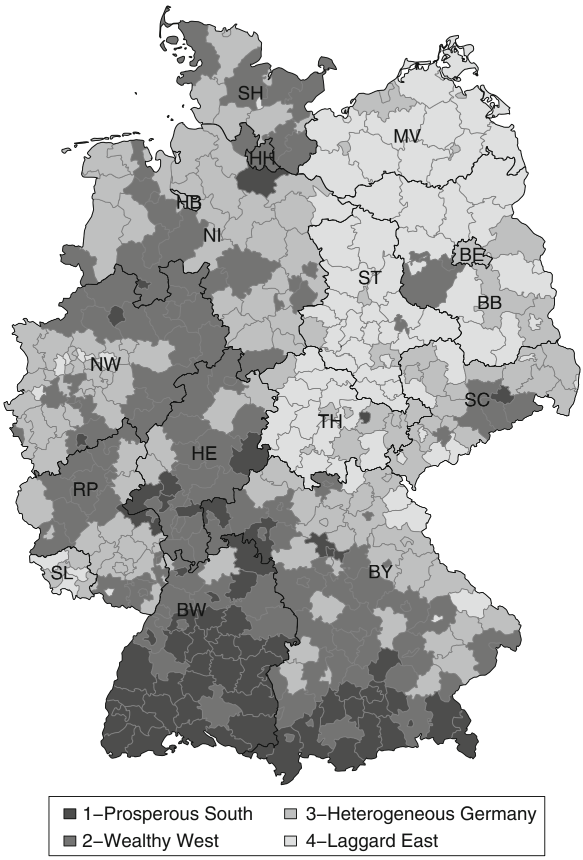

Fig. 4.15 Classification of districts into four clusters according to life expectancy level and change by district; 1995–2006 (pooled). *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* 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
$\Delta\, e_0$, 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
$\Delta\, e_0$, 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

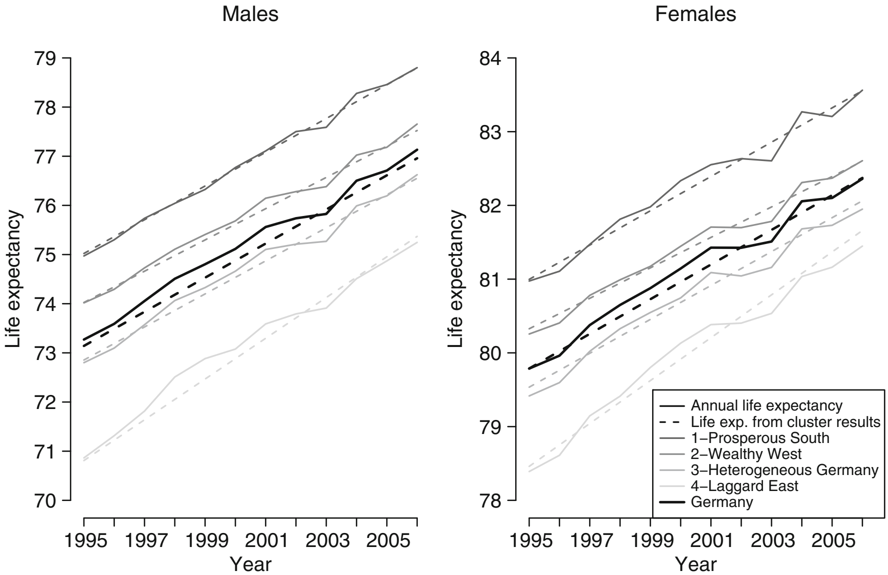

Fig. 4.16 Life expectancy by cluster; 1995–2006. *Dashed lines* show cluster results as in Table 4.7, *solid lines* show population-weighed life expectancy; 1995–2006 (Data source: Federal State Offices of Statistics, Germany)

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

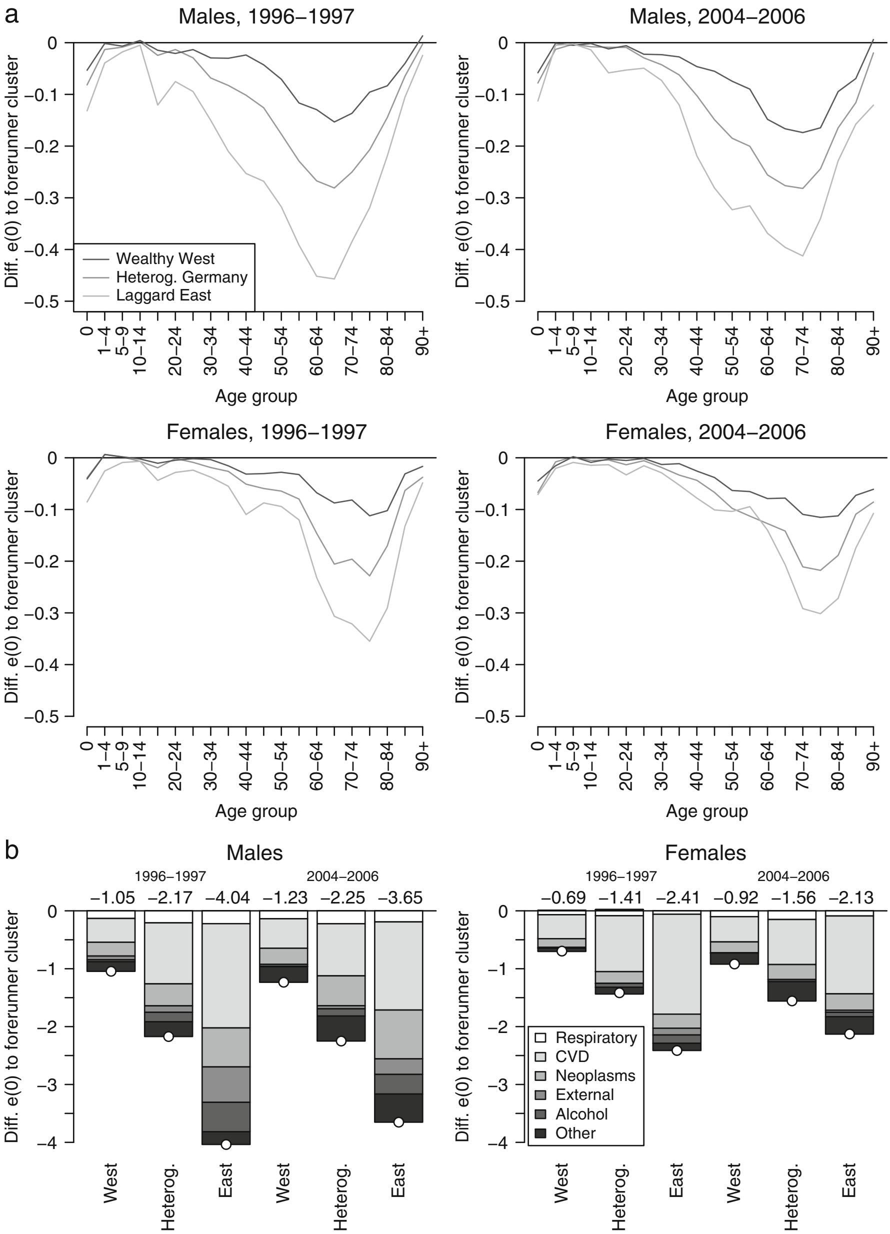

Fig. 4.17 Contribution of age- and cause-specific mortality to differences in life expectancy between the Prosperous South cluster and the three other clusters; 1996–1997 and 2004–2006. (**a**) Contribution of age-specific mortality to life expectancy differences. (**b**) Contribution of cause-specific 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 m^2	**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 sociostructural variables, the classification is similar to the one chosen for this study. This confirms the results, and additionally shows that clustering, whether based on socioeconomic 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.

Chapter 5
Determinants of Old-Age Mortality and Its Regional Variation: Composition and Context

5.1 Introduction

Having addressed the issues of how mortality varies across the districts, how it changes over time, and how it is associated with determinants that are measured at a regional level, this study now looks at the influence of the characteristics of individuals on regional mortality variation. It is clear that the associations at the regional level are partly related to the characteristics of individuals living in different areas of Germany and are partly related to the environmental contexts in these places.

Indeed, as stressed in the literature review and in the previous chapter, it is known that the mortality of Germans, wherever they live, strongly depends on their own socioeconomic status (e.g., Cromm and Scholz 2002; Lauterbach et al. 2006; Reil-Held 2000; Shkolnikov et al. 2008; Strohmeier et al. 2007). Earlier studies addressed either the determinants of regional mortality variation on an aggregate level or the mortality determinants from an individual's perspective. None of the studies attempted to estimate the influence of individual-level factors on regional mortality variations.

The aim of this chapter is to fill this knowledge gap by applying a multilevel model to estimate the impact of individual- and contextual-level determinants on regional mortality variation.

First, a review is provided of the development of multilevel approaches and of results from multilevel studies in the field of mortality and health research. The subsequent chapters introduce the specifics of the data and describe the theoretical framework of the multilevel modeling strategy applied in this study (Sects. 5.2 and 5.3). The results from single- and multilevel models are presented in Sect. 5.4. Finally, the results are summarized and discussed (Sects. 5.5 and 5.6).

E.U.B. Kibele, *Regional Mortality Differences in Germany*, Demographic Research Monographs, DOI 10.1007/978-94-007-4432-5_5,

5.1.1 Review of Multilevel Modeling in Health Research

The following review of the literature will demonstrate why a multilevel approach in studying determinants of regional mortality variation is suitable and why this approach is preferable to a single-level approach. German studies on health outcomes that have incorporated a multilevel approach are briefly summarized. Examples of international studies that have looked at the impact of both individual- and regional-level risk factors on mortality, and at the interplay of these factors, are then given. The evidence from international studies is much broader than the evidence for Germany, and the results may be indicative of the anticipated findings of the present study.

5.1.1.1 From Single- to Multilevel Approaches

Multilevel models have frequently been applied in the educational sciences, sociology, and demography, and these models have also been adopted in public health research (Diez-Roux 2000). Traditionally, health outcomes have been studied at either the individual or the aggregate level. The multilevel models also take advantage of the hierarchical structure of the data. In educational research, the classic example refers to pupils who are nested in classes and schools. In the area of health, researchers have been showing an increased interest in the relationship between area-level characteristics and individual health outcomes since the 1990s. This trend was facilitated by advances in statistical methods and programs (Diez-Roux 2000; Pickett and Pearl 2001; Riva et al. 2007).

A conventional approach used in studying the determinants of regional health and mortality differences is to examine the ecological setting, based on the assumption that the health outcomes at the population level are related to environmental influences. However, relationships at the aggregate population level (macro level) can differ substantially from those observed at the individual level (micro level). As early as in 1950—at a time when many researchers dealt with aggregate data—Robinson (2009) recognized the problem of ecological fallacy (cf. Courgeau 2007). He exemplified this fallacy by demonstrating the presence of qualitatively different relationships at the aggregate and individual levels between literacy and ethnic background. Diez-Roux (2002) illustrated the presence of the ecological fallacy in the field of public health. For example, while traffic accident mortality is positively correlated to income across countries, traffic accident mortality is lower for individuals with higher incomes within countries. So far, ecological studies have been dominating the studies on the determinants of regional mortality differences in Germany (cf. Brzoska and Razum 2008; Cischinsky 2005; Heins 1991; Kuhn et al. 2006; Queste 2007; von Gaudecker 2004; Wittwer-Backofen 1999).

Studies conducted exclusively at the individual level prevail in epidemiology. These studies capture the strongest effects on the health of individuals (such as health behaviors or social status) but overlook the health-relevant features of the individuals' surroundings. If the relationships analyzed at the individual level cannot be transferred to the area level, atomistic fallacy is encountered (Courgeau 2007; Diez-Roux 2002).

It has been suggested that a multilevel approach is appropriate for analyzing regional mortality when data on both individuals and the areas where they live are available. Such approaches can overcome the ecological and the atomistic fallacies. They can also take into account the possibility that regional features may moderate relationships at the individual level, that is, that relationships observed at the individual level differ by context (Hox 2002). As a consequence, multilevel models can be used to develop better public health strategies, as these models indicate at which level—for example, individual, community, or state—health inequalities are determined.

5.1.1.2 Existing Multilevel Studies on Health in Germany

Nationwide multilevel studies of mortality that combine individual- with regional-level data appear to be nonexistent (an earlier version of the present study with federal states as geographical units was published, Kibele 2008). There are only a few multilevel studies analyzing health outcomes other than mortality that link health with its determinants in certain regions of Germany (e.g., presented by Berger et al. 2008; Kroll and Lampert 2007; Kruse and Doblhammer-Reiter 2008). This chapter provides brief summaries of eight multilevel studies that were published before 2010. Section 5.1.1 then reviews selected international multilevel studies in mortality research.

Breckenkamp et al. (2007) based their study on the six regions of the German Cardiovascular Prevention Study of 1984–1986, which included 11,202 individuals. The health outcome measures were body mass index, blood pressure, and total cholesterol level. After controlling for the effects on the health outcome measures of age and individual socioeconomic status, the effects of regional characteristics—such as low regional SES, unemployment, the Gini coefficient of income inequality, gross value added, and the poverty rate—were found to be mainly statistically insignificant. It is, however, important to note that only six regions were under study, which is a very small number of units (cf. Chaix and Chauvin 2002; Maas and Hox 2005).

A pooled study of 326 neighborhoods in nine German and Czech cities also analyzed the neighborhood effect (unemployment and household overcrowding) on a number of health outcome measures (obesity, hypertension, smoking, physical inactivity) after controlling for individual-level variables in a logistic model with mixed effects (Dragano et al. 2007). Out of the 326 neighborhoods, 106 were situated in Germany ($N=4,814$). The German data stem from the Heinz Nixdorf Recall Study, and the baseline examination was conducted from 2000 to 2003. The area-level effects were found to be mostly statistically significant, especially when unemployment was included as an area characteristic. Health variations across individuals in the observed neighborhoods were found to be greater among individual characteristics than among area characteristics.

Based on the same study ($N = 4{,}301$), Dragano et al. (2009a) analyzed the relationship between the subclinical coronary artery calcification (a predictor of subsequent CVD) and individual- and neighborhood-level factors. After adjusting for individual-level factors, a statistically significant relationship remained between coronary artery calcification and neighborhood deprivation. Cardiovascular risk factors partly mediated this micro-macro link. A similar group of researchers, again using the Heinz Nixdorf Recall Study, found that the values of coronary artery calcification were highest for people with low SES and high traffic exposure. The adverse effects of low SES and high individual traffic exposure were found to be additive (no significant cross-level interaction) (Dragano et al. 2009b). Both studies applied multilevel logistic regression models.

The substantial regional mortality differentials within Bavaria were the starting point for a study on the self-reported health of 4,519 individuals in five administrative districts (Kreise) in Bavaria in 2005. It revealed that self-reported health varies more by individual characteristics than by regional-level characteristics (Kemptner et al. 2008). Using a logistic two-level model, the study found that the share of high school graduates among all school graduates was the regional-level variable with the greatest impact on self-rated health.

A drawback of this study was again the small number of spatial units.

Wolf (2004) analyzed the health of 695 respondents in 38 city neighborhoods in Cologne (1999–2000). The outcome measures were physical health, mental health, the number of adverse medical conditions, and body mass index. Except for mental health, area-level variation in the outcome measures was found to exist. This variation could be partly explained by the mean social and the mean family status, as well as by the air pollution level in a neighborhood. Cross-level interactions were estimated but were found to be insignificant.

Klocke and Lipsmeier (2008) analyzed the health and health behavior of children and teenagers in a three-level logit model in which 7,274 pupils were nested in 197 schools and in five federal states. Most of the variation in the dependent variables is explained by individual-level and school-level characteristics, whereas the federal states could explain only a very small part of the variation. Again, the small number of units at the highest level was a shortcoming of the data under study.

Koller and Mielck (2009) analyzed the health of 9,353 children who were expected to enter school in 2004 in Munich. A two-level logistic regression was applied to the data with individual-level and school district-level ($N = 125$) variables. The study found that more children in lower-status school districts were overweight and had missed health checkups but that these children were less likely than children in higher-status school districts to have missed vaccinations.

Most of the German studies—while diverse in terms of outcome measures, explanatory variables, and the number and size of regional units—have shown that contextual variables may have an impact on health. In most cases, the contextual effects were found to be smaller than the effects of individual-level variables. No evidence was found to confirm the proposition that less advantaged individuals suffer more from adverse contextual conditions than their more advantaged counterparts.

5.1.1.3 Some International Evidence

International multilevel studies in the health field are more numerous than those in Germany and provide greater opportunities for making generalizations. There are two literature reviews of multilevel modeling in health research: Pickett and Pearl (2001) and Riva et al. (2007). These reviews make it easier to identify the most common study designs and to classify results. Pickett and Pearl (2001) reviewed 25 studies published in the English language before June 1, 1998. The literature review by Riva et al. (2007) includes 86 articles published in English language between July 1998 and December 2005.

Ten out of the 25 studies included in the literature review by Pickett and Pearl (2001) dealt with mortality as an outcome measure. Except for one study, all found a modest neighborhood effect on mortality when individual factors were controlled for, and that this effect was equally likely to exist in studies with health measures as an outcome variable. A modest effect is defined as a relative risk below two. It must be noted that only one of the mortality studies used a multilevel modeling technique. The other studies were built upon hierarchical data but used single-level regression models. Among the 86 studies reviewed by Riva et al. (2007) that were published later, 17 were studies on mortality and 15 of them revealed significant area effects after controlling for individual-level factors. Riva et al. (2007) also observed that (considering all outcome measures) significant cross-level interactions were found; that is, that the effect on mortality or the health measure of individual-level variables varies by context. Both literature reviews hence noted the existence of area effects for mortality and other health outcome variables.

The literature reviews on multilevel modeling in health statistics have pointed out that, if the model does not control for individual socioeconomic status, an overestimation of the context effect may occur. Thus, it seems clear that models should control for more than just one individual characteristic.

Contextual characteristics may be correlated with each other so that the inclusion of few of them may be enough. However, sometimes only very particular contextual factors have a significant effect. Area effects also depend on the outcome measure and spatial scale used (Pickett and Pearl 2001; Riva et al. 2007). For example, the study on mortality risk and religious affiliation of 882 neighborhoods in Israel by Jaffe et al. (2005) found that mortality risk was lower in areas of greater religious affiliation, after individual characteristics and area-level SES were adjusted for. Area-level SES altered the effect of religious affiliation among women, whereas for women in high-SES areas, the effect of strong religious affiliation was detrimental (Jaffe et al. 2005; Riva et al. 2007).

A few selected international studies on regional mortality differences incorporating multilevel modeling are now briefly examined. Table 5.1 therefore summarizes the study design and results of selected international mortality studies. Of special interest to us are studies from Finland and Norway, as they incorporate data similar to the data used in this study (i.e., register data). Apart from the Nordic countries, multilevel studies on health are numerous in the USA and in England and Wales (e.g., Chaix et al. 2007; Duncan et al. 1993; Lochner et al. 2001; Macintyre et al. 1993; Riva et al. 2007; Subramanian et al. 2001).

Table 5.1 Study descriptions of selected multilevel mortality studies

Reference, country, and sample size for individual (N_i) and region (N_j) level	Health outcome and population included	Individual-level variables	Contextual-level variables	Model[a]	Results[b]
Blomgren et al. (2004) Finland N_i=1.1 mio. N_j=84	Alcohol-rel. mortality men, 25–64 years	Age, education, SES, marital status, mother tongue	% manual workers, unemployment, median household income, Gini coefficient, family cohesion, voting turnout, level of urbanization, share Swedish-speaking inhabitants	Poisson	Moderate mort. effect of some area-level variables; individual level explains 41%, individual and area level explain 79% of regional mortality variation
Blomgren and Valkonen (2007) Finland (urban only) N_i=1.25 mio. N_j=43	Mortality 35–54 years	Sex, age, mother tongue, education, occupational class, family type, labor market position, long-term unemployment	Unemployment, level of urbanization, voting turnout, family cohesion, geographic location	Poisson CrLIA	Moderate mortality effect of some area-level variables; more deprived suffer more from adverse area conditions
Kravdal (2006) Norway N_i=98,992 N_j=435	Cancer mort. 20–79 years	Sex, age, education, income, period, time cancer diagnosis, cancer type	Hospital affiliation, distance to local hospital, average educ. and average income, unemployment	Logistic discrete-time hazard model	No clear mortality effect of regional economic performance; little survival differences between hospital affiliation and distance to hospital; higher survival in high-educated area due to early diagnosis
Kravdal (2007) Norway N_i=27 mio. PY N_j=435	Mortality 50–89 years; separately by sex and age group	Age, year, education, marital status, income, recent in-migration	Average education, average income, prop. in-migrated, prop. divorced, prop. never married	Logistic discrete-time hazard model Fixed effects for j	Moderate mort. effect of high proportion of unmarried, more so among women; significant mortality effect of average education level, but not of average income

Martikainen et al. (2003) Finland (Helsinki) $N_i = 252{,}000$ $N_j = 55$	Cause-specific mortality, men 25–64 years; 65+ years	Age, education, social class, housing tenure, housing density, living arrangement	% manual workers, % pop. 60+ years, social cohesion	Poisson CrLIA	Moderate mort. effect of some area-level variables; weaker area- and ind.-level effects for age group 65+; individual level explains 70%, individual and area level explain > 90% of variation; no clear cross-level interaction; greater area effects at ages 25–64 years; area effects greater for accidents, violent and alcohol-related causes at ages 25–64 years
Martikainen et al. (2004) Finland $N_i = 41.3$ mio. PY $N_j = 85$	Suicide, (alc.- and non-alcohol associated) 15–99 years	Sex, age, SES, household inc., housing tenure, econ. activity, marital status, family type, household size, mother tongue	% manual workers, unemployment, median household income, Gini coefficient, family cohesion, voting turnout	Poisson CrLIA	Moderate mortality effect of some area-level variables; interaction between individual- and area-level factors not significant; higher area variability of mortality for women and for alcohol-associated suicide
Sloggett and Joshi (1994) England $N_i = 300{,}000$ N_j not reported (wards)	Mortality by sex 16–65 years	Age, period, zone of residence, economic activity and social class, presence of spouse, housing tenure and access to car	Deprivation score (Townsend and Carstairs)	Logistic Single-level model	Association between mort. and deprivation is mostly outweighed by individual-level factors; small area effect for women
Turrell et al. (2007) Australia $N_i = 6$ mio. $N_{j1} = 1{,}317$; $N_{j2} = 187$ $N_{j3} = 59$; $N_{j4} = 9$	Mortality 25–64 years separately by sex	Age, occupation	Index of relative socioeconomic disadvantage	Binomial logit-link 5-level RC-model CrLIA	Moderate mortality effect of area index; among men, blue-collar workers are overly disadvantaged in the more deprived area quintiles

CrLIA cross-level interaction, *PY* person years, *RC* random coefficient
[a]If not mentioned otherwise: two-level random-intercept model
[b]All studies show significant effects of individual-level variables

The studies listed in Table 5.1 all have large sample sizes at each hierarchical level. Sloggett and Joshi (1994) demonstrated that the mortality effects of area characteristics may be overestimated when the model does not control for individual-level variables (cf. also Blomgren et al. 2004).

The studies on Finland and Norway are based on register data that provide detailed information about socioeconomic status and partial information about living conditions, marital status, and other individual characteristics. Contextual factors were found to have modest effects on all-cause and cause-specific mortality in the studies summarized in Table 5.1. Blomgren and Valkonen (2007) and Turrell et al. (2007) found that more deprived individuals are more likely to suffer from adverse contexts in terms of mortality.

Kravdal (2006) studied cancer mortality among 20–79-year-olds in Norway, applying a multilevel logistic discrete-time hazard regression model. The inclusion of regional-level characteristics after controlling for individual-level characteristics showed unclear results. Cancer survival was found to be enhanced in regions of high average education due to earlier diagnosis, and survival was shown to be lower in areas of high unemployment, while average income was shown to have no effect. Moreover, hospital affiliation (the size of the nearest hospital and the health region) was proven to be of minor importance. A disadvantage of this study, which was noted by the author, is the lack of an individual employment variable. Such a variable could pick up some of the area-level effect of unemployment.

Blomgren and Valkonen (2007) applied a Poisson regression model to estimate individual-level effects of all-cause mortality in the urban Finnish population aged 30–54 years. Interestingly, individual-level characteristics were significant, but did not explain regional mortality variation. When all individual characteristics were controlled for, family cohesion was found to be the only significant area-level variable among men, and unemployment was shown to be the only significant area-level variable among women. However, mortality risk was found to decrease with increasing unemployment levels. Cross-level interactions revealed that the long-term unemployed are more susceptible to their environment, as their mortality risk was found to vary by area-level characteristics. For all others, however, the mortality risk was shown to be more or less constant across regions.

The latter two studies both used register data. While this data is of high quality, it may not provide all of the desirable individual-level variables.

All in all, and in line with Riva et al. (2007) and Pickett and Pearl (2001), it is apparent that area effects on mortality are statistically significant but are mainly modest in strength. They are more pronounced for men and among younger people (such as in the active population). When they were checked for, the cross-level interactions between the area and individual levels were not always found to be significant. If they were found to be significant, the interactions indicated that relatively deprived individuals suffer more from adverse regional contexts than the better-off.

Meaningful multilevel studies based on an ecological design exist as well. In such studies, very small geographical units are tagged with their socioeconomic position and are nested in higher-level units (e.g., Congdon et al. 1997; Langford and Day 2001).

5.2 Data

In this section, the data used in the current multilevel analysis are described. First, a brief explanation of the organizational structures in the German Federal Pension Fund, which determine data availability, is given (Sect. 5.2.1). A description of the variables then follows (Sect. 5.2.2). Then, the selection of the study population and the distribution of population exposures and deaths by the variables in the dataset are provided (Sects. 5.2.3 and 5.2.4). Section 5.2.5 briefly reflects on contextual factors at the district level, which are included for the regional level in the multilevel analysis.

5.2.1 Data from the German Federal Pension Fund

With the establishment of the research data center of the German Federal Pension Fund in 2004, it became possible to obtain detailed data on individuals registered within the process of the pension payments. This is particularly valuable as the data cover almost the entire population aged 65 and over in Germany. These data can be used for the study of mortality determinants, not only at the individual level, but also by the place of residence, which is broken down into 438 districts. There is no other data source in Germany that provides a full sample of individual-level data for mortality analyses.

The German Federal Pension Fund is the old-age security system covering all people who have ever worked in Germany. The insured population has been divided into the following categories: salaried employees, workers, and, until 2005, miners.[1] Special systems exist for the self-employed and civil servants. Around 78% of income for people aged 65 and above stems from the pension insurance fund, which is sometimes referred to as the first pillar in the old-age insurance. The second and third pillars are the occupational pension scheme and the private old-age provisions (Stahl 2003). The German Federal Pension Fund pays out several types of pensions, such as insured person's pensions, widow's pensions, and pensions due to reduced earning capacity. Pensioners are allowed to draw several pensions at a time. Only pensioners who draw an insured person's pension (*Versichertenrente*) are dealt with here, as this yields the highest population coverage. Since the pension insurance fund is interested in pension payments, and not in single persons, it is not possible to establish how many and which pensions a person receives. It is common, for example, for a widowed woman to receive an insured person's pension related to her working life and a widow's pension based on her deceased husband's income (cf. Scholz 2005). Old-age pensions are paid to people aged 60 and older who meet the age criterion and have achieved a minimum period of insurance. When a

[1] The last occupation of pensioners is recorded unless the pensioner has ever worked as a miner. In this case, the pensioner's former occupation is always recorded as miner.

younger beneficiary receives a pension due to reduced earning capacity, the pension is transformed into an old-age pension at age 60.

In Germany, the legal retirement age, at which an individual is entitled to receive an old-age pension, is 65 (gradually increases to 67 years in 2029), assuming the minimum period of insurance of 5 years is met. Several exceptions regarding the retirement age exist. For women, the legal retirement age was 63 years until the year 2000. Insured people who met a minimum insurance period of 35 years and had reached the age of 63 could claim an old-age pension for the long-standing insured. Severely handicapped persons, or insured persons who are incapable of working due to a handicap of at least 50%, and who have reached the age of 60, can claim an old-age pension. Under certain circumstances, the unemployed and women who have reached the age of 60 can claim an old-age pension. Deductions must be accepted if insured persons retire before their 65th birthdays (Stahl 2003). The mean age at retirement is 63.2 years for old-age pensioners in Germany. It is lower in eastern than in western Germany (Deutsche Rentenversicherung Bund 2006).

Old-age pensions reflect the pensioners' employment careers. The calculation of the old-age pension, which is based on so-called earning points, deserves special attention. People with employment subject to social insurance contributions pay 19.9% (19.5% before 2007) of their income to the pension insurance fund. Every year of employment, the yearly income is compared to the average income and translated into earning points. Each year of average earnings yields one earning point if the individual earnings are equal to the mean earnings nationwide. Earnings above or below the average income are credited proportionally. Earning points are calculated separately for eastern and western Germany to account for still existing income differences between the two parts of Germany. There is an annual contribution ceiling. The maximum number of personal earning points that can be credited per year is two, but was higher in the past. The cumulation of the earning points yields the sum of earning points, which represents the lifetime earnings, and is thus a proxy of the pensioner's socioeconomic status.

Lifetime earnings reflect the income status over the entire life course and do not take into account short-term changes caused by health loss or other temporary circumstances. At old age, pension income is an adequate proxy of male socioeconomic status, but it is problematic for women, many of whom have spent long periods of their lives as housewives and as caregivers for family and children (cf. Hoffmann 2005; Shkolnikov et al. 2008; Wolfson et al. 1993).

Contribution periods usually arise from occupations subject to insurance contributions, but also from periods in which contributions were paid voluntarily. Earning points can also be gained from periods exempted from contributions. Such periods include sick leave, disability leave, maternity leave, unemployment, or education beyond the age of 16. Substitute qualifying periods are allowed for military services. Periods spent as caregivers further contribute to the sum of personal earning points (Heilmann 2002). Between July 1, 2003, and June 2007, the current annuity value (*aktueller Rentenwert*) per earning point amounted to 22.97€ in eastern Germany and 26.13€ in western Germany. The annuity value is flexible over time and is based on the wage level and inflation.

Technical data issues are now discussed. The data from the German Federal Pension Fund are process-produced. Data on pension payments (*Rentenbestand*) and data on the terminated pension payments (*Rentenwegfall*) are used. People are recorded in the statistics as long as they receive a pension payment. Death is recorded as the end of a pension payment due to death. Pension payments and terminated pension payments are separate datasets which cannot be linked individually. In addition, a longitudinal dataset cannot be established, and married couples cannot be identified. For the purposes of this study, data are therefore set up as count data according to the variables described below in Sect. 6.2.2. The data is left-truncated, as information on those people who did not survive until legal retirement age is not available. Because virtually all people have retired by age 65, this age is set as the lowest age in the current analyses.

The data quality is high. The information on death counts and the number of pensioners in the pension statistics is highly reliable, as the pension insurance fund receives the death notice from the undertaker, the postal payout service, or directly from the relatives. These are legally obliged to notify the pension insurance fund if pensions for the deceased person were paid out. This implies that the number of pensioners is also of high quality.

Germany conducted a pension reform in 1992, which also had an impact on the pension statistics. Since then, additional types of information, such as on marital status or sick leave, have been recorded. Within this transformation, the GDR system in East Germany was converted to the FRG system. The pension statistics were affected by this conversion. Detailed individual-level data are available for the period starting in 1994. Some variables were not recorded until after the pension reform in 1992 and are thus incomplete or missing for those pensioners who retired earlier.

Early mortality analyses based on pension insurance data of the mid-1980s were done by Rehfeld and colleagues. Rehfeld and Scheitl (1986, 1991) found lower remaining life expectancy at age 65 in the 1980s for pensioners who collected a disability pension before receiving an old-age pension. They further analyzed the remaining life expectancy at age 65 in relation to the length of the individual's employment career. The mortality of widows of workers and employees in 1985–1987 was studied by Rehfeld and Scheitl (1991). Müller and Rehfeld (1985a, b) described the remaining life expectancy at age 65 by the length of employment (more than 40 contribution years vs. fewer than 40 contribution years) and find few differences, with slightly higher life expectancy for the pensioners who were employed for longer periods.

As certain population groups are not covered by the data of the German Federal Pension Fund, mortality estimates in this analysis may differ from the mortality estimates of the total population. Given that lifetime civil servants—a group with high socioeconomic status and above-average income and among whom below-average mortality can be assumed (cf. Shkolnikov et al. 2008; von Gaudecker and Scholz 2007)—are not included in the dataset, it is possible that it provides an overestimation of mortality in West Germany. The number of old people with very low incomes and high mortality risk who are not covered by the German Federal

Pension Insurance is assumed to be very small and to have no significant impact on mortality estimates.

In a calendar year, about 82% of the labor force makes contributions to the German Federal Pension Fund (Stahl 2003). At the end of a working life, more than 90% of the population residing in Germany receives an old-age pension (Scholz 2005).

The pension statistics are of very high quality. At present in the Human Mortality Database (www.mortality.org), the pension statistics are even used to correct population estimates at very high ages (Jdanov et al. 2005; Scholz and Jdanov 2006).

5.2.2 Variables in the Pension Insurance Dataset

This chapter explains the variables from the pension insurance dataset. Count data are used and are aggregated by the variable values described here (DRV Bund 2007). Most variables—except for age of course—are supposed to be time constant as of the time when the current pension payment started. In cases in which the place of residence, the health insurance coverage, or the nationality changes, the latest value is recorded. Person years lived are calculated as the mean of the pensioners' populations at the beginning and at the end of the reporting year.

The following variables are considered in the study.

Age. Given the legal retirement age of 65, this is the youngest age in the present analyses. For the age calculation, the original data contain information on the month and the year of birth, as well as on the month and year of death. Five-year age groups are used, with the highest age group being 90+ (65–69, 70–74, 75–79, 80–84, 85–89, 90+).

Sex. Men and women are treated separately in the analyses.

Place of residence. Pensioners residing in Germany are considered. Germany is divided in federal states and districts (*Kreise*).

Federal states. The federal state where the pensioner currently resides is recorded. The federal states are Schleswig-Holstein, Hamburg, Lower Saxony, Bremen, North Rhine-Westphalia, Hesse, Rhineland-Palatinate, Baden-Württemberg, Bavaria, Saarland, Berlin, Brandenburg, Mecklenburg-Western Pomerania, Saxony, Saxony-Anhalt, and Thuringia.

Districts. A total of 438 districts are used in the analyses, which allows for the highest geographical resolution over time (see previous chapter). Thus, and in line with the earlier analyses, the district of Eisenach in Thüringen is coded to Wartburgkreis. The region of Hannover, which has existed as an administrative unit since 2001, was formed through a merger of the rural and urban districts of Hannover. Hamburg and Berlin are city-states that consist of just one geographical unit, whereas the city-state of Bremen has two geographical and administrative units. Berlin is not divided into East and West. The districts in the East German states underwent several substantial territorial changes. Several codes in East Germany can no longer be linked to any of the new districts. This affects a very small number of pensions. Less than 0.2% of records in the original sample cannot be attributed to any district (these are excluded; see Sect. 6.2.3). The districts are either urban or rural. The district councils are responsible, for example, for the organization of parts of the health care system, rescue, waste management, local family policy, or local public transport.

Year. The years 1998, 2001, and 2004 are pooled together. Preliminary analyses showed only small differences in the districts' mortality levels by year, but not in the structure; pooled data yields more stable results once small areas are addressed. The reporting year in the pension fund runs from December 1 to November 30.

Earning points. Lifetime earnings are expressed as the sum of earning points and are calculated as described above. The continuous variable was originally grouped into 0–4, 5–9,…, 50–54, and 55+ points for the purposes of this study. According to some preliminary analyses, they were further summarized as 0–29, 30–44, 45–54, and 55+ earning points, which leads to a reduction of data dimensions without a serious loss of meaning (cf. von Gaudecker and Scholz 2007; Shkolnikov et al. 2008). Additional income sources, such as unearned income or self-employment income, are not included. It is likely that some pensioners, especially men with private health insurance, have retirement income in addition to their old-age pension (for a discussion of this topic, see Shkolnikov et al. 2008; von Gaudecker and Scholz 2007). A man's SES is thought to be equally reflected by the earning points if all of the pensioner's working life refers to employed work (as opposed to self-employed work or civil servants' income), and the share of external income sources is small. Women often benefit from their husband's higher pension and receive a widow's pension more often than men. Because they often worked part-time or stayed at home, it is only possible to a limited extent to take a woman's own earning points as a proxy for income or wealth. In the pension statistics, the group of women with few earning points is composed of women with long employment careers but low earnings and also of women who were engaged for long periods in unpaid family care and housework. A woman's socioeconomic status can be represented by the pension data to a lesser extent than that of a man's because the earning career of a woman may show many interruptions and often interacts with the husband's career. The problematic reflection of women's socioeconomic status has been addressed elsewhere (e.g., Hoffmann 2005; Shkolnikov et al. 2008; Wolfson et al. 1993).

Nationality. The dataset distinguishes between people of German and of foreign nationality. Nationality is a feature reported to the pension fund by the employer. Employees are obliged to inform the employer about changes. But unlike, for example, a change in marital status, a change in nationality has no financial implications. Nevertheless, the quality of this variable is considered to be high (Mika 2006). Unfortunately, nothing is known about changes in nationality or migration background over the life course. Mortality among pensioners of foreign nationality is slightly higher than mortality among Germans (Kibele et al. 2008).

Health insurance. Three groups of health insurances are recorded: compulsory (public) health insurance (CHI), private medical insurance (PMI) or voluntarily public, and a remainder group. The compulsory health insurance is compulsory for all workers and employees up to a contribution ceiling (currently about 3,500€ monthly gross income). Above this income ceiling, employees can decide whether they want to be voluntarily insured in the CHI or to purchase private medical insurance. The group of private medically insured pensioners includes both people with actual private medical insurance and people who are voluntarily insured in the CHI. The remainder category of pensioners with another type of health insurance is comprised of pensioners with either foreign health insurance or with *Nullrenten*[2] and of cases in which the type of pension insurance has not yet been clarified or is simply unknown or in which pensioners have foreign health insurance.

Occupation. The insurance branch can be considered as a proxy of the former occupation of a pensioner, reflecting the workload and type of occupation. Until the end of 2004, the pension fund provided three types of pension insurance: for workers, for employees, and for miners (the social miners' and mine employees' fund). For workers and employees, the last affiliation is given. People who have ever worked in the mining industry—not necessarily doing work in mines (cf. Shkolnikov et al. 2008)—are always registered in the mine employees' fund, regardless of how long they worked in the mining industry. For simplicity, these people are called "miners" hereafter. Women are only allowed to work in the administration of mining industries; the physical work continues to be performed by men. There are special regulations for miners, such as earlier legal retirement age and financial betterment. From 2005 onward, the distinction between the occupational insurance branches has no longer been made because of an integration of the systems. This is why data after 2004 are not analyzed here. The loss of information on this highly important variable would be too high relative to the small advantage of using slightly more recent data.

Age at retirement. The age at which the first pension payment is received from the pension fund is taken as a proxy for the age at retirement. The legal retirement age is 65 (before 2001: age 63 for women). It is possible to retire at an earlier age, but this results in a reduced pension amount. As mentioned above, the long-term unemployed who see no opportunities on the labor market may retire when they turn 60, which renders them ineligible to receive unemployment benefits. Old-age pensions are paid out at ages no younger than 60. Disability pensions are usually transformed into old-age pensions at age 60. Those who retire before the legal retirement age are assumed to be disabled individuals who are retiring at the first available opportunity, the long-term unemployed, or well-off people who no longer have the financial need to work. Kühntopf and Tivig (2008) found minor mortality differences by retirement age among women, but differences amounting to up to 2 years of remaining life expectancy at age 65 among men.

[2] Pensions that are not paid out because the pensioners receive income. The pensions of these people are called *Nullrenten*.

With the pension reform in 1992, the statistics and availability of data improved. In the latter years, information has become more and more complete. The affected variables are, for example, the start of pension payments, the current pension payment, and the proxy for the age at retirement.

Further variables are available, but are not used due to inadequacy. The use of various types of information—such as the number of children, marital status, unemployment spells, periods spent on sick leave, contribution periods, education, profession, and occupation—would be desirable, but the coverage is deficient. For example, the variable on the number of children is valid only if a parent has had allowable contribution periods due to childrearing. For a great majority of cases (especially for men), the number of children is recorded as zero. It is simply unnecessary for the calculation of the pension level. Information on education, occupation, and profession has been available only since 2000. For pensioners who received their first pension payment before that time, no such information is available. The same applies to the other variables listed above, such as marital status. In future, the availability of meaningful variables will increase, and the amount of missing data will be reduced.

5.2.3 Selection of the Study Population

In the analyses of regional mortality differentials, the original dataset is narrowed down to a smaller subset. The data sample is restricted to those with presumably long and active lives as dependent employees. Table 5.2 documents the sample size.

The following selection criteria were applied to the original data, resulting in the selected sample used in the analyses:

- Pensioners for whom the district of residence is unknown are excluded. This affects only pensioners in eastern Germany, where several territorial changes after reunification made some places untraceable. The federal state is known for these cases, but the small-area division is crucial for the analyses here (experimental analyses using this missing information did not differ qualitatively nor quantitatively). As mentioned above, this affects less than 0.2% of the pensions in the original dataset.
- Only pensioners with German citizenship are considered, given the differing employment histories of Germans and non-Germans. The vast majority of foreign pensioners in the dataset are immigrants of the first generation who came to Germany as labor migrants between the 1950s and 1970s or within the context of a subsequent family reunion. These migrants arrived in Germany at some point during their active employment careers. Not having spent their entire working lives in Germany reduces their contributions to the German pension insurance fund. Contributions to foreign pension schemes are not considered by the German pension scheme unless there are special agreements between the countries of origin and Germany, as was the case, for example, in the EU countries. Shorter contribution periods have resulted in lower lifetime earnings, as registered by the

Table 5.2 Population exposure (P) and number of deaths (D); original and final sample; 1998, 2001, 2004 (pooled)

	Males		Females	
	P	D	P	D
	Original sample			
N	14,803,574	774,802	21,831,177	884,651
	Final sample			
N	11,875,621	620,364	5,501,364	171,558

Data source: FDZ-RV SUFRTBNRTWF94-04TDemoKibele

German pension insurance. This has produced an artificial difference between the socioeconomic composition of the foreign and the German populations. The foreign population constitutes 3% of the male and 1.3% of the total population in the original data (Table 5.3).

- Only pensioners with 30 or more earning points are considered. Preliminary analyses and prior studies on the same data have shown that the group with fewer than 30 earning points consists of pensioners with heterogeneous features (Shkolnikov et al. 2008; von Gaudecker and Scholz 2007). A similar study on income-related mortality based on Canadian pension data faced the same problem (Wolfson et al. 1993). It is generally assumed that nearly the entire working life will be reflected in the earning points, which indicate the lifetime earnings. This is less likely to be the case if individuals have long periods of part-time work, no work, or no work liable to social insurance contributions. This often applies to elderly women with long periods of childrearing and domestic work. In addition, most self-employed people or civil servants have contributed to the pension scheme during some part of their active lives and are therefore entitled to draw a pension at old age. However, these people usually have only a few earning points, together with some alternative income sources from their time working in civil service or private entrepreneurship. The group of pensioners with fewer than 30 earning points hence consists of (relatively wealthy) civil servants and self-employed people but also of people with very low lifetime earnings and no additional sources of pension income. Shkolnikov et al. (2008) and von Gaudecker and Scholz (2007) have shown that pensioners in low pension income groups have a lower mortality risk than pensioners in the second-lowest pension income group, which may be due to the heterogeneous composition of pensioners. For these reasons, pensioners with fewer than 30 earning points are excluded here. The 30-point threshold was derived from an experimental mortality analysis that takes into account greater data integrity. This leads to the exclusion of 18% of the male and almost three-quarters of the female population found in the original data (Tables 5.2 and 5.3).

Table 5.2 shows the final sample on which the subsequent analyses are based. The sample consists of 11.9 million men and 5.5 million women for 1998–2004 and is made up of 80% of the men and 25% of the women in the original sample.

Table 5.3 Percentage distribution of population exposure (P) and deaths (D) by variable values; original and final sample; 1998, 2001, 2004 (pooled)

	Original data				Final sample			
	Males		Females		Males		Females	
	P	D	P	D	P	D	P	D
Age								
65–69	38.8	16.4	28.7	6.7	38.5	16.1	35.7	10.8
70–74	27.9	19.7	25.1	10.7	27.9	19.6	26.2	14.3
75–79	18.2	20.8	22.2	17.5	18.3	20.9	20.6	20.5
80–84	9.0	17.4	13.3	20.6	9.1	17.6	10.8	21.3
85–89	4.3	14.3	7.1	20.8	4.4	14.4	4.6	16.6
90+	1.8	11.3	3.6	23.8	1.8	11.4	2.1	16.4
Year								
1998	29.5	32.5	30.9	32.3				
2001	33.1	33.1	33.3	33.4				
2004	37.4	34.4	35.8	34.3				
Nationality								
German	97.0	97.8	98.7	99.2				
Foreign	3.0	2.2	1.3	0.8				
Occupation								
White-collar	39.4	33.9	43.1	37.0	41.6	36.1	62.3	60.0
Blue-collar	54.0	59.0	55.6	61.5	51.0	55.8	35.9	38.1
Miner	6.5	7.1	1.3	1.6	7.4	8.1	1.8	1.9
Health insurance								
PMI	14.1	8.8	6.3	3.7	7.9	3.9	3.7	2.1
CHI	84.7	89.7	89.8	94.2	91.8	95.7	96.1	97.6
Other	1.3	1.5	3.9	2.1	0.3	0.4	0.2	0.3
Retirement age								
Missing	0.5	0.2	0.4	0.1	0.5	0.2	0.2	0.1
≤59	13.1	18.2	10.6	14.0	13.1	17.5	10.7	13.0
60–64	57.7	49.4	52.4	51.7	65.5	54.8	83.1	78.0
65+	28.7	32.2	36.6	34.1	20.9	27.5	6.0	8.9
Earning points								
0–29	18.2	18.8	74.5	80.5				
30–44	23.5	26.8	20.5	15.8	28.0	32.6	80.6	80.6
44–54	27.6	27.2	3.4	2.5	33.9	33.6	13.3	13.0
55+	30.8	27.2	1.5	1.2	38.1	33.7	6.1	6.4
Federal state								
SH	3.4	3.5	3.4	3.5	3.2	3.3	2.4	2.6
HH	2.0	2.1	2.2	2.3	1.9	2.1	2.5	2.8
NI	9.8	9.9	9.6	9.4	9.3	9.5	6.2	6.3
HB	0.8	0.9	0.9	0.9	0.8	0.9	0.7	0.8
NW	22.6	22.8	21.2	20.1	22.5	23.0	13.9	14.7
HE	7.4	7.5	6.9	6.6	7.0	7.1	5.3	5.3
RP	5.1	5.1	4.5	4.1	4.8	4.8	2.7	2.7

(continued)

Table 5.3 (continued)

	Original data				Final sample			
	Males		Females		Males		Females	
	P	D	P	D	P	D	P	D
BW	12.3	11.7	12.1	11.4	11.6	11.0	10.8	10.7
BY	14.1	13.9	14.1	13.7	12.7	12.3	11.5	11.9
SL	1.4	1.5	1.1	0.9	1.4	1.5	0.5	0.5
BE	3.4	3.5	4.0	4.9	3.5	3.7	6.7	7.8
BB	2.9	2.8	3.1	3.4	3.5	3.3	5.8	5.3
MV	2.1	2.0	2.3	2.4	2.5	2.4	3.7	3.1
SC	5.9	5.8	7.0	7.8	7.1	7.0	14.1	13.4
ST	3.4	3.6	3.9	4.3	4.1	4.3	6.6	6.0
TH	3.3	3.4	3.7	4.0	3.8	3.8	6.7	6.2

Data source: FDZ-RV SUFRTBNRTWF94-04TDemoKibele

The pensioners in the sample actively participated in dependent employment during long periods of their active lives. The sample takes care of the previously mentioned data peculiarities and should yield comparable data for the subsequent analyses for men and women.

As the selected data sample drops many cases for women due to the income criterion, the data are not only analyzed for the selected dataset. The analyses are also conducted for a dataset which includes all earning point groups but excludes non-Germans and those pensioners with missing or unknown district of residence. These results are shown in the appendix.

Although the present data cover the majority of the population aged 65 years and above, a small part of the population remain uncovered by the data, and some pensioners had to be excluded in order to achieve data comparability. How does this affect mortality? Remaining life expectancy at age 65 for men is 15.80 years, based on the original data, and is 15.84 years, or 0.3% higher, based on the final sample. For women, remaining life expectancy at age 65 is 19.93 years, based on the original data, and is 20.15 years, or 1.1% higher, based on the data from the final sample. Hence, mortality is only slightly affected by the reduction of the sample size. Compared to civil servants, pensioners in the German statutory pension insurance have a higher mortality risk (Himmelreicher et al. 2008).

5.2.4 Distribution of Population Exposures and Deaths

This section deals with the distribution of population exposures and death counts according to the individual-level variables and by federal state. While Table 5.2 lists the absolute population exposure and deaths by sex, Table 5.3 provides an overview of the relative distribution of population exposure and deaths by variable values for the sample and the original data. The regional distributions of population and of deaths by federal states are thus given for informational purposes only.

The pensioner population declines with age. In the selected sample, this distribution is shifted to an even great extent to younger ages among women, relative to the original data. About 3% of the male and 1.3% of the female pensioners are of foreign nationality (Table 5.3).

In the original sample, 54% of the male and 56% of the female pensioners had been blue-collar workers. Around 40% of both males and females had been white-collar workers. About 7% of all male pensioners had been occupied in the mining industry. Among women, this percentage is much lower, just above 1%. Following the selection criteria described above, the final sample contains many fewer blue-collar workers due to the drop in the number of pensioners with a low number of earning points. Among women, white-collar employees are now overly represented compared to the total population, making up about 60% of all pensioners (Table 5.3).

The type of former occupation, as indicated by the insurance branch, shows considerable variation across the federal states. The city-states (Berlin, Hamburg, and Bremen) have a high share of white-collar employees. Miners exhibit the largest degree of variation. Saarland and North Rhine-Westphalia are the traditional mining states. In eastern Germany, which has a higher share of miners in total, mining has been an important industrial sector in the southern part of the region (figures not shown).

A breakdown of health insurance coverage types reveals that 85% of males and 90% of females in the pensioner population in the original sample are members of a compulsory health insurance fund. About 14% (men) and 6% (women) have private health insurance. Many of them, however, have only a few earning points (Table C.1 in the appendix), mainly due to inadequate registration of the entire pension income (cf. Shkolnikov et al. 2008). Excluding the group of pensioners with a small number of earning points leads to a reduction in the number of people with private health insurance in the final data sample (Table 5.3). East Germans are less likely to have private health insurance (figures not shown).

The retirement age of most pensioners lies between 60 and 64. Among men, 13% retired before they reached the age of 60; the respective figure for women is 11%. Only 29% of male and 37% of the female pensioners worked until they reached the legal retirement age of 65. Excluding the aforementioned cases from the original data yields a similar picture among men, but a somewhat altered picture among women. In the final sample, more than 80% of female pensioners retired between ages 60 and 64 (Table 5.3).

The number of male pensioners across the four income groups represented by earning points in the original sample increases with the number of earning points. Women are overly represented in the lowest earning point group. Only about one-fifth of the female pensioners accumulated more than 30 earning points over their lifetimes. Excluding the group with the lowest number of points, or 0–29 points, shifts the pattern among males and females. Most female pensioners are now in the second-lowest earning point group, with 30–44 earning points (Table 5.3). Former white-collar employees have higher pension incomes than former blue-collar workers (Table C.1).

The majority of male pensioners have 45 earning points or more; in western Germany this applies to more than half of the population, while in eastern Germany it applies to about 70%. Less than 5% of men in eastern Germany have fewer than

30 earning points. Women have fewer earning points. About three-quarters of them accumulated fewer than 30 earning points over their working lives. Only about 5% have collected 45 earning points or more. Eastern German women accumulated more earning points than their western German counterparts. The pension income distribution is more equal in eastern Germany; however, men have considerably higher pension incomes than women.

The distribution of pensioners across age, year, and the federal states in the original sample roughly reflects the population composition by age, nationality, and federal state, as given by the official population statistics. For example, both data sources show that the most populous states are North Rhine-Westphalia, Bavaria, and Baden-Württemberg; while the states with the smallest populations are the city-states, Saarland, and the eastern German states (Statistisches Bundesamt 2006). Furthermore, most retired pensioners with foreign citizenship live in one of the western German federal states, as does the foreign population aged 65 and over. The highest share of foreigners is found in Baden-Württemberg, Hesse, and Hamburg. Among the eastern German federal states, most of the foreigners live in Berlin, largely because the city partly belonged to West Germany before reunification and because Berlin is Germany's biggest city (figures not shown).

Excluding pensioners with foreign citizenship, an unknown district of residence, and fewer than 30 earning points leaves a homogeneous population sample with regard to the pensioners' employment histories. This was necessary to achieve a comparable sample of men and women who were employees for long periods of time. As the sample excludes a large proportion of women, the subsequent analyses are also conducted for the pensioners' population, excluding those with foreign citizenship and an unknown district of residence but including all earning point groups. These results are presented in the appendix. As a consequence of the more homogeneous sample, mortality differentials may be reduced.

5.2.5 Contextual Factors

The contextual factors for the current analysis were already touched upon in the previous chapter. The data are considered for the years 1995–2003 (see Table 4.3).

Again, the indicators on the districts in different spheres are considered. These are economic conditions (unemployment rate, income, GDP per capita, number of employees and their share in secondary and tertiary sector, net business registrations), social conditions (voter turnout, living space, spread of detached housing, divorce rate, welfare recipients), education (share of employees with a university degree or no degree, school graduates with *Abitur* or no degree), population structure (population change, net migration, population density), and health care and accidents (hospital beds, physicians, traffic accidents, fatal traffic accidents).

Thus, the factors were adjusted according to the current needs. In order to obtain an average indicator of population change, the population change from 1995 to

2003 is considered. The share of foreigners is excluded because of the misleading meaning of this data (see Sect. 4.8.2). The Schufa index of indebtedness is excluded because the data are only available from 2003 onward. The health policy indicator was not considered, as it targets mortality before the age of 75, and is therefore less suitable in the analysis of old-age mortality determinants.

The summary statistics for the contextual factors are given in Table C.2 in the appendix.

5.3 Method

The literature review on multilevel studies is now extended to technical issues before the models applied to the data from the German Federal Pension Fund are described (Sect. 5.3.2).

5.3.1 Theoretical Aspects

Several theoretical aspects, according to which multilevel studies differ crucially, have to be considered in the model setup. Following Pickett and Pearl (2001) and Riva et al. (2007), these are:

- Definition of the spatial unit
- Control for individual-level variables
- Control for area-level variables
- Disentangling context from composition
- Conceptualizing causal pathways
- Model choice
- Sample size, power, and representativeness

The definition of a spatial unit is often borrowed from administrative definitions of boundaries or statistical units for which contextual data are available (Diez-Roux 2001; Pickett and Pearl 2001; Riva et al. 2007). The German district level, with its 438 German districts, is used as the spatial unit; the district is an administrative level in which a number of policies are locally decided and implemented.

Controlling for individual-level variables is essential because contextual effects will be overestimated or wrongly estimated otherwise. Area-level contextual factors are often derived by averaging individual characteristics (Diez-Roux 2002). Area-level factors can absorb some of the individual-level effects and may therefore over-estimate the area mortality effect when individual factors are not adequately included (examples in Sloggett and Joshi 1994; Turrell et al. 2007).

The choice of and controls for area-level contextual factors are also crucial. Contextual factors are often highly correlated with each other (Pickett and Pearl 2001; Riva et al. 2007). Area-level factors can be derived from individual-level data, but there are also factors which do not have an individual-level equivalent. These are called integral variables; examples are income inequality, the type of economy, or population density. Environmental variables are variables with equivalents on both levels, such as being unemployed and the regional unemployment rate (Diez-Roux 2002). Administrative units usually reflect features of the administrative organization and of policies, such as health care, refuse disposal services, and educational systems. In this study, contextual factors which represent a variety of conditions that influence people, such as district-level economic performance or provision of infrastructure, are included.

How contextual effects should be disentangled from compositional effects is a controversial issue. Pickett and Pearl (2001) illustrated a possible confounding problem between individual- and area-level effects in their discussion of smoking prevalence. An individual may smoke because he lives in a deprived area; controlling for individual smoking behavior may then lead to an underestimation of the association between the area effect and the health outcome. The difference between the mediating and the confounding factors is not always clear (cf. also Chaix and Chauvin 2002). Riva et al. (2007, p. 854) state that "[s]ome investigators argue for disentangling the portion of the between area variation in health that is attributable to areas in which people live (contextual effect) from the portion attributable to individuals' characteristics (compositional effect), whereas others argued this is a 'false' issue as context and composition are inextricably intertwined."

In conceptualizing causal pathways, how individuals act within contexts, and how they interact, must be specified. This is related to the need to disentangle context from composition. The causal pathways that explain how individual and contextual features act on health outcomes need more theoretical elaboration (Diez-Roux 2001; Pickett and Pearl 2001; Riva et al. 2007; Voigtländer et al. 2008). Although some researchers consider area-level health differences to be the result of different population compositions, this approach lacks the dimension of area features (Macintyre et al. 1993). Relevant contextual factors at the appropriate spatial scale are therefore important. Furthermore, individual risks can be distributed differently across areas, and area-level factors may serve as mediators (Hox 2002). On the one hand, more deprived individuals may benefit from living in a more advantaged area. On the other hand, it is possible to argue that psychosocial stress is elevated for more deprived individuals in better-off areas, as the discrepancy between individual and area circumstances becomes evident (cf. Blomgren et al. 2004). The former assumption is so far backed by more empirical evidence.

Regional mortality variation can be investigated in an ecological setting through the study of individual mortality risk factors or by using a multilevel approach that integrates the two. With regard to model choice, multilevel models are necessary for taking into account the nested structure (individuals clustered within regions). However, in some instances, they are dispensable. According to Chaix and Chauvin (2002), multilevel models are not essential when the variance of random components is not significantly different from zero, when the number of spatial units is not very great and the number of observations is large, or when only fixed effects are of importance.

The advisable sample size in multilevel modeling depends on the number of levels and the number of units within each group at each level. Furthermore, the model design is important for obtaining reasonable standard errors (Snijders 2001). The sample size guarantees that reasonable estimates for regression parameters are obtained at all levels. Standard errors of proportional effects tend to be downward-biased in single-level models since the hierarchical structure is not taken into account. Having as many as millions of exposures at the individual level and hundreds of districts at the area level, a multilevel model takes into account the nested structure and contains a sufficient amount of data to obtain correct fixed effects and standard errors on both levels. This further ensures statistical power and representativeness (Hox 2002; Maas and Hox 2005; Snijders and Bosker 1999).

Multilevel models usually include a random and a fixed part. When individuals are nested within regions, as in the present data, the fixed part relates to the effects of individual-level variables and contextual variables, while the random part indicates the extent of regional-level variation. In the model estimation, only fixed effects (effects which do not vary randomly across higher-level units) are directly estimated, whereas random effects are given as a standard deviation of the baseline (see, e.g., Rabe-Hesketh and Skrondal 2005). This standard deviation indicates the regional mortality variation across regional units, which here are districts (Kulu and Billari 2004).

A multilevel model is best evaluated in several steps in order to capture the effects and variations at different stages (Hox 2002). It is advisable to build a first model without any explanatory variables, in which a random intercept for each region is estimated, and no explanatory variables or only age are included. The second model should include a random intercept as well as all individual-level variables. Regional-level variables are added in the third model. In the later stages, it should be checked if there is evidence that individual variables have different effects in different regions, that is, whether random coefficients or cross-level interactions are significant.

In theory, the inclusion of individual-level and higher-level variables should—assuming the individual and contextual effects are significant—yield a reduction in the observed degree of variation and in a model with better explanatory power. Analogous to adjusted R^2 in ordinary multiple regression, in multilevel regression, the proportion of variance explained can be calculated. This is calculated as the relative difference between total residual variance in the null model (intercept- or age-only model) and the residual variance of a model with covariates (Hox 2002; Snijders and Bosker 1999). In reality, the variance sometimes increases after the inclusion of individual and contextual factors with significant effects (see, e.g., Blomgren and Valkonen 2007; Hank 2003).

5.3.2 Multilevel Poisson Model

The different models that will be calculated, and their formulae, are now presented. The basic model is a model which contains a random intercept and age. In the next step, all of the individual-level variables are added and are followed by the district-level context variables (which are further summarized as a mortality context score). Finally, a model with cross-level interactions between individual-level socioeconomic status and the socioeconomic conditions of the districts will be estimated.

Since the pension fund data used in this study contain a hierarchical structure with individuals nested in districts, a two-level model is applied. The district level was chosen as an appropriate regional level, as it is the most detailed level for which data are available. As was previously mentioned, having as many as 438 higher-level units and millions of exposures in the selected sample means that sample size issues become less important.

Poisson regression models are applied to the described count data (cf. Langford and Day 2001; Rabe-Hesketh and Skrondal 2005). Deaths are the events under study, representing the number of occurrences. Exposure time of the population in years (population-years at risk) is taken as an offset. The general model for the mortality hazard μ_i that is defined as occurences$_i$/exposures$_i$ in a single-level model is given as

$$\log(\mu_i) = \beta_0 + \beta_1 x_{1i} + \cdots + \beta_K x_{Ki} = \beta_0 + \sum_{k=1}^{K} \beta_k x_{ki} \tag{5.1}$$

where i refers to the individual and K is the number of individual-level explanatory variables. The first part on the right-hand side e^{β_0} is the baseline hazard that holds when all independent variables take the reference value chosen where $\beta_{1,\ldots K}=0$, and hence, $e^{\beta_{1,\ldots K}}=1$. The following parts on the right-hand side indicate the impact of the independent variables. The specific effect is less than one (= lower risk than in the reference group) for $\beta_{1,\ldots K}$ smaller than zero and greater than one for $\beta_{1,\ldots K}$ with positive values. There are only fixed effects in such a single-level model. Mortality effects are given by mortality rate ratios $\left(\text{MRR}_i = e^{\sum_{k=1}^{K} \beta_k x_{ki}}\right)$. The MRR$_i$ in the reference group is one, and a group with a MRR$_i$ of 1.5 has a mortality risk which is 50% higher than that of the reference group.

Extending the model first to a simple two-level model yields (equations derived from Chaix and Chauvin 2002; Diez-Roux 2002; Healy 2001; Snijders and Bosker 1999):

$$\log(\mu_{ij}) = \beta_0 + \sum_{k=1}^{K} \beta_k x_{kij} + u_{0j} \tag{5.2}$$

where u_{0j} is the variation across the districts j. All other factors are fixed effects. This is a basic *random-intercept model*, and it assumes that the baseline level of the studied events is different for all higher-level units j, for example, that the mortality rate differs from one district to another (Diez-Roux 2002). In this model, the outcome μ depends on the overall intercept β_0, which is the same for all individuals independent of the region, and it also depends on the area-specific u_{0j}, the region-level disturbance, which applies to all individual in the same region. Individual-level covariates (x_k) are included.

In the next step, regional-level factors (z_c) are also introduced:

$$\log(\mu_{ij}) = \beta_0 + \sum_{k=1}^{K} \beta_k x_{kij} + \sum_{c=1}^{C} y_c z_{cj} + u_{0j} \tag{5.3}$$

Finally, cross-level interactions between individual- and higher-level covariates can be introduced if either the respective individual covariate has a significant random coefficient or the theoretical background supports its inclusion (Snijders and Bosker 1999):

$$\log\left(\mu_{ij}\right) = \beta_0 + \sum_{k=1}^{K} \beta_k x_{kij} \left[+ \sum_{c=1}^{C} y_c z_{cj} \right] + \delta_{kc} x_{kij} z_{cj} + u_{0j} \quad (5.4)$$

In this model, a individual-level variable x_k is interacted with a district-level variable z_c. The mortality effect of this interaction is given by δ_{kc}. Empirical evidence in mortality studies analyzing regional variation has shown that there is a tendency for more deprived individuals to suffer more from adverse contextual conditions than better-off individuals in the same context (Pickett and Pearl 2001; Riva et al. 2007).

The model fit is evaluated by means of the log likelihood statistics (LL). Judgments about model fits in model comparisons are based on likelihood ratio tests.

Regarding the contextual factors, the arithmetic means of the variables in the available time period (if possible from 1995 to 2003) were taken in order to obtain a factor less sensitive to random changes. Except for urban-rural residence, all variables are continuous and were standardized so that they have a mean of 0 and a standard deviation of 1.

In the analyses, first the impact of each regional-level factor z_c is assessed separately. Dragano et al. (2009a, p. 32) noted that, although the uni-contextual indicator approach is frequently used in the absence of better data, it may lack important information. Therefore, in the second step, those contextual factors with the biggest mortality impact are incorporated into a mortality context score. This score unites several aspects of the individuals' context in a region and can be regarded as a general factor of regional well-being or deprivation. The score weights the impact of the contextual factors according to their mortality effects:

$$\text{Score}_i = \frac{1}{n} \sum_{1}^{n} \sum_{i}^{j} \left[1 + \left(RR_n - 1 \right) * z \text{ value}_{in} \right] \quad (5.5)$$

where n is related to the number of contextual factors and i are the 438 districts. RR is the relative risk of variable n, and z value$_{in}$ is the standardized variable value of district i in variable n.

The number n of contextual factors to be included in the score is derived from a stepwise procedure. Successively, the model including all individual-level variables incorporated those contextual factors which improved the model fit most until no additional improvement was obtained.[3] Calculations were done separately by sex, as the impact of the context factors differs for the sexes. The mortality context scores were also standardized.

[3] This yielded the selection of eight variables: unemployment rate, GDP per capita, voter turnout, income per capita, living space, share of employees without any degree, population change, and the population forecast.

Stata 10.1 was used to estimate the single-level models, and the β-coefficients were then taken as the starting values for the estimation of the two-level models in the aML package (Lillard and Panis 2003), with both implementing the maximum likelihood estimation.

5.4 Results

The results on individual- and regional-level determinants of old-age mortality are now presented. First, the regional pattern of old-age mortality is derived from a single-level model (Sect. 5.4.1). Having established the spatial pattern of old-age mortality in Germany, the question of which factors explain this pattern is now investigated. As outlined in the methods section, this is done in several steps. In the first step of the multilevel modeling procedure, mortality differentials between population groups are analyzed (Sect. 5.4.2). Next, the question of how differential population composition affects district mortality variation is explored (Sect. 5.4.3). Regional context factors are also introduced (Sect. 5.4.4). These are then interacted with variables on individuals' socioeconomic status in order to find out whether the effect of individual-level mortality risk factors differs by regional context (Sect. 5.4.5).

5.4.1 Single-Level Models: Mortality Across Districts

The geographic mortality patterns of pensioners' mortality across Germany's districts are quite similar to those based on population-level data (see previous chapter, Sect. 4.4). Figure 5.1 displays the spatial distribution of the age-standardized mortality rate ratio (MRR) across districts.[4] The MRR categories on the map are based on quintiles of the geographic distribution.

Once again, a notable degree of mortality variation can be observed, with higher mortality in the East than in the West and lower mortality in the South than in the North.

Among male pensioners, mortality is especially low in Baden-Württemberg, southern Bavaria, and Hesse. Additional low-mortality regions are the Köln-Bonn area, several districts in Saxony, and southwestern Lower Saxony extending to the north of North Rhine-Westphalia. Mecklenburg-Western Pomerania, Saxony-Anhalt, Saarland, the Ruhr area, and the northeastern border region of Bavaria (Upper Franconia, Upper Palatinate, Lower Bavaria) are high-mortality regions among men.

Women show a similar spatial pattern of high- and low-mortality districts, but with a few deviations from the male pattern. Almost all female pensioners in the

[4] The reference district is the urban district of Flensburg, a district situated in Schleswig-Holstein with approximately average mortality.

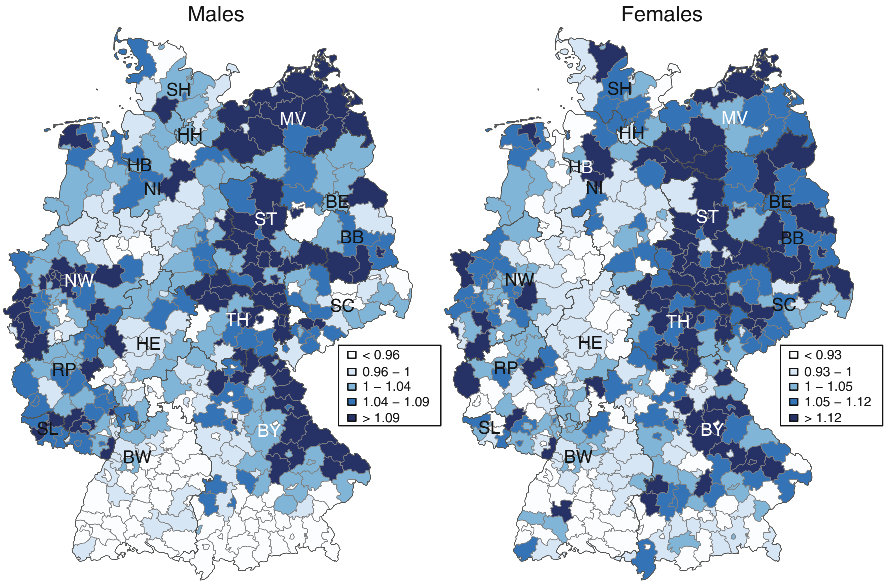

Fig. 5.1 Age-standardized MRR by district; 1998, 2001, 2004 (pooled). *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western Pomerania, *SC* Saxony, *ST* Saxony-Anhalt, *TH* Thuringia (Data source: FDZ-RV SUFRTBNRTWF94-04TDemoKibele. Base map: German Federal Agency for Cartography and Geodesy 2007)

East German districts suffer from higher mortality. And, relative to men, greater parts of Lower Saxony exhibit lower mortality, and Rhineland-Palatinate includes several low-mortality districts.

Figure C.1 in the appendix shows the respective map based on the sample without income restrictions. The geographical old-age mortality pattern looks very similar to that for men. Among women, Saxony holds a better position in the not-restricted sample.

5.4.2 Multilevel Models: Individual-Level Fixed Effects

First, the question of which factors explain mortality differences from the individual-level perspective is addressed. The results stem from two-level random-intercept models, with the random intercepts corresponding to the 438 districts. Table 5.4 shows the MRRs for the explanatory variables (occupational branch, type of health insurance, retirement age, and earning points) when only age is controlled for (Model 1)

Table 5.4 Multilevel models: MRRs by individual-level variables with 95% confidence intervals (in parentheses); 1998, 2001, 2004 (pooled)

	Males		Females	
	Model 1	Model 2	Model 1	Model 2
Occupation				
White-collar	1	1	1	1
Blue-collar	**1.35**	**1.18**	**1.22**	**1.19**
	(1.35; 1.35)	(1.17; 1.19)	(1.21; 1.23)	(1.18; 1.21)
Miner	**1.28**	**1.08**	**1.09**	**1.06**
	(1.26; 1.29)	(1.07; 1.09)	(1.05; 1.12)	(1.02; 1.09)
Health insurance				
PMI	1	1	1	1
CHI	**1.55**	**1.32**	**1.44**	**1.35**
	(1.52; 1.57)	(1.30; 1.34)	(1.40; 1.49)	(1.30; 1.40)
Other	**1.67**	**1.68**	**1.49**	**1.51**
	(1.60; 1.74)	(1.62; 1.74)	(1.35; 1.64)	(1.37; 1.67)
Retirement age				
65+	1	1	1	1
60–64	**1.13**	**1.10**	0.99	0.99
	(1.12; 1.13)	(1.09; 1.10)	(0.98; 1.00)	(0.97; 1.00)
Before 60	**2.03**	**1.84**	**1.60**	**1.59**
	(2.01; 2.04)	(1.82; 1.85)	(1.57; 1.63)	(1.56; 1.62)
Missing	**0.20**	**0.21**	**0.08**	**0.08**
	(0.19; 0.21)	(0.21; 0.22)	(0.06; 0.09)	(0.06; 0.10)
Earning points				
30–44	1	1	1	1
45–54	**0.85**	**0.89**	**0.89**	**0.96**
	(0.85; 0.86)	(0.88; 0.89)	(0.88; 0.91)	(0.94; 0.97)
55+	**0.67**	**0.78**	**0.83**	**0.92**
	(0.67; 0.68)	(0.77; 0.78)	(0.81; 0.85)	(0.90; 0.94)

Data source: FDZ-RV SUFRTBNRTWF94-04TDemoKibele
Model 1: controlled for age
Model 2: controlled for age and all other individual-level variables
Bold figures indicate values significant at 5% level

and when all covariates are controlled for (Model 2). As expected, the mortality effects of the explanatory variables are lower in Model 2 than in Model 1.[5]

Mortality risks differ by the type of former occupation. Former white-collar employees experience the lowest mortality among all pensioners, while blue-collar workers have the highest mortality level. The mortality level of former miners lies in between the two.

[5] An East-West dummy variable is not introduced here as its effect is small once explanatory variables and random intercepts for the districts are introduced (results not shown).

Table 5.5 Multilevel models: log likelihood (LL), constant (β_0), and random part (u_{0j}) in the models including age and further inclusion of another individual-level covariate; 1998, 2001, 2004 (pooled)

	Males				Females			
	LL	β_0	u_{0j}	%	LL	β_0	u_{0j}	%
Age	−185,491	−3.381	0.071	1.85	−64,945	−4.683	0.087	1.86
+ Occupation	−181,222	−4.026	0.063	1.55	−64,274	−4.767	0.079	1.66
+ Health insurance	−183,894	−4.224	0.065	1.53	−64,686	−5.031	0.083	1.66
+ Retirement age	−172,505	−4.053	0.084	2.08	−62,175	−4.747	0.091	1.92
+ Earning points	−180,196	−3.676	0.081	2.20	−64,695	−4.659	0.083	1.78
+ All indiv.-level cov.	−166,455	−4.269	0.089	2.10	−61,295	−5.097	0.084	1.65

Data source: FDZ-RV SUFRTBNRTWF94-04TDemoKibele

With regard to the type of health insurance, people with private medical insurance or voluntary compulsory health insurance have a clear mortality advantage. Their mortality risk is one-quarter lower than the mortality risk of pensioners who have compulsory health insurance (Model 2). Out of the three health insurance groups, those pensioners with foreign or unknown health insurance have the highest MRRs.

Mortality also varies by retirement age. The later people retire, the lower their mortality risk. Therefore, pensioners who retired at age 65 or later have the lowest MRR, followed by those who retired between ages 60 and 64. The distinction between these two groups is not significant among women. This may be related to the formerly legal retirement age of 63 years for women, as female pensioners who worked beyond this age may have been financially dependent on further income. As mentioned before, retirement before the age of 60 is related to the receipt of a disability pension. Hence, the high mortality risk of pensioners with low retirement ages mainly reflects a worse initial health status, which is obviously a good mortality predictor (cf. Wolfson et al. 1993).

The pension income, expressed in lifetime-cumulated earning points, reveals a mortality gradient: mortality risks gradually decrease with increasing pension income. This gradient is steeper among male pensioners.

The different models yield different model fits. Starting with the model that only includes age, the further inclusion of any other individual-level covariate improves the model fit significantly (log likelihood in Table 5.5). Among the models with age and one other covariate, the inclusion of the variable "retirement age" (which is a proxy for disability) yields the greatest improvement of the model fit. For men, the earning points are the second-strongest mortality predictor, but they are the least important predictor for women. The model fit is the best when all individual-level covariates are included (Table 5.5; Table C.3 for single-level models).

So far, the individual-level fixed effects of the multilevel models have been described. A comparison of the fixed mortality effects in the multilevel models (Tables 5.4 and C.6) and in the single-level models (Tables C.4 and C.5) does not reveal major differences in the mortality effects of the explanatory variables.

The model fits are significantly better in the multilevel than in the single-level models (Tables 5.5 and C.3).

5.4.3 Multilevel Models: District-Level Random Effects

It has become clear that considerable mortality differences exist between population groups. Thus, the issue of to what extent differential population composition contributes to the explanation of the variation in regional old-age mortality across districts will be addressed. To answer this question, the random part u_{0j} from Eq. 5.2 is examined, that is, the mortality variation across districts (Table 5.5). The random part u_{0j} is the standard deviation of the intercept β_0 across districts j. As the intercept β_0 varies between the models, u_{0j} is also given as the percentage of the constant (last column). This relative district mortality variation constitutes 1.85% for men and 1.86% when the model controls only for age. If this were translated to remaining life expectancy at age 65, the observed variation would correspond to a 95% confidence interval of about 2 years.

In the models that also control for occupational branch, health insurance, and, among women, also for earning points, the relative mortality variation across districts decreases. It increases when the model controls for the retirement age and, among men, also when the model controls for earning points in addition to age. When all of the individual-level covariates are controlled for, there is a relative regional mortality variation of 2.10% among men and of 1.65% among women.

Compared to the basic model, which controls only for the age structure in the pensioners' population, the regional mortality variation among men increases when all individual-level explanatory variables are included, despite the increasing model fit. For women, the variation decreases as expected from the age-standardized model to the model controlling for all covariates. Increasing regional mortality variation when explanatory variables are added suggests that regional mortality variation would be even higher if the respective population had had a less favorable population composition with regard to mortality (cf. Blomgren and Valkonen 2007, p. 121). It may mirror an unequal distribution of individual characteristics, such as income by districts. It may also reflect the possibility that individual characteristics, such as income, could have different effects on mortality in different districts.

5.4.4 Multilevel Models: Context Effects

Context factors are now introduced to the full model, including age and all other individual-level covariates. This makes it possible to check whether regional factors explain some of the district-level mortality variation beyond the individual-level factors.

The full model with all individual-level factors was first enhanced by single contextual factors. Table 5.6 gives the results for the models with the mortality

Table 5.6 Multilevel models with context factors: MRRs, log likelihood (LL), and percentage of random part u_{0j} in constant β_0(%), controlled for all individual-level variables; 1998, 2001, 2004 (pooled)

	Males			Females		
	MRR	LL	%	MRR	LL	%
All ind. variables	na	−166,455	2.10	na	−61,295	1.65
All ind. variables +						
Economy						
Unemployment rate	1.08***	−166,265	1.32	1.05**	−61,241	1.29
Household income	0.96[a]	−166,385	1.83	0.96**	−61,257	1.39
GDP	0.98**	−166,442	2.03	0.97**	−61,275	1.50
% employed	1.02**	−166,446	2.17	1.01	−61,292	1.61
% employed sec. sector	0.99*	−166,445	2.13	1.00	−61,294	1.64
% employed tert. sector	1.01*	−166,444	2.11	1.00	−61,295	1.65
Net business registrations	0.96***	−166,412	1.97	0.99	−61,289	1.63
Social conditions						
Voter turnout	0.95***	−166,370	1.81	0.96**	−61,265	1.41
Living space	0.93***	−166,322	1.56	0.96**	−61,262	1.39
Detached housing	0.97***	−166,424	2.04	1.00	−61,295	1.64
Divorce rate	1.01	−166,455	2.08	1.00	−61,294	1.65
Welfare recipients	1.02**	−166,437	2.11	1.00	−61,295	1.65
Education						
% empl. w university degree	1.02*	−166,443	2.07	1.00	−61,294	1.64
% empl. w/o degree	0.94***	−166,358	1.77	0.95***	−61,244	1.29
% school graduates. w *Abitur*	1.03**	−166,433	1.99	1.00	−61,295	1.65
% school grad. w/o degree	1.04***	−166,426	2.04	1.03*	−61,280	1.50
Population						
% annual population change	0.95***	−166,396	1.87	0.98*	−61,284	1.56
Net migration	0.96***	−166,420	2.01	0.99	−61,292	1.60
Population density	1.01*	−166,447	2.15	1.00	−61,294	1.64
Urban-rural	0.97*	−166,445	2.18	1.02	−61,293	1.65
Population forecast	0.95***	−166,372	1.78	0.97*	−61,278	1.52
Health care and traffic accidents						
Hospital beds	1.01	−166,453	2.15	0.99	−61,293	1.63
Physicians	1.00	−166,455	2.07	0.98*	−61,285	1.58
Traffic accidents	1.01*	−166,447	2.15	1.02	−61,290	1.60
Fatal traffic accidents	1.00	−166,454	2.10	1.01	−61,291	1.62
Mortality context score[b]	1.08***	−166,239	1.22	1.05***	−61,226	1.22

Data sources: FDZ-RV SUFRTBNRTWF94-04TDemoKibele; see Table 4.3 for information and data sources of contextual variables

Significance levels: *5%; **1%; ***0.1% level

[a] Convergence not achieved, no significance level derived

[b] Based on: unemployment rate, income, GDP, voter turnout, living space, employees without degree, population forecast, population change

effect MRR, the log likelihood, and the district-level mortality variation. As the contextual variables were standardized with a zero mean and a standard deviation of one, the mortality effects are one when a district takes on the average of the respective context factor.

For many contextual factors, there is a mortality effect; that is, the MRR is above or below one. In general, the mortality effects of contextual factors are small compared to mortality differences produced by individual characteristics. The context effects are more significant among men. Of the economic indicators, the average disposable income per capita, GDP per capita, and unemployment produce the greatest mortality effects. Unemployment has the strongest effect, and men in a district where the unemployment rate is one standard deviation above the mean have a mortality risk that is 8% higher than among men in a district with average unemployment. For women, the respective figure is 5%.

Of the social conditions, living space and voter turnout have the greatest mortality effects. Some of the education indicators yield a significant mortality effect, but not always in the expected direction. For example, pensioners living in districts with a higher share of employees without any degree have a lower mortality risk. This suggests that the contextual educational variables capture not only the educational level but also other unobserved factors. Indicators on the degree of population change have the greatest mortality impact of the population indicators. Male pensioners in rural districts have a mortality risk that is 3% lower than among pensioners in urban districts, whereas female pensioners have an elevated, but statistically insignificant, mortality risk in rural districts. Health-care factors are of little importance.

As was mentioned previously, several of the contextual factors measure performance in similar spheres in order to avoid multicollinearity, and a mortality context score is derived (Eq. 5.5) by combining the most important contextual factors (see, e.g., Riva et al. 2007). From the results that include all individual-level variables plus one context factor, the seven best contextual indicators for males and females are chosen. Because one of the seven best factors is not the same for men and women, eight factors in total are included. This ensures that a variety of factors are included. For both sexes, the factors are income, unemployment, the share of employees without any degree, the future population expected, living space, and voter turnout. The inclusion of population change yields a considerable improvement of the model among men, while among women, an improvement is seen with the inclusion of GDP.

In a second step, these best contextual factors are brought together in a model from which the mortality context score is derived. Controlling for all of the eight selected contextual factors individually decreases the regional mortality variation. The mortality context score improves significantly when the model includes all of the individual variables and more than when any of the single context factors is included. In terms of explanatory power, the score is equivalent to all factors included in the score. A low mortality context score—a favorable position—yields a low mortality risk. In addition to overcoming multicollinearity between several contextual factors, the combined score offers the advantage of being able to represent the general districts' well-being or deprivation in a single indicator.

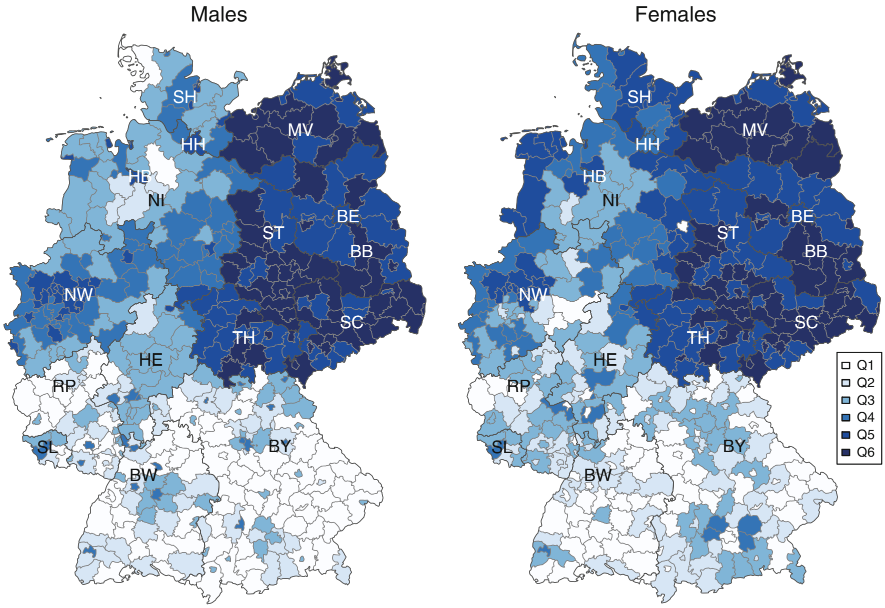

Fig. 5.2 Sex-specific mortality context scores by district (sextiles). *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western Pomerania, *SN* Saxony, *ST* Saxony-Anhalt, *TH* Thuringia (Data source: FDZ-RV SUFRTBNRTWF94-04TDemoKibele; see Table 4.3 for information and data sources of contextual variables. Base map: German Federal Agency for Cartography and Geodesy 2007)

Figure 5.2 shows the spatial distribution of the mortality context scores for men and women. With a few exceptions, southern Germany has the lowest mortality context scores. Meanwhile, the districts with the highest mortality context scores are found in the East, but also in the Ruhr area.

Because the effect of contextual factors on mortality is significant, this effect also has an impact on regional mortality variation. The last column in Table 5.6 shows the mortality variation across districts after the inclusion of different contextual factors into the model with all individual-level variables. The mortality effects of contextual variables are small when compared to individual-level risk factors, but they contribute significantly to the explanation of regional mortality variation. Including unemployment in the model, along with all individual covariates, decreases regional mortality variation by 37% among men and by 22% among women.

When the respective sex-specific mortality context scores are added, regional mortality variation decreases from 2.10% to 1.22% among men and from 1.65% to 1.22% among women, when the model also includes all individual-level covariates. District-level factors hence explain 42% (men) and 26% (women) of the remaining regional mortality variation that exists after all individual-level covariates are controlled for.

5.4.5 Multilevel Models: Cross-Level Interactions

Having confirmed that context matters, the question of whether context matters differently based on socioeconomic status will now be addressed. To this end, cross-level interactions between the mortality context scores and individual-level variables are introduced. Of the individual-level variables, former occupation and earning points are used, as they best represent an individual's SES. These variables are interacted with the regional mortality context score. Figure 5.3 shows the mortality effect of the mortality context score in sextiles[6] by individual SES in models controlling for all of the other individual-level covariates, with 95% confidence intervals. Table 5.7 gives further information on the log likelihood, the constant, and the random part that can be used to compare the models. Including the cross-level interactions yields a small but significant improvement of the model fit in all cases for men.

Increases in MRR depending on the sextile of districts, which is based on the mortality context scores, visually demonstrate the importance of the context. It is immediately apparent that, among men, socioeconomic mortality differences tend to be greater in the more deprived sextiles of districts. Indeed, in each occupational or income group, there is a certain mortality disadvantage associated with a higher district score.

As was seen previously, among the occupation types, former white-collar workers have the lowest mortality risk, and blue-collar workers the highest (upper left panel in Fig. 5.3). The regional mortality gradient is smallest among the white-collar employees, while, at the other end of the spectrum, the regional effect is strongest among blue-collar workers. Compared to the former white-collar employees in the most favorable sextile of districts, those in the least favorable sextile of districts have a moderately increased mortality risk of 16% (MRR Q1 1 vs. MRR Q6 1.16). Among blue-collar workers, the respective difference constitutes 28% (MRR Q1 1.13 vs. MRR Q6 1.45). Whereas in Q1, the mortality of former blue-collar workers relative to white-collar workers is elevated by 13% (MRR blue-collar workers 1.13 vs. MRR white-collar workers 1), in Q6, the mortality of blue-collar workers is elevated by 25% (MRR blue-collar workers 1.45 vs. MRR white-collar workers 1.16; Table 5.8). The mortality risk of former miners decreases from the first to the second quartiles, but then increases. The mortality difference between Q1 and Q6—the least and the most deprived districts—constitutes 35% (MRR Q1 1.04 vs. MRR Q6 1.41).

Like the mortality gradients by occupation, men with the highest pension income (based on 55 and more earning points) are least affected by regional effects. Those living in the most disadvantaged sextile (mainly East German districts) have mortality that is 15% (MRR Q1 0.83 vs. MRR Q6 0.96) higher than the mortality of high-income pensioners in the most favorable sextile (mainly districts in the southern part

[6] Sextiles were chosen as the division of districts into quartiles or quintiles would mainly leave eastern Germany in one quantile; such an artifact should be avoided.

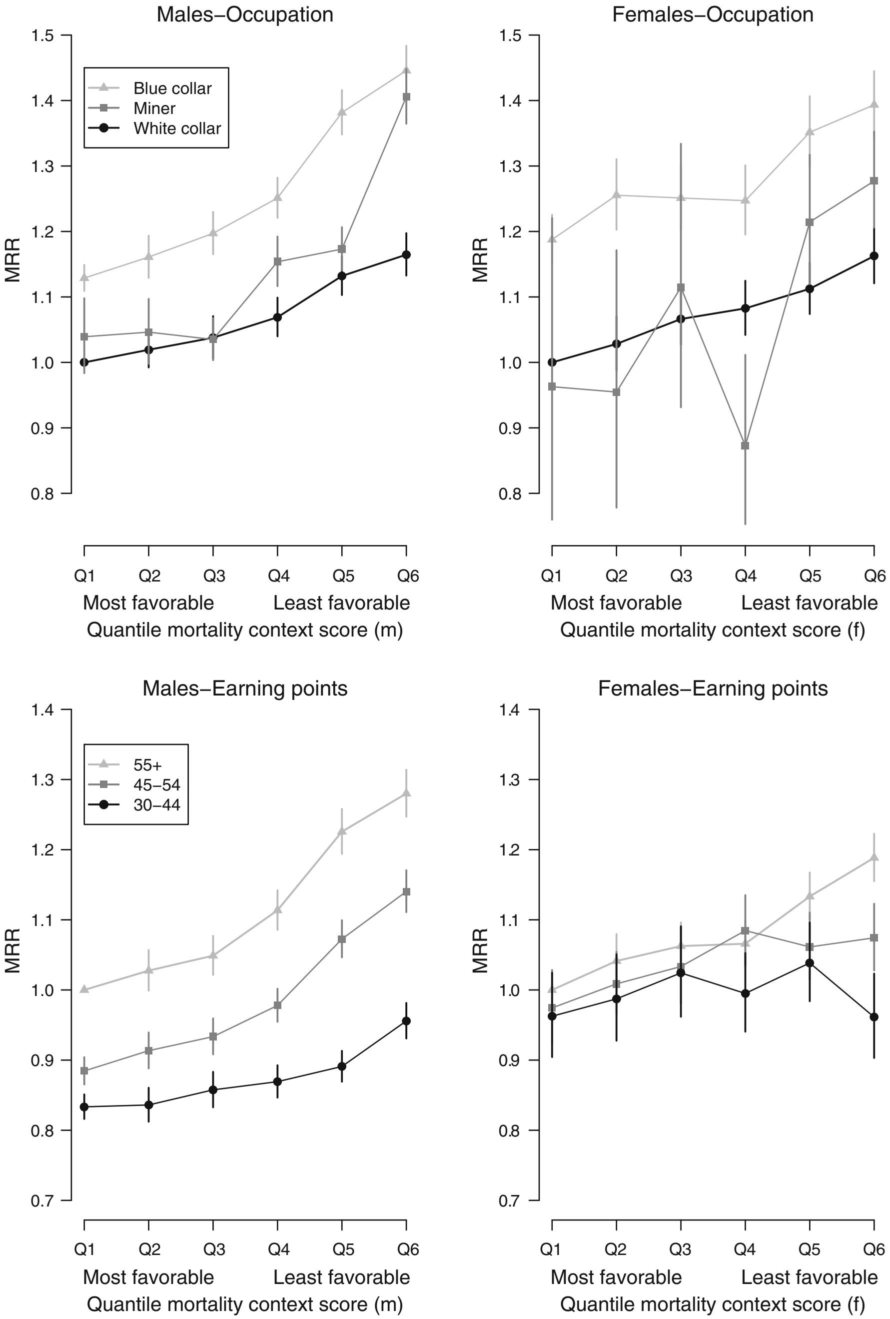

Fig. 5.3 Multilevel models: MRRs with 95% confidence intervals of cross-level interactions between the sextiles of sex-specific mortality context score and occupation and between the sextiles of sex-specific mortality context score and earning points; models controlled for all individual-level variables; 1998, 2001, 2004 (pooled) (Data source: FDZ-RV SUFRTBNRTWF94-04TDemoKibele; see Table 4.3 for information and data sources of contextual variables)

Table 5.7 Multilevel models with cross-level interactions between the sextiles of sex-specific mortality context score and occupation and between the sextiles of sex-specific mortality context score and earning points; models controlled for all individual-level variables: log likelihood (LL), constant (β_0), random part (u_{0j}), and percentage of random part in constant (%); 1998, 2001, 2004 (pooled)

	LL	β_0	u_{0j}	%
Males				
Age	−185,491	−3.381	0.071	1.85
Age + ind. var.	−166,455	−4.269	0.089	2.10
Age + ind. var. + Mortality context score (m)	−166,239	−4.275	0.052	1.22
Age + ind. var. + Mort. cont. score (m)*occupation	−166,126	−4.340	0.051	1.17
Age + ind. var. + Mort. cont. score (m)*earning points	−166,120	−4.382	0.051	1.17
Females				
Age	−64,945	−4.683	0.087	1.86
Age + ind. var.	−61,295	−5.097	0.084	1.65
Age + ind. var. + Mortality context score (f)	−61,229	−5.092	0.062	1.22
Age + ind. var. + Mort. cont. score (f)*occupation	−61,210	−5.165	0.062	1.20
Age + ind. var. + Mort. cont. score (f)*earning points	−61,202	−5.174	0.062	1.20

Data source: FDZ-RV SUFRTBNRTWF94-04TDemoKibele; see Table 4.3 for information and data sources of contextual variables

of Germany). For the two other pension income groups, individual mortality effects are different, but the regional effects are the same. Pensioners with 45–54 earning points have 11% lower mortality than pensioners with 30–44 earning points (Table 5.4). Between the sextiles Q1 and Q6, the difference amounts to about 30% in both pension income groups.

The regional mortality impact on the different SES groups is less regular for women than for men. The mortality risk of former blue-collar workers is about 20% higher than for former white-collar workers over all regional quintiles (upper right panel in Fig. 5.3; Table 5.8). For both groups, mortality is higher in the more deprived district quartiles than in the most advantaged sextile. However, the mortality difference between Q6 and Q1 constitutes 16% for white-collar workers (MRR Q1 1 vs. MRR Q6 1.16) and 17% for blue-collar workers (MRR Q1 1.19 vs. MRR Q6 1.39). This means that the regional contrast does not differ between the two occupational groups. The few female pensioners formerly working in the mining industry show no significant mortality difference between Q1 and Q6.

While the regional patterns among men are similar in both SES variables, they differ among women. All women in the first sextile have the same mortality risk, independent

Table 5.8 Multilevel models: MRRs with 95% confidence intervals (in parentheses) of cross-level interactions between the sextiles of sex-specific mortality context score and occupation, and between the sextiles of sex-specific mortality context score and earning points; models controlled for all individual-level variables; 1998, 2001, 2004 (pooled)

	Mortality context score						
	*Q*1	*Q*2	*Q*3	*Q*4	*Q*5	*Q*6	*Q*6/*Q*1
Occupation-males							
White-collar	1	1.02 (0.99–1.05)	1.04 (1.01–1.07)	1.07 (1.04–1.10)	1.13 (1.10–1.16)	1.16 (1.13–1.20)	1.16
Blue-collar	1.13 (1.11–1.15)	1.16 (1.13–1.19)	1.20 (1.17–1.23)	1.25 (1.22–1.28)	1.38 (1.35–1.42)	1.45 (1.41–1.48)	1.28
Miner	1.04 (0.98–1.10)	1.05 (1.00–1.10)	1.04 (1.00–1.07)	1.15 (1.12–1.19)	1.17 (1.14–1.21)	1.41 (1.36–1.45)	1.35
Occupation-females							
White-collar	1	1.03 (0.99–1.07)	1.07 (1.03–1.11)	1.08 (1.04–1.12)	1.11 (1.07–1.15)	1.16 (1.12–1.21)	1.16
Blue-collar	1.19 (1.15–1.23)	1.26 (1.20–1.31)	1.25 (1.20–1.30)	1.25 (1.20–130)	1.35 (1.30–1.41)	1.39 (1.34–1.44)	1.17
Miner	0.96 (0.76–1.22)	0.95 (0.78–1.17)	1.11 (0.93–1.33)	0.87 (0.75–1.01)	1.21 (1.12–1.32)	1.28 (1.21–1.35)	1.33
Earning points-males							
30–44	1	1.03 (1.00–1.06)	1.05 (1.02–1.08)	1.11 (1.09–1.14)	1.23 (1.19–1.26)	1.28 (1.25–1.31)	1.28
45–54	0.88 (0.87–0.90)	0.91 (0.89–0.94)	0.93 (0.91–0.96)	0.98 (0.95–1.00)	1.07 (1.05–1.10)	1.14 (1.11–1.17)	1.29
55+	0.83 (0.82–0.85)	0.84 (0.81–0.86)	0.86 (0.83–0.88)	0.87 (0.85–0.89)	0.89 (0.87–0.91)	0.96 (0.93–0.98)	1.15

(continued)

Table 5.8 (continued)

	Mortality context score						
	*Q*1	*Q*2	*Q*3	*Q*4	*Q*5	*Q*6	*Q*6/*Q*1
Earning points-females							
30–44	1	1.04	1.06	1.07	1.13	1.19	1.19
		(1.00–1.08)	(1.03–1.10)	(1.03–1.10)	(1.10–1.17)	(1.16–1.22)	
45–54	0.97	1.01	1.03	1.08	1.06	1.07	1.10
	(0.92–1.03)	(0.97–1.05)	(0.98–1.09)	(1.04–1.14)	(1.01–1.11)	(1.03–1.12)	
55+	0.96	0.99	1.02	1.00	1.04	0.96	1.00
	(0.90–1.02)	(0.93–1.05)	(0.96–1.09)	(0.94–1.05)	(0.98–1.10)	(0.90–1.02)	

Data source: FDZ-RV SUFRTBNRTWF94-04TDemoKibele; see Table 4.3 for information and data sources of contextual variables of their pension income. Socioeconomic mortality differentials as expressed by earning points increase over the sextiles of the mortality context score. Mortality differences between women with 30–44 and those with 55+ earning points are only significant in the two most deprived sextiles. In the upper two pension income groups (45–54 and 55+ earning points), the regional mortality differences across the sextiles are negligible (and also shaky). In the lowest pension income group, the mortality risk in Q6 is 19% higher than in Q1 (MRR Q1 1 vs. MRR Q6 1.19; 1.16–1.22).

5.5 Summary

The aim of this analysis was to investigate whether regional mortality differentials among the elderly can be explained by differing population compositions, whether regional context has an impact on mortality independent of individual characteristics, and whether individual mortality risks have different mortality effects depending on the context. This analysis is the first multilevel study on the determinants of regional mortality variation in Germany. The multilevel model is based on individual-level data from the German Federal Pension Fund and context data from official statistics on the 438 German districts.

As life expectancy at birth is largely driven by old-age mortality, the spatial pattern of mortality of German pensioners aged 65 years and older resembles the spatial pattern of life expectancy at birth described in the previous chapter (see Sect. 4.4). Southern German districts exhibited the lowest mortality levels. In eastern Germany, the region of Potsdam and the federal state of Saxony exhibited the lowest mortality levels. High-mortality areas in western Germany can be found in the Ruhr area in North Rhine-Westphalia, Saarland, and northeastern Bavaria. Apart from these areas, several districts in Lower Saxony, Schleswig-Holstein, and Rhineland-Palatinate showed high mortality, while other districts in these federal states exhibited favorable mortality patterns.

In the first step of the analysis, individual-level mortality determinants were examined. Mortality differentials according to all of the individual-level mortality risk factors were found to exist; these factors were—apart from age—type of former occupation, type of health insurance, retirement age, and lifetime earnings. Pensioners who worked as white-collar employees had the lowest mortality risk, while the mortality risk of former blue-collar workers was approximately 20% higher. The mortality risk of former miners lay in between the risks of white- and blue-collar workers. Disregarding socioeconomic mortality differences, the results indicated that pensioners who had compulsory health insurance had a mortality risk that was about one-third higher than people with private medical insurance. As this finding is independent of the pensioner's income, it implies that privately insured pensioners have better access to high-quality health care. Pensioners who drew a pension before the age of 60 had a greatly elevated mortality risk compared to those pensioners who retired around the legal retirement age (84% elevated for men, 59% for women). This is because early retirement is related to severe disability. Lifetime earnings, as measured by earning points, revealed an expected mortality gradient: pensioners with higher incomes exhibited a lower mortality risk. While among men, mortality was 22% lower in the highest income group than in the lowest income group, the female difference amounted to 18%.

Regional mortality variation—expressed as the standard deviation of the districts' random intercepts—was found to exist. It had been expected that the inclusion of individual-level mortality determinants would lead to a decrease in regional mortality variation. This was shown to be true for women, among whom 11% of the regional variation could be explained by individual-level characteristics. After controlling for all characteristics, men had 14% higher regional variation than before. This was unexpected, but it is not implausible. It implies that regional mortality variation was hidden at the aggregate level (cf. Blomgren and Valkonen 2007, p. 121).

In the next step, the questions of whether regional context influences mortality, and of whether the control for regional context factors would lead to decreased regional mortality variation across the districts, were addressed. Many district-level context factors were shown to have significant mortality effects, but unemployment was found to have the strongest effect. Other district-level economic factors were also shown to be important, as were indicators of population change, an education indicator, and two social indicators (living space and voter turnout). Indicators of health care, population density, and traffic accidents had little or no impact on mortality. As contextual factors were correlated, those factors with the strongest mortality effect were summarized into a mortality context score which indicates the level of deprivation of a district.

Inclusion of the mortality context score decreased the regional mortality variation by a further 42% among men and 26% among women. Regional characteristics therefore play an important role in explaining regional mortality variation.

The impact of individual mortality risk factors was found to vary, however, according to the regional context, as was shown by cross-level interactions between the mortality context score and individual socioeconomic status (occupation and lifetime earnings). The results were very distinct for men. The socioeconomic mortality gradient was greater in the more deprived areas; conversely, the regional mortality gradient was smaller among the better-off, that is, among former white-collar workers and those with higher lifetime earnings. This means that more deprived older men suffer disproportionately from adverse contextual conditions, while a favorable individual socioeconomic background has a protective effect. Among women, the results are less indicative. It appears that the regional gradient is independent of individual characteristics.

5.6 Discussion

The analysis of regional variation in old-age mortality was based on process-produced data from the German Federal Pension Fund. This is the first data source that allows for individual-level mortality analysis of the virtually entire population aged

65+ years in Germany. The reliability of the information in the dataset, such as on lifetime earnings, is high (Himmelreicher et al. 2008).

Previous studies of the same data source on socioeconomic differences in old-age mortality in Germany were extended (Scholz 2006; Shkolnikov et al. 2008; von Gaudecker and Scholz 2007) by including more variables and data for several years and by excluding the problematic group of pensioners with low numbers of points. As the dataset is a full sample of the elderly population, it also allows for a regional breakdown into small areas that is not possible when using survey data (Luy 2006; Reil-Held 2000; Unger 2003).

The data has some drawbacks. Only a limited number of variables were available. Due to a reform of the organizational structure of the German Federal Pension Fund, the distinction between occupational branches is no longer available after 2004. As this appears to be a crucial variable in the study of old-age mortality, having a greater selection of mortality determinants was prioritized over having slightly more recent data.

All of the variables are time constant, and only the last place of residence is recorded. This means that a life course perspective cannot be considered. Furthermore, because of these limitations, possible migratory movements, which would expose people to differential regional contexts, have to be disregarded.

Some variables must be interpreted with caution. Early retirement, for example, is tied to severe disability (Brockmann et al. 2009; Wolfson et al. 1993, for male Canadian pensioners). Earning points reflect the lifetime earnings, but there is no further information on the presence of additional financial sources, such as property, wealth, or an occupational pension.

Socioeconomic mortality differences at old ages are likely to reflect differences in lifestyle and health behavior to some extent. These factors are more directly linked to mortality outcomes, but are not available from this administrative data source.

The German Federal Pension Fund cannot provide cause-specific data. Not including crucial individual-level variables in a multilevel study on regional mortality variation could yield an overestimation of the area-level effects on mortality (Blomgren et al. 2004; Sloggett and Joshi 1994).

Unfortunately, the selection procedure leaves us with a highly select group of women, which is only a quarter of the original sample size. Many women of the elderly population spent much of their lives as housewives and family caregivers. An adequate representation of women's SES is not possible using the pension data, as the records do not allow for a linkage to their husbands. The conclusions drawn from the analyses must therefore focus on men (cf. Himmelreicher et al. 2008; Shkolnikov et al. 2008). Excluding pensioners with foreign citizenship also leaves a more homogenous study population. This could have resulted in an underestimation of the existing social gradients. However, because the older foreign population is small, the exclusion of this population can, if at all, be seen as only a source of minor bias.

In order to capture the mortality effect of a broader context, several mortality-relevant indicators were included, and a mortality context score constructed.

The use of a score made it possible to overcome the collinearity of contextual characteristics, and this approach offers advantages over similar studies from other countries. Including only one contextual factor could have led to an insignificant mortality impact of the context (Pickett and Pearl 2001; Riva et al. 2007).

Studying regional mortality variation in an ecological setup, or using a single-level approach, is not satisfactory in terms of the content, and it can also cause problems of statistical inference. The present study demonstrates a methodological novelty for the German context, and, statistically, it offers the greatest level of accuracy of the studies that have so far been published.

The results of this study on regional mortality variation are in line with results from comparable studies in other countries. Modest context effects on mortality (stronger for men) were shown, and a greater social gradient for people living in more deprived areas was demonstrated. These were also among the general findings of other multilevel mortality studies (Pickett and Pearl 2001; Riva et al. 2007; Turrell et al. 2007).

What remains unclear is the causal link between area-level factors and individual mortality. Area-level deprivation, as expressed in the mortality context score, is mainly driven by unemployment. It could be argued that pensioners are unaffected by unemployment and therefore that no causal effect on mortality should be possible. However, unemployment is highly correlated with other factors of economic and social well-being and also with population patterns. The context score must be seen as a broad indicator of regional well-being.

The district level is the finest geographical resolution and reveals most of the regional mortality variation. Although this leads to a comparison of districts with different population sizes, any aggregation of districts would mask regional mortality variation. It would be interesting to find out whether relationships similar to those found between individual mortality determinants and the district-level context would be seen if even smaller regional divisions (e.g., neighborhoods) were considered. At such fine geographical levels, it would also be worthwhile to look at the mortality risk in relation to the existence of specific modifiable context conditions, like the availability of green space or sport facilities. If such factors were shown to have an effect on mortality, this would help in the formulation of appropriate policy interventions.

Thus, if the goal is to reduce mortality inequalities, men with low socioeconomic status in deprived areas should be addressed first. This is where mortality disadvantages have been shown to be the greatest. Attention should be devoted to health contexts in areas with poorer populations and worse economic performance. The vast majority of regions with the highest area-level deprivation are situated in eastern Germany and the Ruhr area, where unemployment tends to be high.

Chapter 6
Conclusion

6.1 Summary

The aim of this study was to investigate regional mortality patterns and trends at different spatial scales in Germany and to identify mortality determinants at the individual and contextual levels. The principal results of this study are briefly reviewed here. This section provides responses to each of the research questions based on the knowledge gained from the analyses in the previous chapters.

What mortality patterns can be observed at different levels of regional aggregation? With increasing life expectancy in Germany over time, how is the life expectancy increase distributed over the regions? Which regions modify the general regularities in regional patterns? Can meaningful aggregated regions with distinct mortality structures be identified?

For the most part, life expectancy in West Germany was higher than in East Germany after the 1950s. Since reunification, life expectancy has converged in East and West Germany among women, while male life expectancy in the East continues to be lower. Whereas earlier research dwelled upon the fact that East German life expectancy greatly improved, reaching the previously higher West German levels, this study looked at an extended time period and found that most of the convergence took place during the 1990s, while only a minor additional improvement in life expectancy occurred in eastern Germany in the 2000s (Chaps. 3 and 4).

Among the 16 federal states, Baden-Württemberg is clearly the state with the lowest mortality, followed by Hesse and Bavaria (life expectancy in 2004–2006 for males 78.3, 77.6, and 77.3 years, respectively; for women 83.2, 82.5, and 82.4 years, respectively). After a short period of life expectancy decline around the time of the fall of the Berlin Wall, the eastern German federal states experienced strong life expectancy increases. Of the eastern German federal states, Saxony has had the greatest success in reducing mortality. Indeed, the life expectancy among women in

E.U.B. Kibele, *Regional Mortality Differences in Germany*, Demographic Research Monographs, DOI 10.1007/978-94-007-4432-5_6,

Saxony is now higher than the nationwide average. The highest mortality is found in Mecklenburg-Western Pomerania and Saxony-Anhalt (life expectancy in 2004–2006 for males was 74.8 and 74.7 years, respectively; for women, it was 81.6 and 81.4 years, respectively).

With its high mortality profile, Saarland is an outlier in the German North-to-South gradient; while Saxony, with its low mortality in more recent years, especially among women, is an outlier in the East-to-West gradient. Saarland has significantly higher mortality than the surrounding southern German federal states. Saxony, on the other hand, has much lower mortality, especially among women, than the other eastern German federal states. While Saarland has experienced slow mortality decreases over time, mortality decreases have been strong in Saxony (Chap. 3).

The results of the mortality analysis at the small-area level (district level) show that the spatial life expectancy pattern is more diverse across the districts than across the federal states. The life expectancy increases also show greater levels of variation for the districts than for the federal states. In the mid-1990s, a large triangle of high life expectancy extended from the southwest of Bavaria over Baden-Württemberg to Hesse. Parts of northern Rhineland-Palatinate, the region of Cologne-Bonn and the northeast of North Rhine-Westphalia, and the southwest of Lower Saxony, also had high life expectancy. East German districts almost consistently exhibited low life expectancy.

The study found that spatially diverse life expectancy changes over time led to distortions in the original spatial pattern. The most prominent of these are the extraordinarily steep life expectancy increases that occurred in most East German districts. On the other hand, several districts in the most western parts of Germany experienced below-average life expectancy increases. In the 2000s, the initial life expectancy pattern partly persisted, but it was less consistent than before, especially for women. In eastern Germany, the regions of Berlin-Brandenburg, Saxony, and, to a lesser extent, southern Thuringia turned into well-performing regions. In western Germany, the Ruhr area and Saarland faced serious problems, and high mortality also persisted in northeastern Bavaria (Chap. 4).

Looking at the district level, the study clearly shows that mortality within federal states often deviates significantly from the state averages. Most strikingly, the northeastern Bavarian border area and the Ruhr area in North Rhine-Westphalia diverge from the patterns of their respective federal states. Without the northeastern Bavarian districts, the state would be the longevity forerunner in Germany, leaving even Baden-Württemberg behind. Similarly, North Rhine-Westphalia would rise considerably in the federal state ranking without the problematic Ruhr districts (cf. Klapper et al. 2007). Even in Baden-Württemberg, there are substantial mortality differences between the districts (von Gaudecker 2004). Berlin, with its special historical situation, stands out somewhat from the general eastern German pattern. The city's surrounding areas, especially Potsdam-Mittelmark, have exceptionally low mortality, which may be the result of selective migration patterns.

As a result of the trends in regional life expectancy, dispersion both across federal states, as well as across districts, increased during the process of reunification in the early 1990s and decreased over the rest of the 1990s. Subsequently, the regional dispersion of life expectancy leveled off. Some increase in the regional longevity dispersion can be observed in West Germany since the late 1990s (Chaps. 3 and 4).

Urban-rural differences in Germany are small, with rural areas of western Germany and urban areas of eastern Germany enjoying lower mortality. With time, however, the eastern German urban advantage has been decreasing, which suggests that the urban-rural mortality pattern in eastern Germany could eventually resemble that of western Germany.

The most salient features of regional longevity patterns can be expressed through a classification of the districts into four mortality clusters based on the life expectancy level and the life expectancy increase over time. A cluster analysis identified three different patterns of life expectancy increases for the four clusters. As the cluster with the lowest life expectancy experienced the greatest gains in life expectancy over time, it gradually came to resemble the other three clusters with higher life expectancies. Age- and cause-specific mortality differed considerably in the levels, though to a lesser extent in the structures between the clusters (Chap. 4).

How do age- and cause-specific mortality contribute to these regional patterns, and to changes in these patterns? Are there different underlying age- and cause-specific distributions that produce the same overall mortality outcome?

In relative terms, regional mortality variation tends to be greater at younger ages. Total and absolute life expectancy variation across regions is explained to a large extent by mortality variation in infant mortality, and in mortality at ages 50–85, that is, the ages at which the majority of deaths occur. The East German age pattern deviates somewhat from the West German pattern. In East Germany, mainly due to traffic accidents, the mortality of young adult men varies considerably. This contributes to dispersion of regional life expectancy, as well as of mortality at young and old ages. Between the 1990s and the 2000s, the age-specific contributions to regional dispersion shifted toward older ages in both East and West, and the importance of accident humps diminished (Chap. 3).

Compared to all-cause mortality, spatial patterns of cause-specific mortality are more diverse, and the respective regional differences tend to be greater.

The spatial pattern of cardiovascular mortality resembles and shapes the pattern of all-cause mortality. In contrast to the all-cause pattern, respiratory mortality is lowest in eastern Germany, but it is particularly high in many areas of North Rhine-Westphalia, Rhineland-Palatinate, and northern Bavaria. Large regional mortality differences are also found in external and alcohol-related causes. Excess external mortality prevails in the countryside, while alcohol-related mortality is higher in the cities. Notably, the causes that exhibit the strongest regional gradients usually also show strong mortality differences with respect to socioeconomic status (cf. Leon 2001).

Across the four clusters determined by life expectancy and its changes, age- and cause-specific mortality changed gradually. However, the cluster with the lowest life expectancy experienced unexpectedly high levels of external and alcohol-related mortality during the 1990s. Steep decreases in mortality from these causes contributed the most to the mortality convergence of the four clusters (Chap. 4).

The study showed that the regularities that are characteristic of life expectancy also dominated the age- and cause-specific mortality patterns; that is, generally high or low mortality was seen over all of the age groups and all causes of death. However, there are some exceptions in which different age- and cause-specific mortality trajectories produced the same overall mortality outcome (Chaps. 3 and 4).

Lifespan disparity, which measures the variation in the age-at-death distribution, indicates the average number of years lost due to death. While mortality reduction at any age leads to an increase in life expectancy, only the prevention of early deaths reduces lifespan disparity (Shkolnikov et al. 2011; Vaupel and Canudas Romo 2003). The measure is therefore an important complement to life expectancy when it comes to assessing age-specific mortality inequalities. It appears that regional patterns in lifespan disparity differ from regional patterns in life expectancy.

Before reunification, East Germans experienced lower lifespan disparity than West Germans at the same life expectancy levels. This can be explained by lower East German mortality at young and working ages, combined with excess mortality at older ages, a pattern that is characterized by lower variability in ages at death.

The comparison of lifespan disparity between federal states shows the importance of having a balance between mortality at younger ages and mortality at advanced ages. The same life expectancy can be produced by a combination of lower young-age and higher old-age mortality, or by higher young-age and lower old-age mortality. However, higher lifespan disparity corresponds to the latter combination, as was observed in the German city-states, such as Hamburg and Bremen. The city-states are among the federal states with the highest lifespan disparity and the highest life expectancy losses (Chap. 3).

What factors explain mortality variation between individuals and between regions? Are the determinants of mortality differences between regions different from the mortality determinants that drive the mortality change in the regions over time?

The variation in mortality risks is greater between population groups than between regions. This study provides evidence that the socioeconomic position of both individuals and regions predicts mortality in Germany (Chaps. 4 and 5).

Individual-level determinants of old-age mortality reveal strong social gradients. In addition to an obvious mortality effect of early retirement that reflects disability, all of the social status variables produce strong impacts on mortality. The lowest levels of mortality are found among high-income pensioners and among those who were active as white-collar employees. Mortality risk gradually increases with decreasing lifetime earnings. Pensioners with compulsory public health insurance have higher mortality risk than those with private or voluntary public health insurance. Independent mortality effects of single determinants remain even if all of the other individual-level determinants are controlled for, but this substantially decreases the strength of the effects of the single individual-level determinants (Chap. 5).

District-level analyses revealed an association between regional life expectancy and average per capita income, the educational level (of school graduates), and the effectiveness of health policy (high quality of health care and successful management of behavior-related diseases) implementation across districts. To a lesser extent, this association existed between regional life expectancy and GDP per capita. In western Germany, the regional pattern of life expectancy was also found to be associated with population change, while in eastern Germany, it was shown to be associated with average living space. Not all of these cross-district relationships hold true with respect to changes in district-specific life expectancy over time. Notably, per capita income, living space, and effective health policy changes were found to be related to life expectancy changes over time.

In general, the regional pattern of life expectancy is above all associated with regional differences in socioeconomic factors. From the perspectives of both space and time, per capita income and the level of efficiency of the implementation of health policies are the strongest predictors of mortality (Chap. 4).

What is the role of the East-West divide in the mortality variation across space and time?

East-West differentials are recurrent issues when mortality differentials within Germany are examined, and they are also pertinent in this study. In the early 1990s, almost all mortality patterns showed this divide, despite the considerable convergence that took place over the 1990s, especially among women. In the mid-2000s, life expectancy of East and West German districts widely overlapped among women, with the East German districts being only slightly below West German districts. Among men, the life expectancy of the lower half of West German districts overlaps with the life expectancy of the better-performing East German districts (Chap. 4).

Even though overall mortality in several federal states and in many districts does not differ between eastern and western Germany, the study found evidence that different cause-of-death structures (and/or coding practices) prevail in the East and in the West. These differences are exemplified by the remainder group of "other causes" (and, in particular, ill-defined causes), which is consistently smaller in the East German regions, and also by the respiratory mortality group, which is smaller in the East German districts (Chaps. 3 and 4).

Several explanations for the East-West mortality gap before reunification, and the converging mortality that followed, have been proposed (reviewed by Diehl 2008; Dinkel 2000; Luy 2004). They include positive and negative migration effects, the health care system, the economic situation, psychosocial conditions, and environmental pollution, as well as lifestyle factors, such as smoking, alcohol consumption, and nutrition. These factors are partly related to specific situations that differ in eastern and western Germany. Factors like socioeconomic conditions, occupational structures, or environmental problems differ greatly within Germany, and not only between East and West. In addition to what was already known, our analysis revealed that existing spatial differences in districts' life expectancy, and their changes in eastern and western Germany, can largely be explained by differing socioeconomic structures across the districts. If the respective differences were eliminated, similar life expectancy outcomes would be expected in the East and in the West (Chap. 4).

The East-West effect in regional mortality in Germany hence remains, though its importance appears to be decreasing with time.

Do differences in population composition across regions account for all small-area mortality variation in Germany? What regional-level context factors explain the remaining small-area mortality variation? Is there evidence that the regional context alters the mortality impact of individual-level mortality risk factors?

Differential regional population composition across districts does not explain the entire mortality variation. Variation of age-standardized mortality across districts becomes larger when additional individual-level variables are controlled for among men, though it becomes smaller for women. However, all individual-level mortality determinants are of great importance in explaining general mortality variation between population groups. The increase in the regional mortality variation, when individual-level factors are controlled for, suggests that the prevalence of individual risk factors differs across districts and/or that the mortality impacts of individual risk factors differ by region.

However, the regional context also contributes to the mortality variation across districts. District-level unemployment level explains a large part of the variation, which suggests that higher-unemployment regions experience higher mortality levels. After individual-level factors are controlled for, about 40% of the remaining male and about 25% of the remaining female regional variation can be attributed to multiple regional-level context factors. District-level unemployment is the strongest context factor and is a strong indicator of the social and economic district-level context.

The regional context matters. The study found evidence that the strength of the effect of an individual-level mortality determinant is modified by regional context conditions. Specifically, the social mortality gradient was shown to be greater in more deprived areas, as living in these areas appears to have particularly detrimental effects on old people with low socioeconomic status. Conversely, high socioeconomic status appears to protect the elderly from the adverse conditions associated with living in a deprived area (Chap. 5).

In sum, the regional mortality pattern in Germany is characterized by a gradually diminishing East-West and a persisting North-South gradient, though some areas, like Saarland and the Ruhr area, diverge from the general pattern. Old-age mortality levels are driving the regional mortality differences, though there are also significant differences in mortality levels among young and working-age adults. Regional mortality patterns are related to differences in population composition, as well as to different area-level socio(economic) characteristics.

6.2 Discussion

This concluding part briefly summarizes the context in which the study of regional mortality differences is embedded. It highlights some important scientific contributions of this study, reflects on its shortcomings, and offers suggestions for future research. In addition, some potential mortality scenarios are outlined.

Germany exhibits substantial regional mortality differences and has also experienced significant changes in its regional mortality pattern over the past two decades. From a broader European perspective, Germany appears to have a medium level of regional mortality inequality when heterogeneity in population and region sizes across the countries are taken into account (European Communities 2009; Valkonen 2001).

This study on the regional mortality differences in Germany has highlighted mortality disparities at different levels, although the question of how (regional) excess mortality can be reduced in order to minimize these inequalities has yet to be addressed. There is still a strong need to further reduce excess mortality at young ages, especially in behavior-related causes of death. This will require taking a regional perspective, as certain areas are more affected by excess mortality at these ages than others. The study furthermore showed how close the links are between regional mortality levels and socioeconomic inequalities. Policymakers should be aware of the interplay between individual- and regional-level mortality risk factors and pursue a multisectoral approach in reducing mortality inequalities.

Studying the regional forerunners of low mortality illustrates the potential for global pathways to increased longevity. The potential for mortality reductions is, in some respects, obvious. The study showed that the regions with the highest life expectancy are not necessarily the forerunners in the reduction of unnecessary deaths. This is, for example, the case in Baden-Württemberg and Bavaria, two regions with high life expectancies, but where external cause mortality is not consistently low in all of the high life expectancy districts. Reducing this excess mortality would therefore result in even greater life expectancies. This shows the potential of mortality reductions that have already been realized and that are possible pathways to greater longevity.

Regional mortality variation in Germany was investigated at the level of federal states and districts. This study is embedded in the processes of demographic change in Germany, as mortality contributes to population aging and decline, and the size of the elderly population is mainly determined by mortality, as migration levels become very low after retirement. Germany is an interesting case to examine when studying regional demographic change, as the country has both shrinking and growing regions, as well as one of the highest shares of the elderly in Europe. Gaining knowledge about trends in mortality, fertility, and migration rates is crucial because these demographic indicators form the basis of population forecasts, and even small differences in these indicators can have a significant impact on population size in the long run. Regional population forecasts are the basis for regional planning in such diverse fields as education, public transport, and health care. Understanding the (regional) mortality distribution and its changing inequalities is therefore important for future planning.

The principal focus of this study was on identifying regional mortality trends over time, as well as the reasons behind these differentials. This investigation benefited from important innovations that this study introduced in the research area of regional mortality differentials in Germany and hence contributes to a gain in scientific knowledge in multiple aspects.

Our database was comprised of large sample sizes for several years, mostly of full samples of the population residing in Germany. It included time series data, which made it possible to investigate changing small-area mortality differentials over time. A large number of variables were incorporated and enabled us to look at possible mortality determinants.

One of our innovative contributions to regional mortality studies is the analysis of how lifespan disparities reflect inequalities in age-at-death distributions, in addition to the average length of life. It showed that different age-specific mortality pathways lead to comparable life expectancies, but also to different lifespan disparity values, as is demonstrated by the East-West mortality gap in Germany. A one-dimensional look at only regional life expectancy would mask the fact that an East-West gap in the inequality in age at death was not observed. Insights into inequalities such as these should be taken into account when policy measures to reduce mortality are being formulated.

As the basis of small-area mortality differences, spatial statistics revealed hot spots of low and high life expectancy, and the dispersion measure of mortality provided an objective measurement of the time trends in overall spatial mortality inequalities.

Through the inclusion of individual-level data, advanced techniques of multi-level modeling allowed to perform complex analyses. This permitted to disentangle effects of population composition and regional (contextual) effects on mortality variation across districts. Such an approach had previously been identified as a pressing need in this research field (Mielck 2007; Razum et al. 2008). This study is the first that makes use of the data provided by the German Federal Pension Fund, with its virtually full sample of the German population aged 65 years and older, in the analysis of small-area mortality differentials.

The meaningful combination of various data sources at different geographical levels and state-of-the-art analytical methods made it possible to draw conclusions from different perspectives, such as the cause-of-death patterns or the socioeconomic contexts. This provides strong empirical evidence for explanations of regional mortality disparities and a solid basis for the formulation of effective policies to reduce these disparities.

The study has several limitations, which are mainly related to the restricted availability of mortality-relevant data at the small-area level. Despite the large sample sizes, some districts still have rather small population numbers, which can present problems when, for example, specific causes of death are considered. Several questions that could not be adequately addressed in this study remain open for future research.

Several variables were not available for these analyses. For the regional context variables, it would have been desirable to have had indicators of income inequality, the educational level of the entire population, or various health-related behaviors. These variables are not, however, available at the small-area level over time. In addition, the individual-level data have some limitations. These data only contain a limited number of variables, which are all time constant. Because of these limitations, it is not, for example, possible to follow people's life courses and to examine dynamic interactions between death hazards and changing explanatory variables.

Alcohol, tobacco, high blood pressure, and high cholesterol have shown to contribute the most to the disease burden in the developed regions of the world, causing a multitude of diseases (Ezzati et al. 2002). However, there are a few mortality predictors from health care and lifestyle research that are suitable for inclusion in a study of regional mortality differences. The regional distribution of alcohol-related mortality and its impact on life expectancy differences between different types of regions in Germany have been shown in this study. In addition, lung cancer mortality as a proxy for smoking-related mortality has been included here.

Smoking has frequently been described as the single most important factor producing premature mortality (Ezzati et al. 2002) and as the factor that underlies many mortality inequalities between population groups (Pampel and Rogers 2004; Rogers et al. 2005). It appears that lung cancer enforces the predominant regional mortality pattern among men in Germany. Among women, the predominant regional mortality pattern is somewhat counteracted by lung cancer mortality, which is especially low in the East.

In the field of health-care provision, the type of health insurance was included as an individual-level variable. This showed that people in private health insurance plans had a greatly lowered mortality risk. Although it is often assumed that health care in Germany is universal, the results suggested that adequate treatment is not universally distributed across all population groups and that it is probably not equally distributed across regions (Lampert and Kroll 2006; Mielck 2005; Rosenbrock and Gerlinger 2004). At the contextual level, classical health-care indicators did not help to explain regional mortality differences.

Future studies should attempt to make the effects of lifestyle and health-care factors on regional mortality differences more explicit, as they are more proximate determinants than socioeconomic factors. From a theoretical point of view, more meaningful indicators reflecting the quality and accessibility of health care at the contextual levels should be developed in order to identify deficiencies in the health care system. At the individual level, the fact that the privately insured live longer than those in compulsory health insurance, independent of their socioeconomic status, is striking. This raises the question of whether prevention and medical care are better for those who are privately insured or whether there are distinct selection effects into private health insurance. From the lifestyle factors determining regional mortality differences, the role of smoking could, for example, be assessed by indirect methods of smoking-attributable mortality (Peto et al. 1992; Preston et al. 2010). It is important to note that both lifestyle and health-care factors appear to be sensitive to socioeconomic deprivation, which has been shown to be associated with regional mortality differences in Germany.

In this study, federal states and especially districts were chosen as territorial units. However, it would have been desirable to have examined the relationship between the socioeconomic characteristics of the individuals and the socioeconomic spatial context in which they are embedded at different geographic scales. This might have shown whether the chosen district level is the most indicative. If data availability had allowed for a more detailed analysis at the neighborhood level of bigger cities such as Berlin and Hamburg, the results might have been more informative (cf. Meinlschmidt 2008).

The consequences of the possible influences of a healthy migrant effect on regional mortality cannot be satisfactorily addressed by the currently available data. It is likely that low mortality in certain regions is the result of favorable general conditions and that it is further strengthened by healthy in-migration. At the regional level, the presence of a healthy migrant effect cannot be disentangled from the general effects of favorable socioeconomic environments, which attract migrants. In order to control for this effect, a life course perspective would be necessary, and longitudinal data including migration histories would be required.

A life course approach would allow researchers to follow people over time, along with the different contexts they are exposed to. This approach would make it possible to assess in which age groups contextual conditions influence health the most. While it has been previously shown that early life conditions can have an impact on mortality later in life (Doblhammer 2004; Elo and Preston 1992), by applying a life course perspective, the changing impact of contextual conditions at different ages over time and the cumulative impact of context could be derived. Furthermore, a longitudinal approach would allow for a comparison of the mortality situation in the region of origin and the destination of the movers. At different regional levels, researchers could assess to what extent selective migration distorts observed regional mortality differences. The results of such research would contribute to a refinement of policy interventions that could then be implemented at different levels.

At the small-area level, the pattern of mortality laggards and leaders was found to be very similar between males and females in the mid-1990s (though at different mortality levels). Within the relatively short period of just over a decade, the picture became spatially diverse between the sexes. Future research should investigate why the mortality impact of the regional context differs by sex. It is, for example, obvious that different sex-specific and regional (time-lagged) smoking patterns lead to different lung cancer patterns by sex and region. This may be the case with other risk factors and related cause-of-death patterns as well, but it is more difficult to disentangle them from other risk factors and subsequent diseases. However, the spatial mortality pattern has changed quickly, and the latency periods between adverse exposure, diseases, and deaths are typically longer.

In the German context, the question of why mortality fell so sharply among eastern German women after reunification is of special interest. Several factors could have had an impact, including medical care, psychosocial stress, material factors, and selection effects. In the long run, it will be interesting to observe whether today's smoking patterns—with higher smoking prevalence among young East German women (Luy 2005; Mensink and Beitz 2004; Müller-Nordhorn et al. 2004)—will have a countervailing effect. In order to learn more about the effects of crisis events on mortality, a comparison between the mortality effects of the "mortality crisis" after German reunification, and the effects of the 2007–2010 financial crisis on mortality, might be worthwhile.

New problem areas in western Germany have arisen, as some old-industrialized areas, such as the Ruhr area, are currently unable to catch up with life expectancy increases observed in other regions. An attempt to limit regional divergence in mortality trends would need to pay special attention to those regions to prevent a worsening of these health disadvantages. Researchers may want to conduct case studies that compare those disadvantaged regions with other regions that were in a similar situation but managed to overcome the challenges of economic transition.

In spite of the aforementioned limitations, the author is confident that the analyses describe the major regularities of regional mortality variation in Germany correctly and that this study contributes to the knowledge gain of regional mortality trends and their determinants.

Despite the strong convergence in life expectancy across all German districts in the 1990s, regional mortality divergence may nonetheless occur in the near future. Slight trends toward regional divergence in mortality are already visible in West Germany. The success story of East German women, whose mortality rates declined substantially after reunification, could be attenuated over the coming decades due to current smoking patterns. Given the close relationship between mortality and (socio) economic determinants in the regions, the regional concentration of economic prosperity that is expected to occur in the future (cf. Kröhnert et al. 2006; Neu 2006) is likely to accelerate trends toward regional mortality divergence.

At the same time, social differences in morbidity and mortality tend to rise over time in Western European countries (cf. Mielck 2008; Valkonen 2001), including in Germany (Lampert and Kroll 2008; Mielck 2008; Scholz and Schulz 2008). The tendency toward mortality divergence between regions may be reinforced by widening mortality inequalities between population groups.

This study sheds light on the complex interplay between health and place in Germany. The study of regional mortality differentials nevertheless remains an important field of research. Research should focus simultaneously on regional-level mortality patterns and on mortality trends in various population groups. This requires the development of more comprehensive datasets, including broader age ranges and more extensive sets of explanatory variables.

Appendices

Appendix A: Mortality Differentials Across Germany's Federal States

Table A.1 Data availability of mid-year population and death counts by single-year age groups with highest age group 90+ by federal state

Federal state	Population	Death counts
Schleswig-Holstein	1980–2006	1980–2006
Hamburg	1980–2006	1980–2006
Lower Saxony	1980–2006	1980–2006
Bremen	1980–2006	1980–2006
North Rhine-Westphalia	1980–2006	1980–2006
Hesse	1980–2006	1980–2006
Rhineland-Palatinate	1980–2006	1980–2006
Baden-Württemberg	1980–2006	1980–2006
Bavaria	1980–2006	1980–2006
Saarland	1980–2006	1980–2006
Berlin	1990–2006	1990–2006
Berlin West	1980–2004	1980–2004
Berlin East	1980–2004	1980–2004
Brandenburg	1982–2006	1980–2006
Mecklenburg-Western Pomerania	1982–2006	1980–2006
Saxony	1990–2006	1980–2006
Saxony-Anhalt	1991–2006	1990–2006
Thuringia	1982–2006	1980–2006

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Table A.2 ICD-9 and ICD-10 codes of leading causes of death

ICD-10 chapter	Cause of death	ICD-10	ICD-9
I	Infectious and parasitic diseases	A00–B99	001–139
II	Neoplasms	C00–D48	140–239
	C. of stomach	C16	151
	C. of colon/rectum/anus	C18–C21	153–154
	C. of pancreas	C25	157
	C. of lung/larynx/bronchus/trachea	C32–C34	161–162
	C. of breast	C50	174–175
	C. of female genital organs	C51–C58	180–184
	C. of prostate	C61	185
	C. of lymph./hematopoietic tissue	C81–C96	200–206
IV	Endocrine, nutritional and metabolic diseases	E00–E90	240–278
	Diabetes mellitus	E10–E14	250
V	Mental and behavioral disorders	F00–F99	290–319
VI	Diseases of the nervous system and the sense organs	G00–H95	320–389
IX	Diseases of the circulatory system	I00–I99	390–459
	Heart diseases	I20–I52	410–429
	Ischemic heart diseases	I20–I25	410–414
	Cerebrovascular diseases	I60–I69	430–438
X	Diseases of the respiratory system	J00–J99	460–519
	Pneumonia	J12–J18	480–486
	Chronic lower respiratory diseases	J40–J47	490–494, 496
XI	Diseases of the digestive system	K00–K93	520–579
XIV	Diseases of the genitourinary system	N00–N99	580–629
XVIII	Symptoms, signs, abnormal findings, ill-defined causes	R00–R99	780–799
XX	External causes of injury and poisoning	V01–Y89	E800–E999
	Transport accidents	V01–V99, Y85	E800–E848, E929
	Suicide and intentional self-harm	X60–X84	E950–E959
	Alcohol-related causes		
	Alcohol abuse (incl. alcoholic psychosis)	F10	291, 303
	Chronic liver disease	K70, K73–K74	571
	Accidental poisoning by alcohol	X45	E860
XXI	Other diseases	Rest (A00–Y99)	Rest (001–E999)

Source: European shortlist (European Communities 2003)

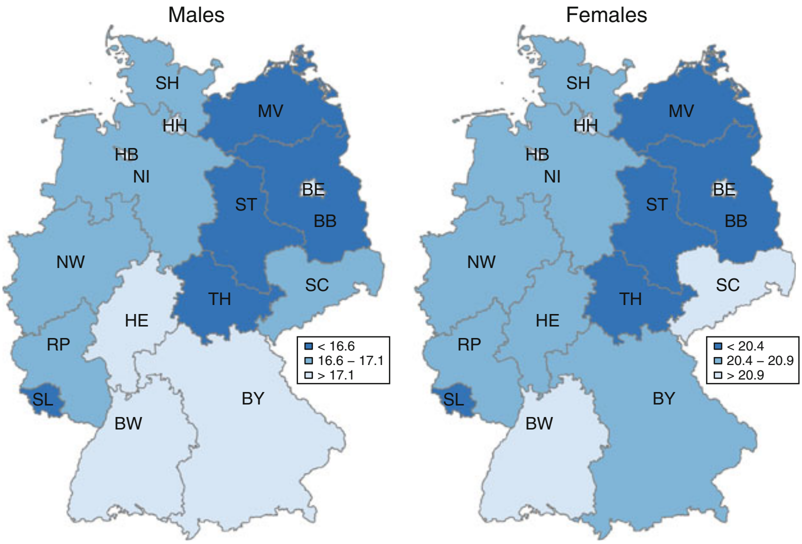

Fig. A.1 Life expectancy at age 65 by federal state; 2004–2006. *SH* Schleswig-Holstein (e_{65} males 17.06 years, females 20.61), *HH* Hamburg (17.15, 21.11), *NI* Lower Saxony (16.96, 20.58), *HB* Bremen (17.20, 21.10), *NW* North Rhine-Westphalia (16.62, 20.41), *HE* Hesse (17.42, 20.89), *RP* Rhineland-Palatinate (16.96, 20.47), *BW* Baden-Württemberg (17.78, 21.41), *BY* Bavaria (17.17, 20.67), *SL* Saarland (16.25, 19.98), *BE* Berlin (17.12, 21.12), *BB* Brandenburg (16.24, 20.28), *MV* Mecklenburg-Western Pomerania (16.10, 20.38), *SN* Saxony (16.69, 20.98), *ST* Saxony-Anhalt (15.82, 20.09), *TH* Thuringia (16.08, 20.16) (Data source: Federal State Offices of Statistics, Germany)

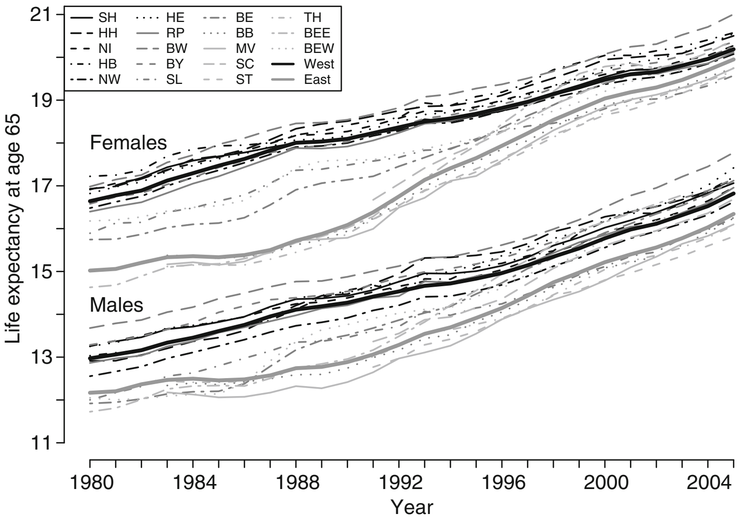

Fig. A.2 Life expectancy at age 65 by federal state; 1979–1981 to 2004–2006. *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western Pomerania, *SN* Saxony, *ST* Saxony-Anhalt, *TH* Thuringia (Data source: Federal states: State Offices of Statistics, Germany; Human Mortality Database 2008c)

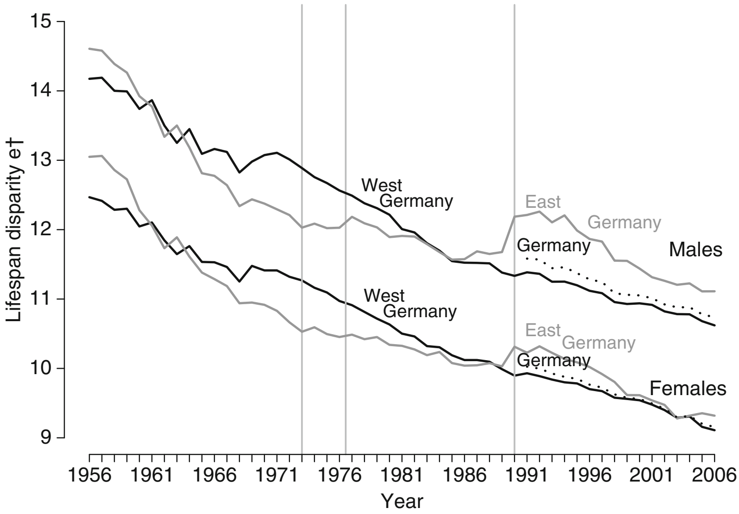

Fig. A.3 Lifespan disparity $e^{\dagger}$ in East and West Germany; 1956–2006. *Vertical lines* distinguish important time periods and indicate when East and West German life expectancies cross and 1990, the year of reunification. 1956–1972 (f) and 1956–1976 (m): life expectancy higher in East Germany; 1973–1990 (f) and 1977–1990 (m): life expectancy higher in West Germany and faster increases compared with East Germany; after 1990: life expectancy higher in West Germany but faster increases in East Germany (Data source: Human Mortality Database 2008c)

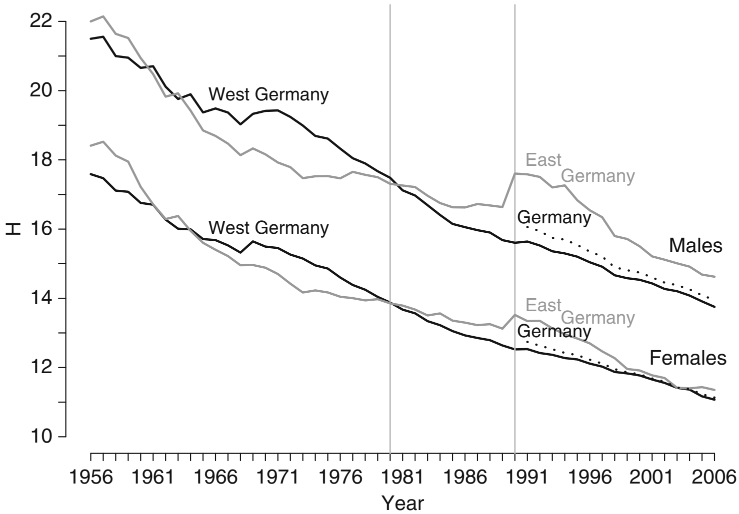

Fig. A.4 Lifespan disparity relative to life expectancy ($H=(e^{\dagger}/e_0)*100$) in East and West Germany; 1956–2006. *Vertical lines* distinguish important time periods and indicate when East and West German life expectancies cross in 1980 and 1990, the year of reunification (Data source: Human Mortality Database 2008c)

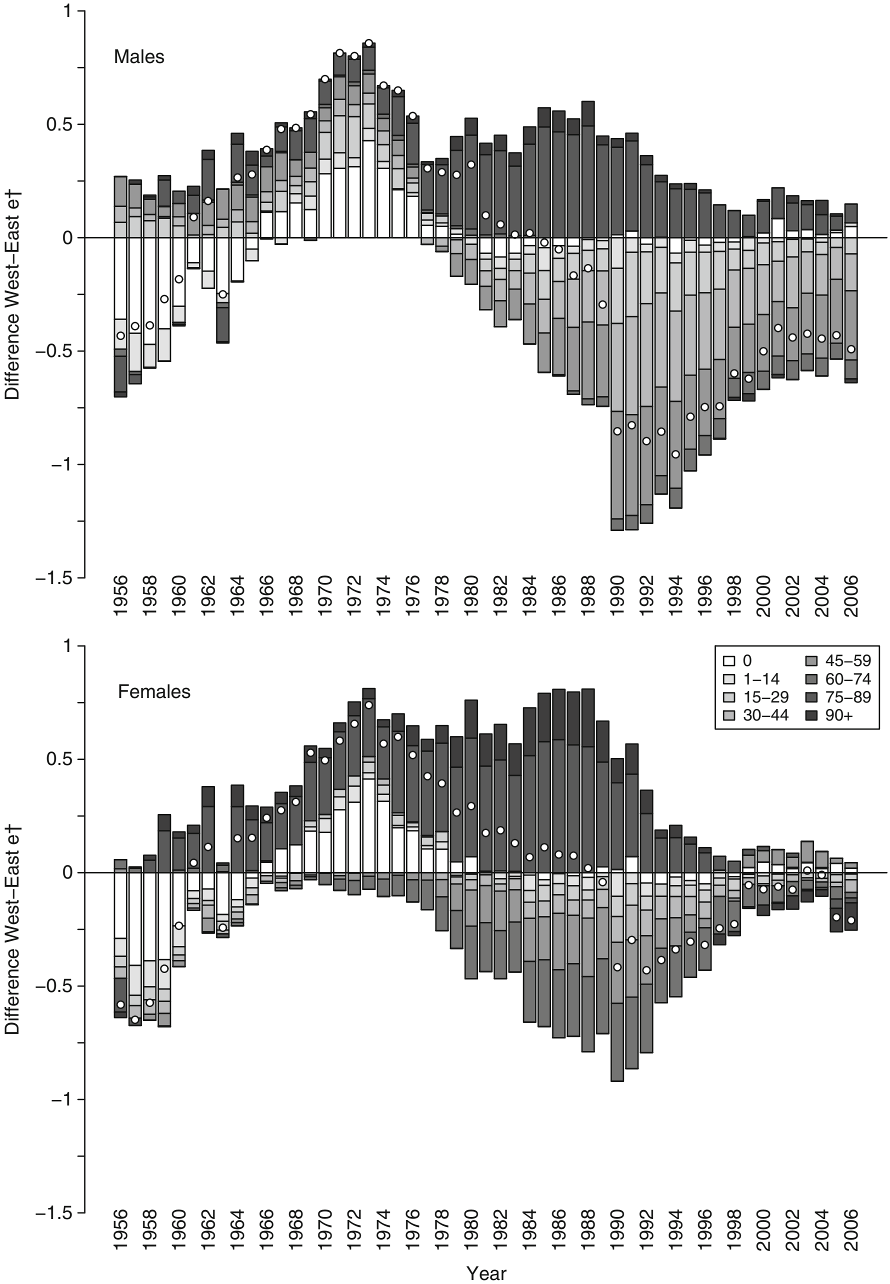

Fig. A.5 Contribution of age-specific mortality to differences in lifespan disparity $e^{\dagger}$ between West and East Germany; 1956–2006 (Data source: Human Mortality Database 2008c)

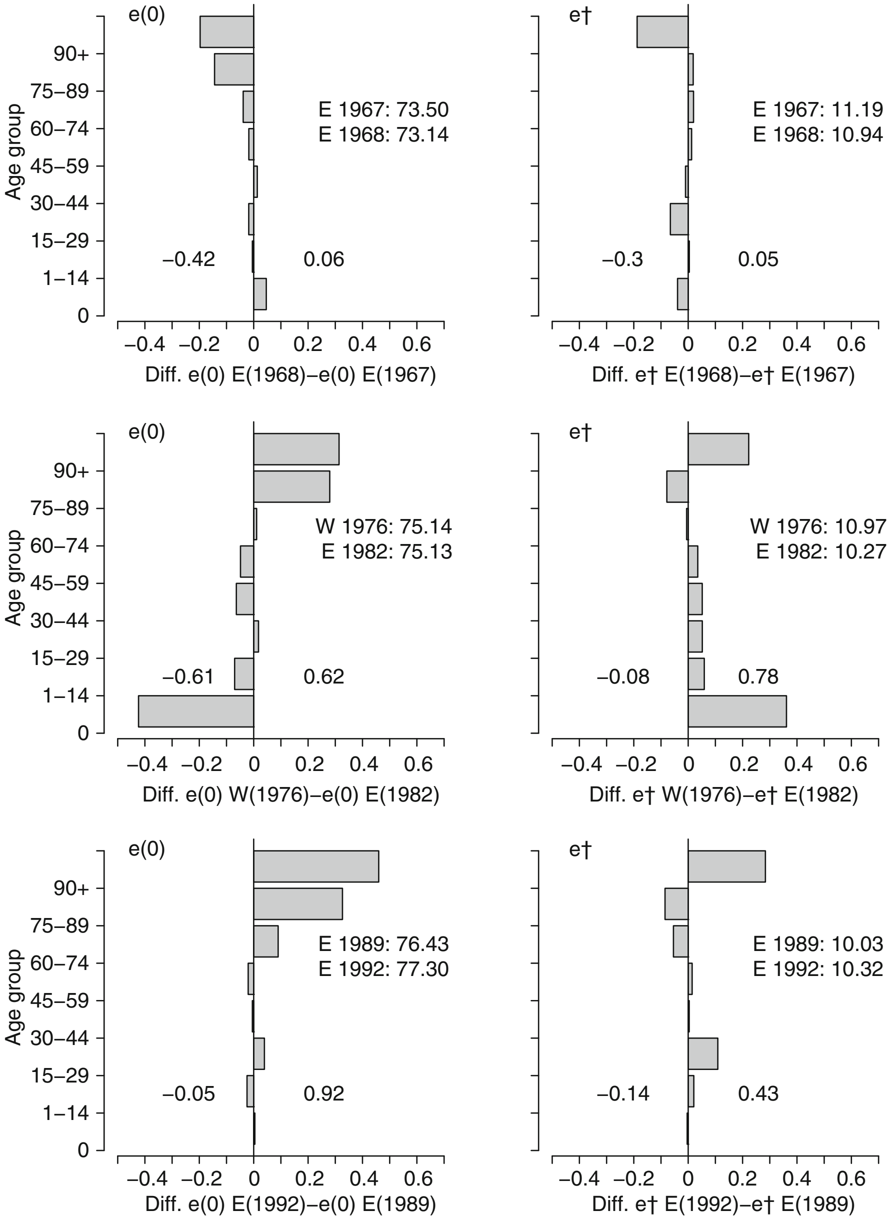

Fig. A.6 Contribution of age-specific mortality to differences in e_0 (*left panel*) and $e^\dagger$ (*right panel*) (in years), females: comparison 1967–1968 in East Germany (Period 2, *upper panel*); comparison West Germany 1976 and East Germany 1982 (Period 3, *middle panel*); comparison 1989 and 1992 in East Germany (Period 4, *lower panel*) (Data source: Human Mortality Database 2008c)

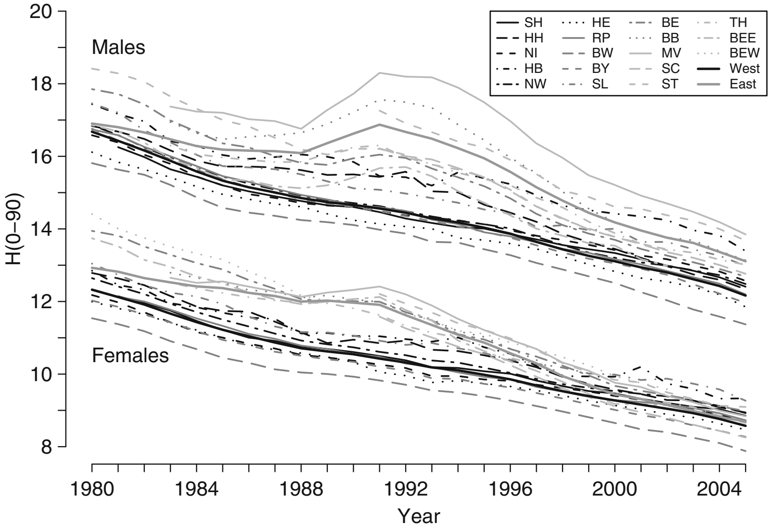

Fig. A.7 Lifespan disparity relative to life expectancy (${}_{90}H_0 = ({}_{90}e_0^{\dagger}/{}_{90}e_0)*100$) by federal state; 1979–1981 to 2004–2006. *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western Pomerania, *SN* Saxony, *ST* Saxony-Anhalt, *TH* Thuringia (Data source: Federal State Offices of Statistics, Germany; Human Mortality Database 2008c)

Table A.3 Constants in the Poisson models by cause-of-death group; 1991–2006

	Model 1	Model 2	Model 3a	Model 3b	Model 3c
	A + T	A + FS + T	A*FS + T	A*T + FS	A + T*FS
Males					
All causes	−7.44	−7.55	−7.54	−7.45	−7.56
Neoplasms	−10.22	−10.30	−10.27	−10.22	−10.29
CVD	−10.95	−11.11	−10.95	−11.16	−11.12
Respiratory	−11.28	−11.41	−11.21	−11.17	−11.26
External	−9.28	−9.29	−9.44	−9.14	−9.35
Alcohol	−15.02	−15.15	−14.52	−15.08	−15.21
Other	−7.87	−7.91	−7.98	−7.70	−7.97
Females					
All causes	−7.70	−7.78	−7.78	−7.67	−7.80
Neoplasms	−10.41	−10.46	−10.42	−10.34	−10.45
CVD	−11.11	−11.27	−11.16	−11.33	−11.29
Respiratory	−11.61	−11.64	−11.65	−11.33	−11.37
External	−9.65	−9.59	−9.79	−9.48	−9.72
Alcohol	−14.86	−14.97	−14.87	−14.41	−15.05
Other	−8.09	−8.03	−8.16	−7.82	−8.10

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

Table A.4 Relative mortality improvement in percent by cause-of-death group; 1991–1994 to 2003–2006 (From Model 3b: A + FS*T)

	Age	All	Neoplasms	CVD	Respiratory	External	Alcohol	Other
Males								
	0–14	38.2	27.1	25.9	53.2	53.8	21.2	36.7
	15–29	39.5	33.5	41.1	40.4	40.4	59.3	38.6
	30–44	33.0	27.5	41.3	31.6	35.2	42.9	16.3
	45–59	27.5	26.2	39.5	28.1	26.6	27.1	0.6
	60–74	26.6	17.4	40.0	29.1	19.3	22.9	−0.03
	75–84	29.7	19.5	40.2	26.7	28.6	29.1	4.4
	85+	17.7	18.7	21.5	14.7	21.6	31.8	−14.4
Females								
Age	0–14	36.2	31.8	15.0	38.7	53.6	na	35.0
	15–29	34.6	38.0	34.3	43.7	37.7	62.5	24.8
	30–44	28.3	26.1	29.1	32.0	33.8	48.4	14.8
	45–59	21.1	18.9	33.6	4.9	32.3	25.8	5.4
	60–74	30.4	18.5	46.8	16.9	32.2	24.5	20.2
	75–84	26.1	16.5	37.3	4.7	33.9	26.6	1.7
	85+	5.8	13.1	9.8	−11.7	30.3	27.7	−27.7

Data source: Federal State Offices of Statistics, Germany

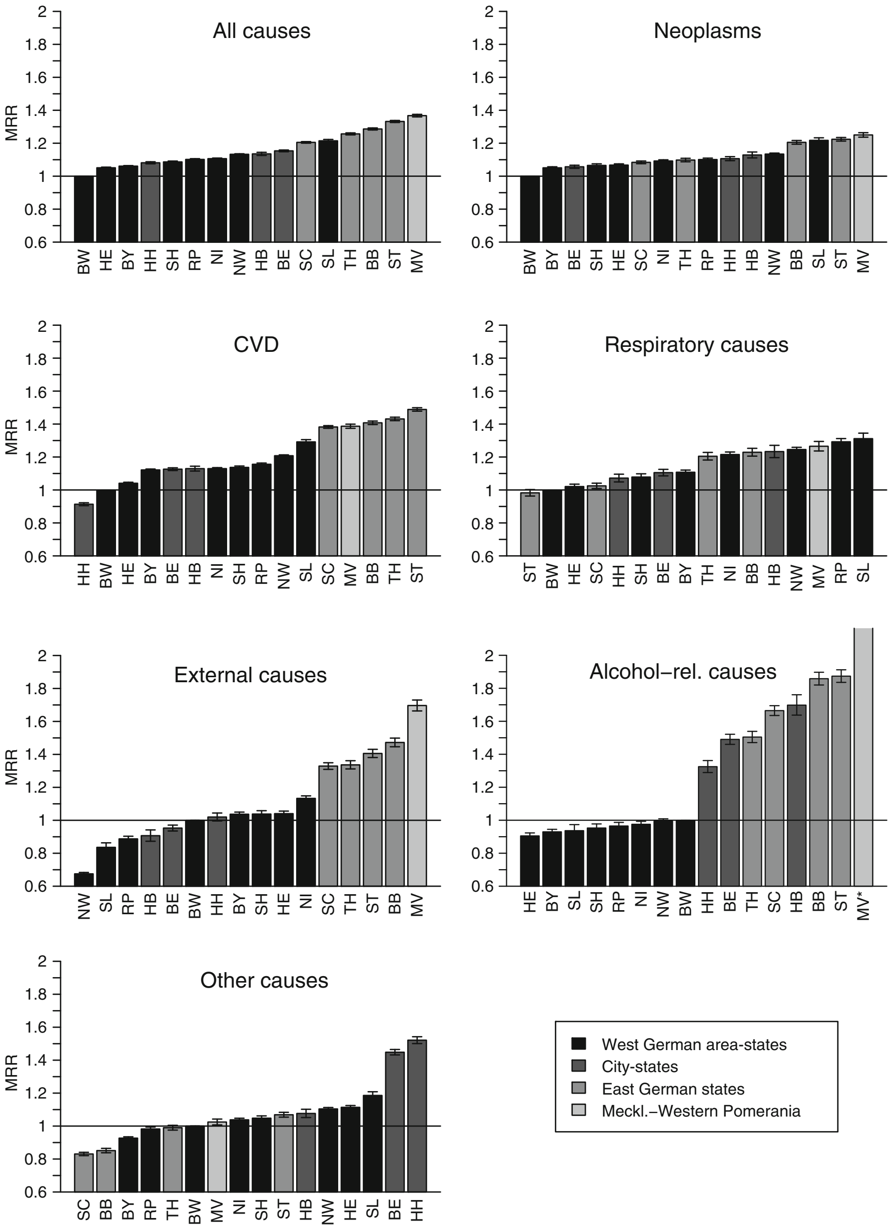

Fig. A.8 MRR of cause-specific mortality by federal state, males; 1991–2006 (space effect in Model 2: A + FS + T; reference state: Baden-Württemberg). Colored by clusters; * value for MV: 2.60 (2.55–2.66). *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western Pomerania, *SN* Saxony, *ST* Saxony-Anhalt, *TH* Thuringia (Data source: Federal State Offices of Statistics, Germany)

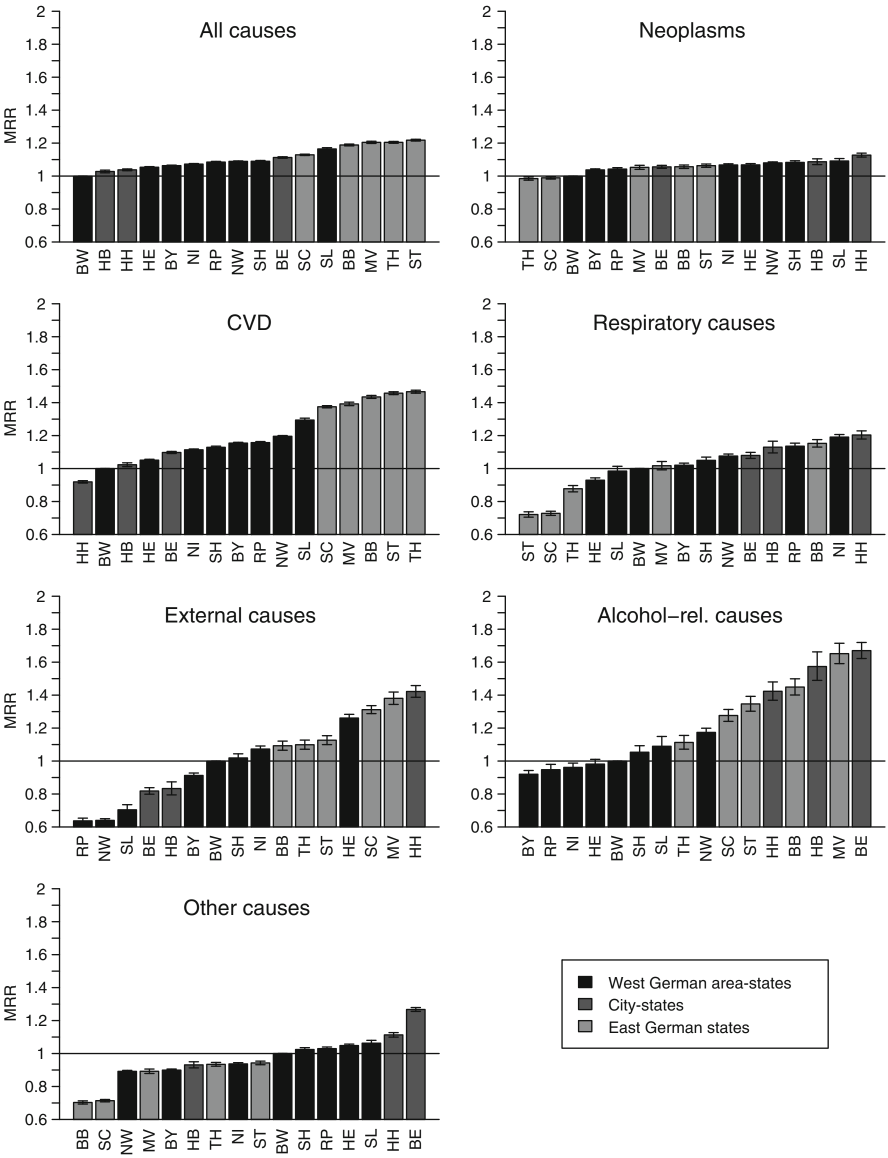

Fig. A.9 MRR of cause-specific mortality by federal state, females; 1991–2006 (space effect in Model 2: A + FS + T; reference state: Baden-Württemberg). Colored by clusters. *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western Pomerania, *SN* Saxony, *ST* Saxony-Anhalt, *TH* Thuringia (Data source: Federal State Offices of Statistics, Germany)

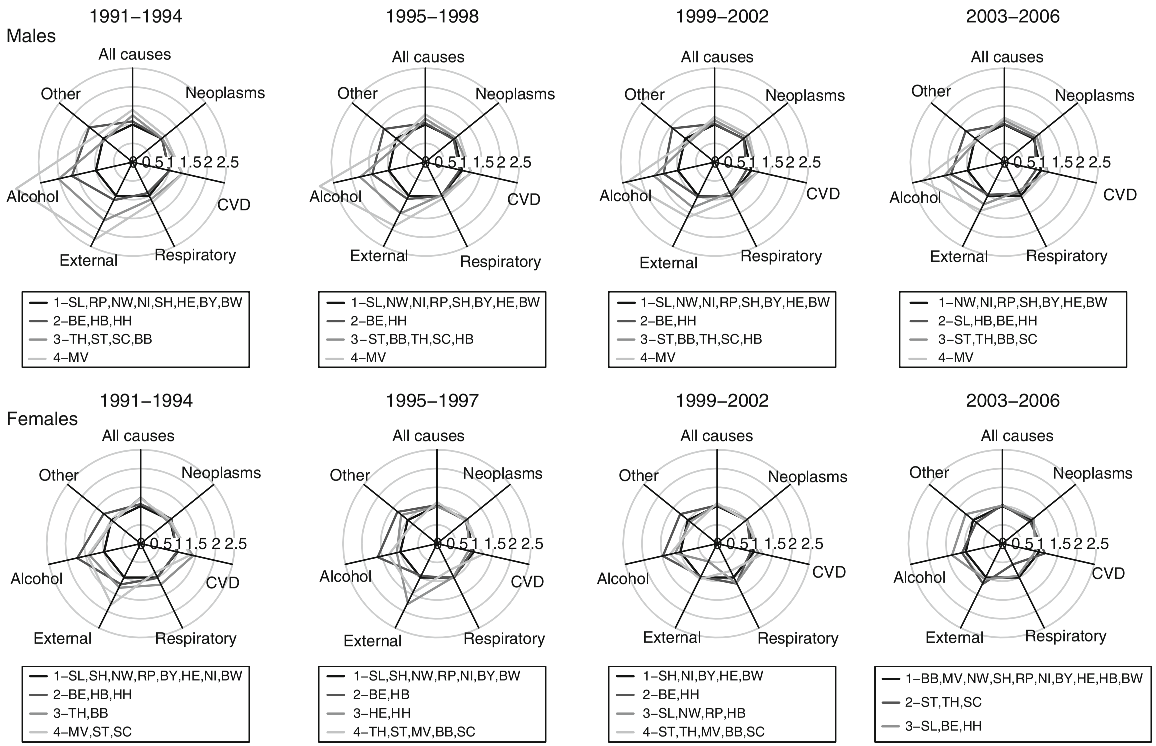

Fig. A.10 MRR of cause-specific mortality by federal state clusters by time period; 1991–2006 (model with A + T*Cluster). *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western Pomerania, *SN* Saxony, *ST* Saxony-Anhalt, *TH* Thuringia (Data source: Federal State Offices of Statistics, Germany)

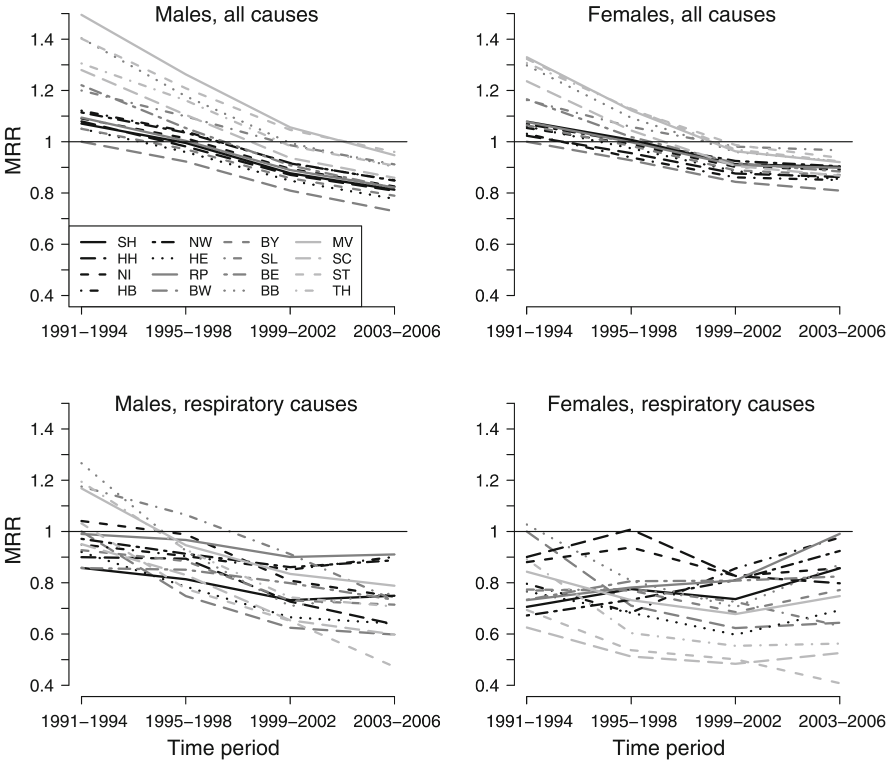

Fig. A.11 MRR of all-cause mortality and respiratory mortality by time period and by federal state (reference time period 1991–1994, reference state Baden-Württemberg; Model 3c: A + FS*T). *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western Pomerania, *SN* Saxony, *ST* Saxony-Anhalt, *TH* Thuringia (Data source: Federal State Offices of Statistics, Germany)

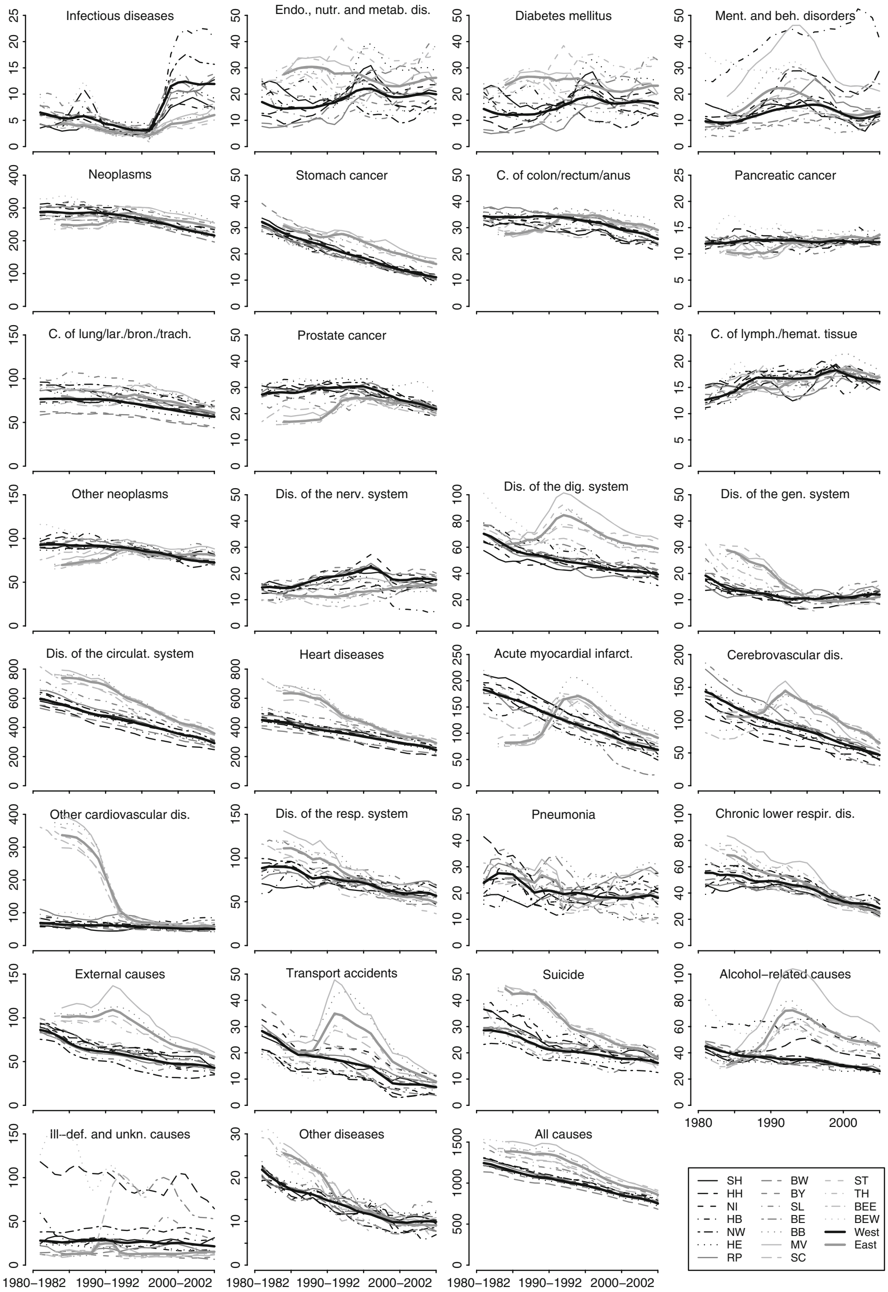

Fig. A.12 SDR by leading causes of death by federal state, males; 1980–1982 to 2004–2006. Berlin not included in West or East German average; directly standardized death rates calculated using the old European standard population (European Communities 2003). *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western Pomerania, *SN* Saxony, *ST* Saxony-Anhalt, *TH* Thuringia (Data source: Federal State Offices of Statistics, Germany)

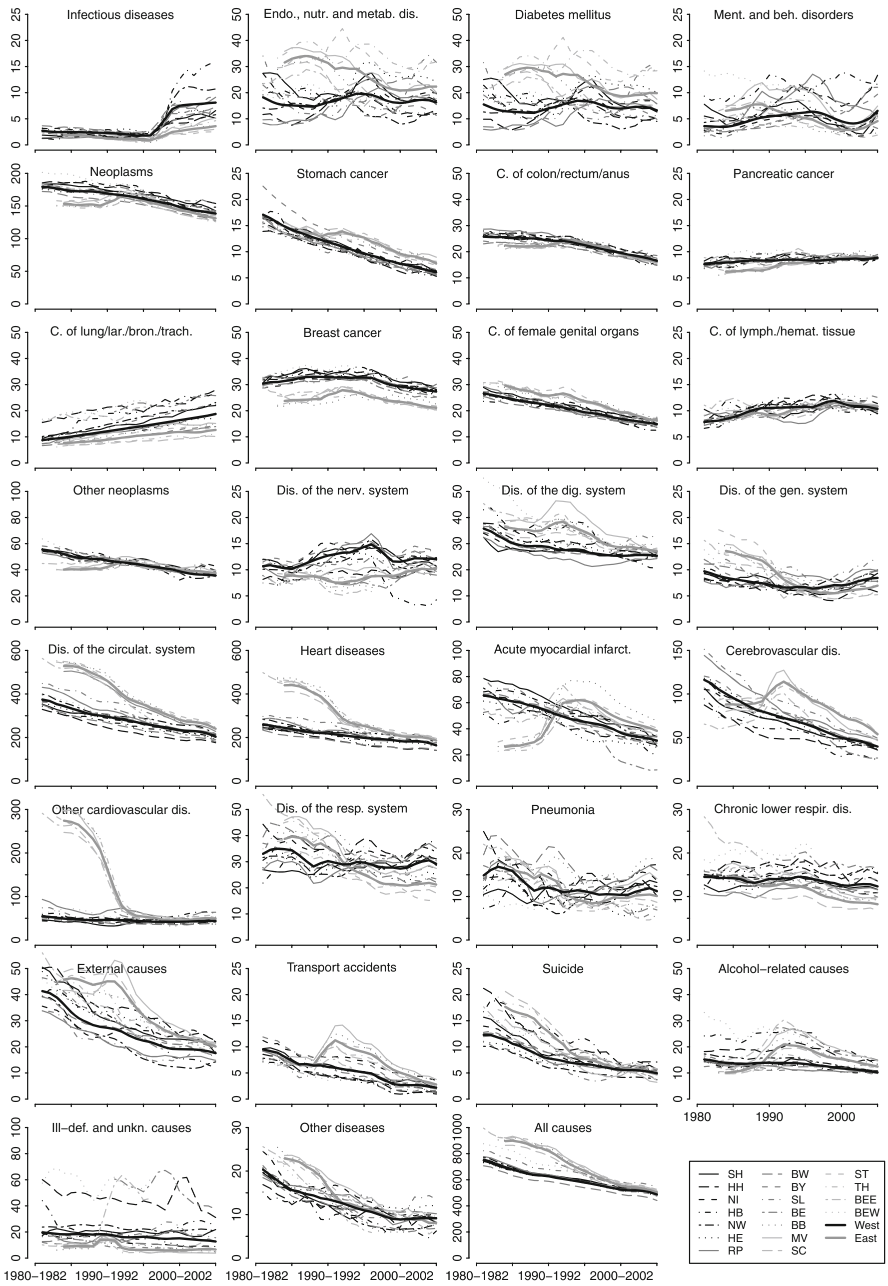

Fig. A.13 SDR by leading causes of death by federal state, females; 1980–1982 to 2004–2006. Berlin not included in West or East German average; directly standardized death rates calculated using the old European standard population (European Communities 2003). *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western Pomerania, *SN* Saxony, *ST* Saxony-Anhalt, *TH* Thuringia (Data source: Federal State Offices of Statistics, Germany)

Appendix B: Mortality Differentials Across Germany's Districts

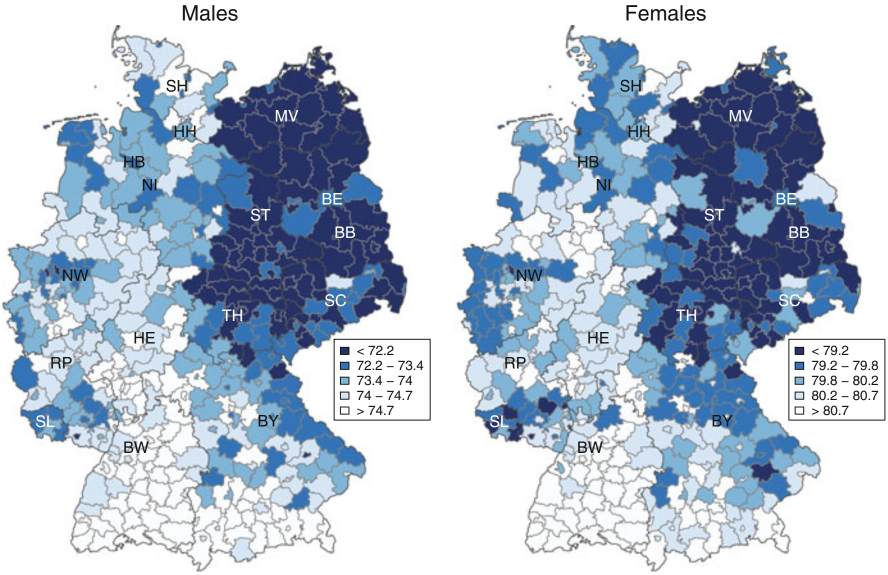

Fig. B.1 Life expectancy by district; 1995–1997. *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western Pomerania, *SN* Saxony, *ST* Saxony-Anhalt, *TH* Thuringia (Data source: Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy 2007)

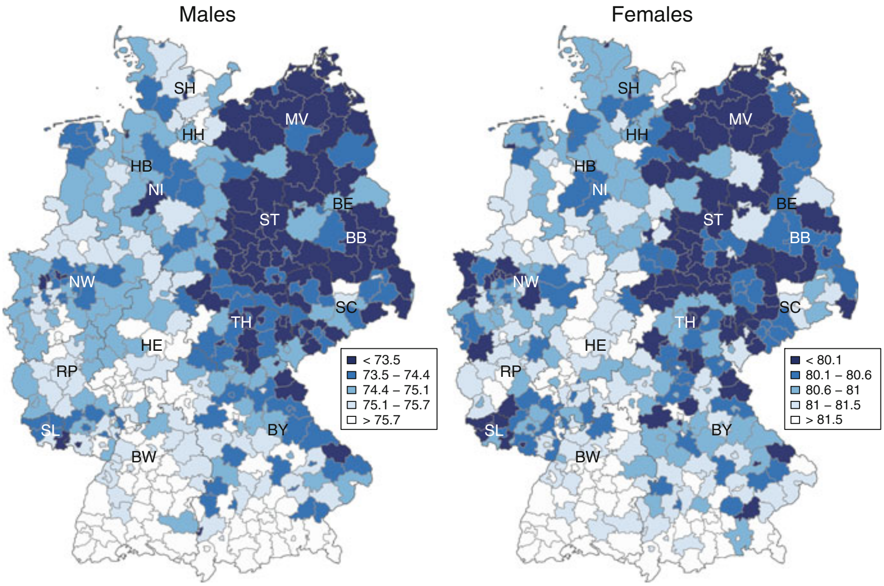

Fig. B.2 Life expectancy by district; 1998–2000. *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western Pomerania, *SN* Saxony, *ST* Saxony-Anhalt, *TH* Thuringia (Data source: Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy 2007)

Table B.1 Dispersion of life expectancy across districts: standard deviation (SD) and centiles; 1995–2006

	Males					Females				
	SD	5%	25%	75%	95%	SD	5%	25%	75%	95%
1995	1.72	69.7	72.1	74.3	75.4	1.09	77.7	79.1	80.4	81.4
1996	1.60	70.5	72.5	74.6	75.7	1.06	77.9	79.2	80.6	81.4
1997	1.56	71.2	73.0	75.0	76.1	1.00	78.5	79.6	81.0	81.8
1998	1.41	71.7	73.6	75.3	76.5	0.98	78.9	79.9	81.2	82.1
1999	1.36	72.3	73.8	75.6	76.8	0.88	79.4	80.2	81.4	82.2
2000	1.41	72.5	74.0	75.9	77.0	0.94	79.6	80.4	81.7	82.7
2001	1.35	73.0	74.5	76.4	77.4	0.89	79.9	80.7	82.0	82.9
2002	1.42	73.0	74.6	76.5	77.9	0.93	79.9	80.8	82.0	82.9
2003	1.41	73.3	74.7	76.6	77.9	0.87	80.1	80.9	82.0	82.8
2004	1.42	73.8	75.4	77.3	78.6	0.89	80.6	81.4	82.6	83.5
2005	1.38	74.1	75.6	77.5	78.7	0.85	80.6	81.5	82.6	83.4
2006	1.35	74.6	76.0	78.0	79.1	0.89	80.8	81.7	82.8	83.8

Data source: Federal State Offices of Statistics, Germany

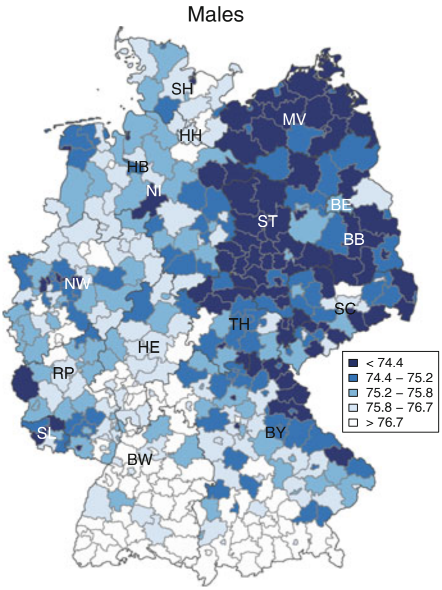

Fig. B.3 Life expectancy by district; 2001–2003. *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western Pomerania, *SN* Saxony, *ST* Saxony-Anhalt, *TH* Thuringia (Data source: Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy 2007)

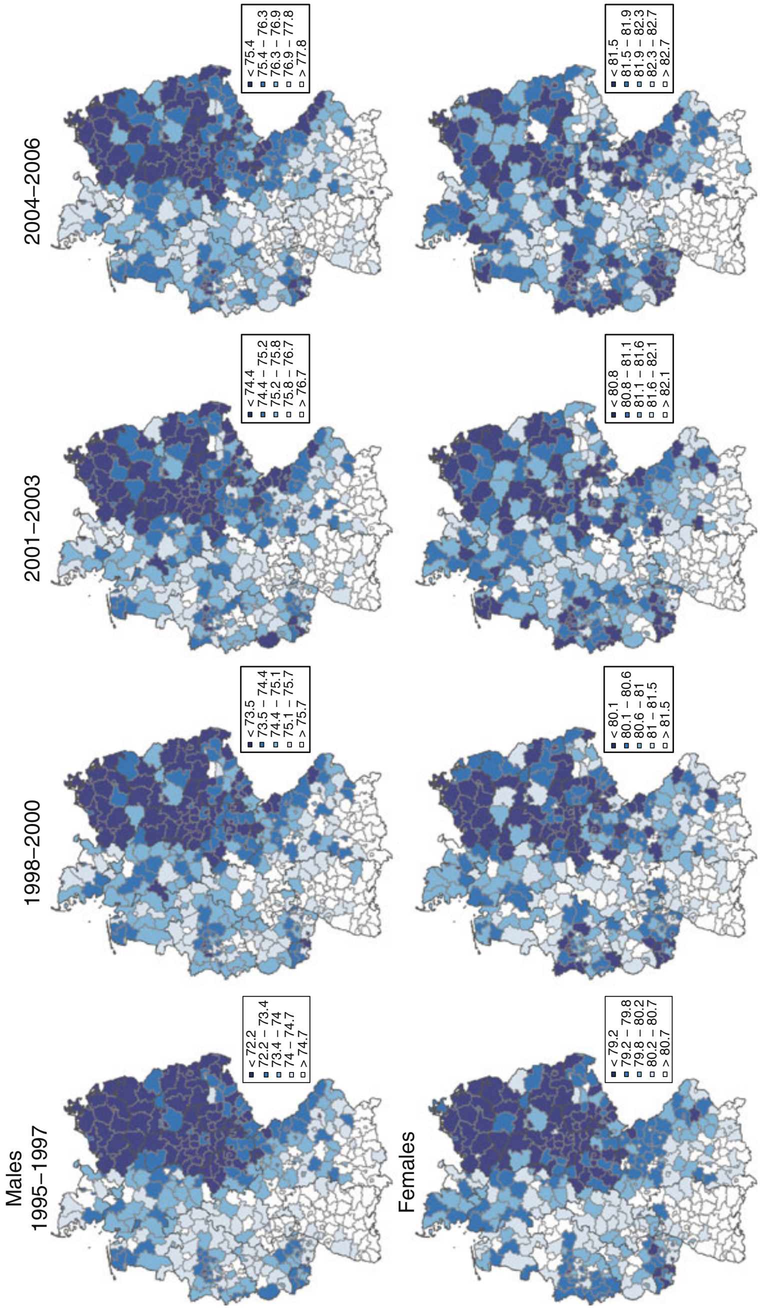

Fig. B.4 Life expectancy by district; 1995–1997, 1998–2000, 2001–2003, 2004–2006 (Data source: Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy 2007)

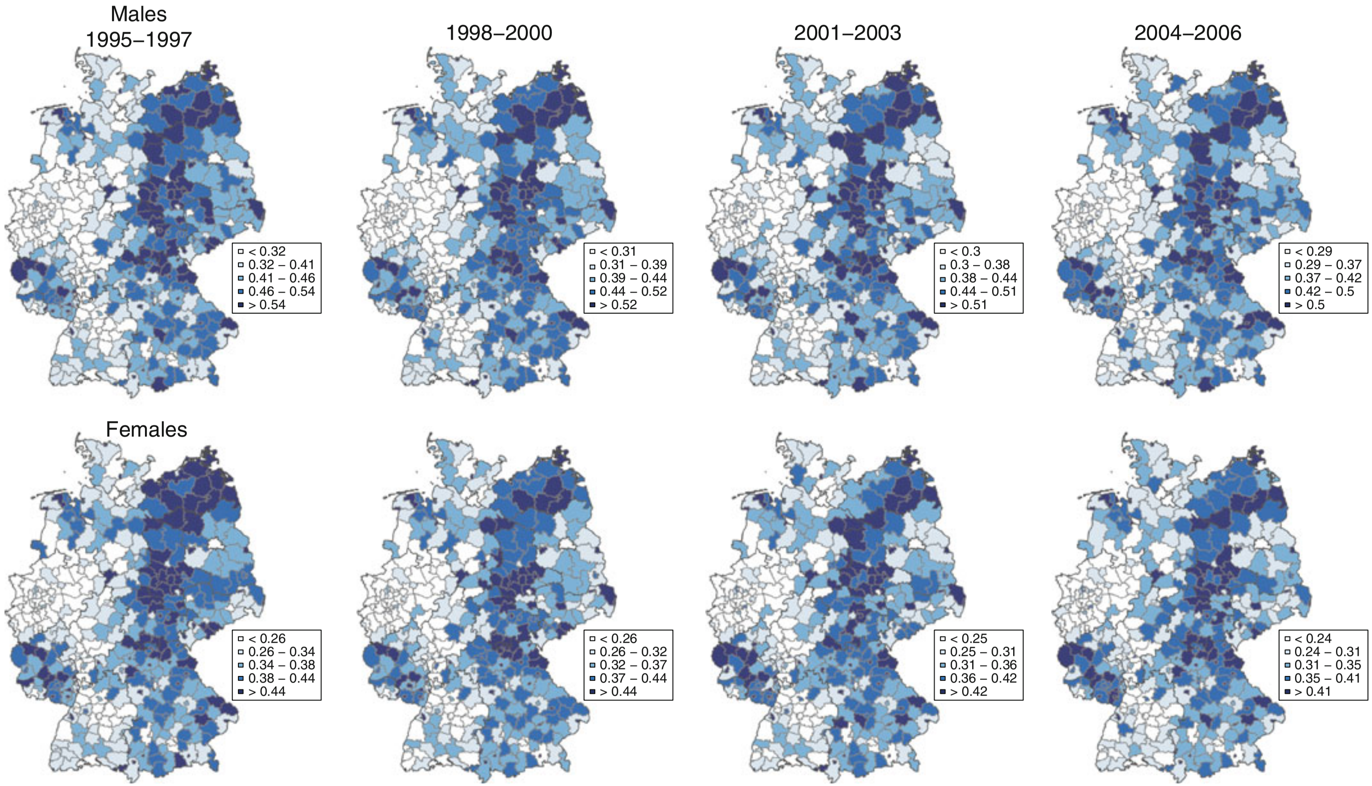

Fig. B.5 Standard error of life expectancy as percentage of life expectancy by district; 1995–1997, 1998–2000, 2001–2003, 2004–2006 (Data source: Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy 2007)

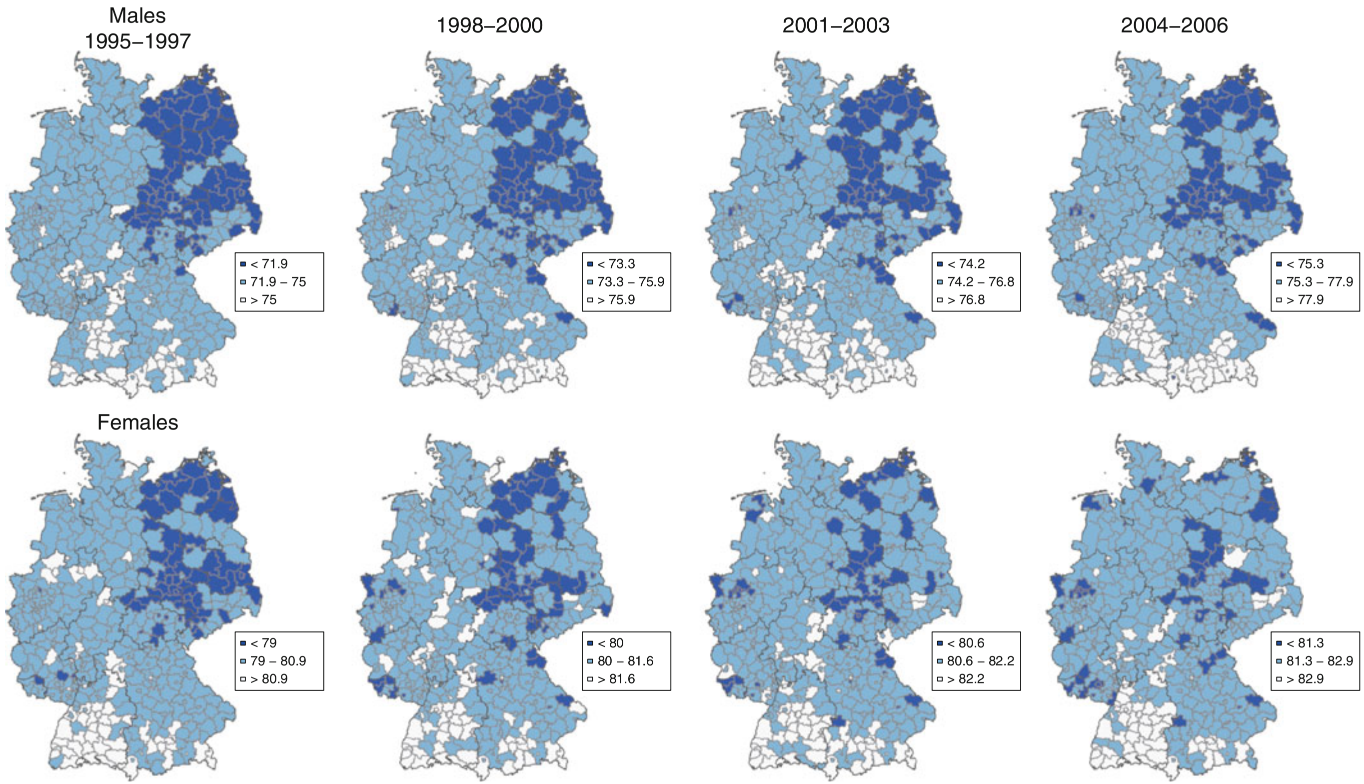

Fig. B.6 Life expectancy by district (cut points: one standard deviation above and below the mean); 1995–1997, 1998–2000, 2001–2003, 2004–2006 (Data source: Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy 2007)

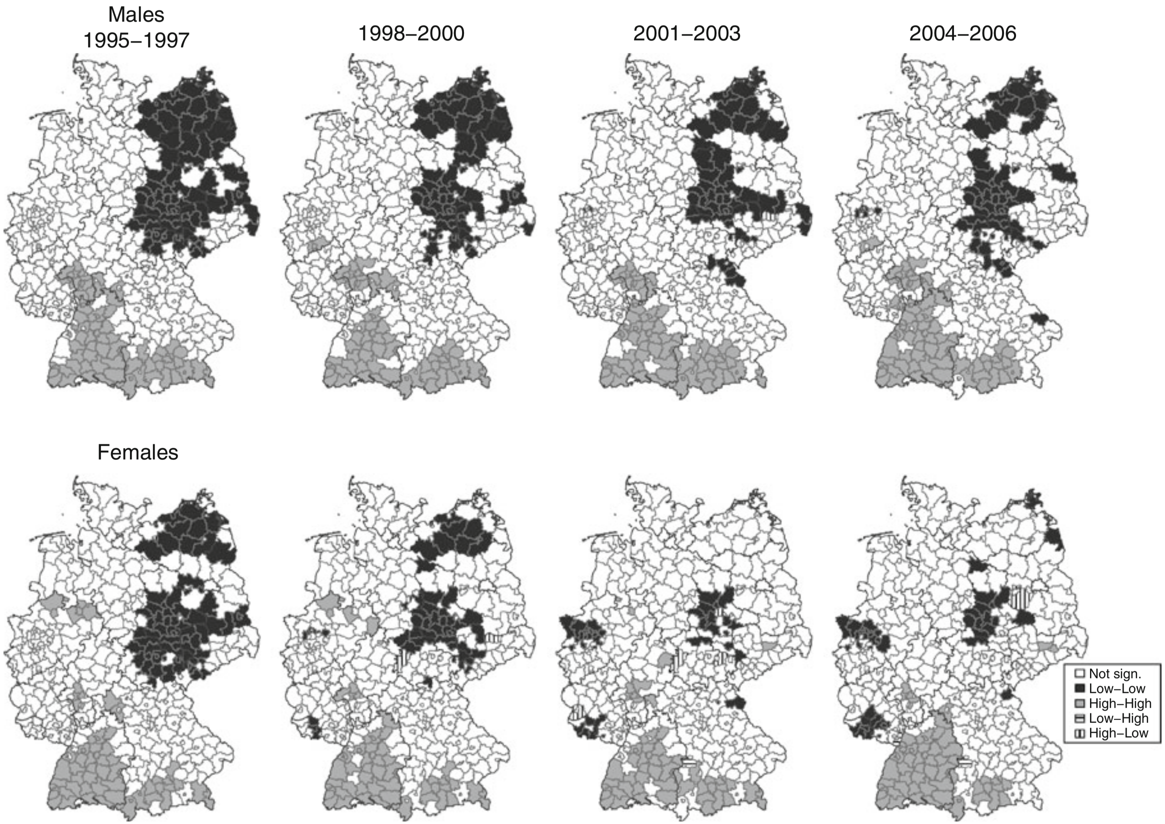

Fig. B.7 Local Moran's I of life expectancy by district, only districts with significant autocorrelation ($p < 0.05$); 1995–1997, 1998–2000, 2001–2003, 2004–2006 (Data source: Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy 2007)

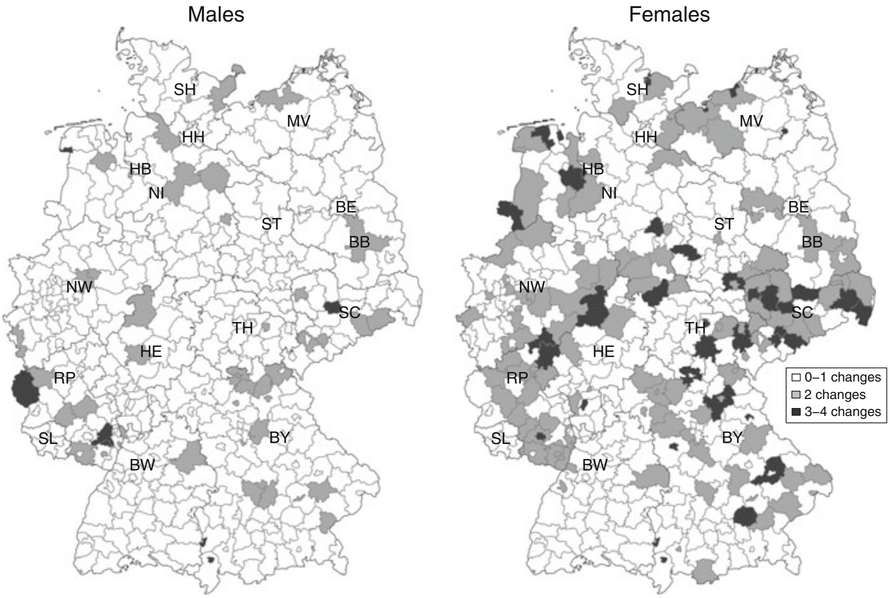

Fig. B.8 Number of maximum rank changes in life expectancy over the four time points 1995–1997, 1998–2000, 2001–2003, and 2004–2006 by district. *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western Pomerania, *SN* Saxony, *ST* Saxony-Anhalt, *TH* Thuringia (Data source: Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy 2007)

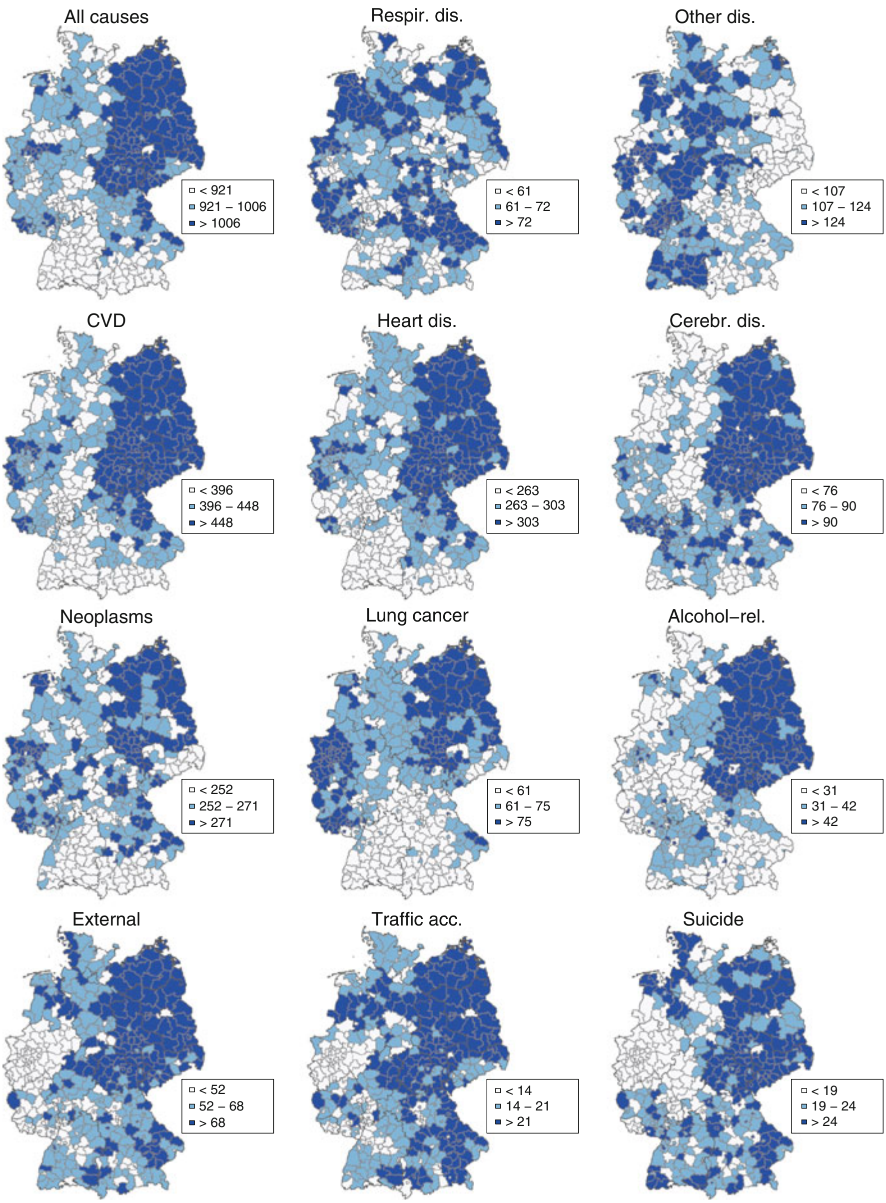

Fig. B.9 SDR by leading causes of death by district, males; 1996–1998 (Data source: Federal State Offices of Statistics, Germany; Research Data Center of the Federal Statistical Office and the Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy 2007)

Fig. B.10 SDR by leading causes of death by district, females; 1996–1998 (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)

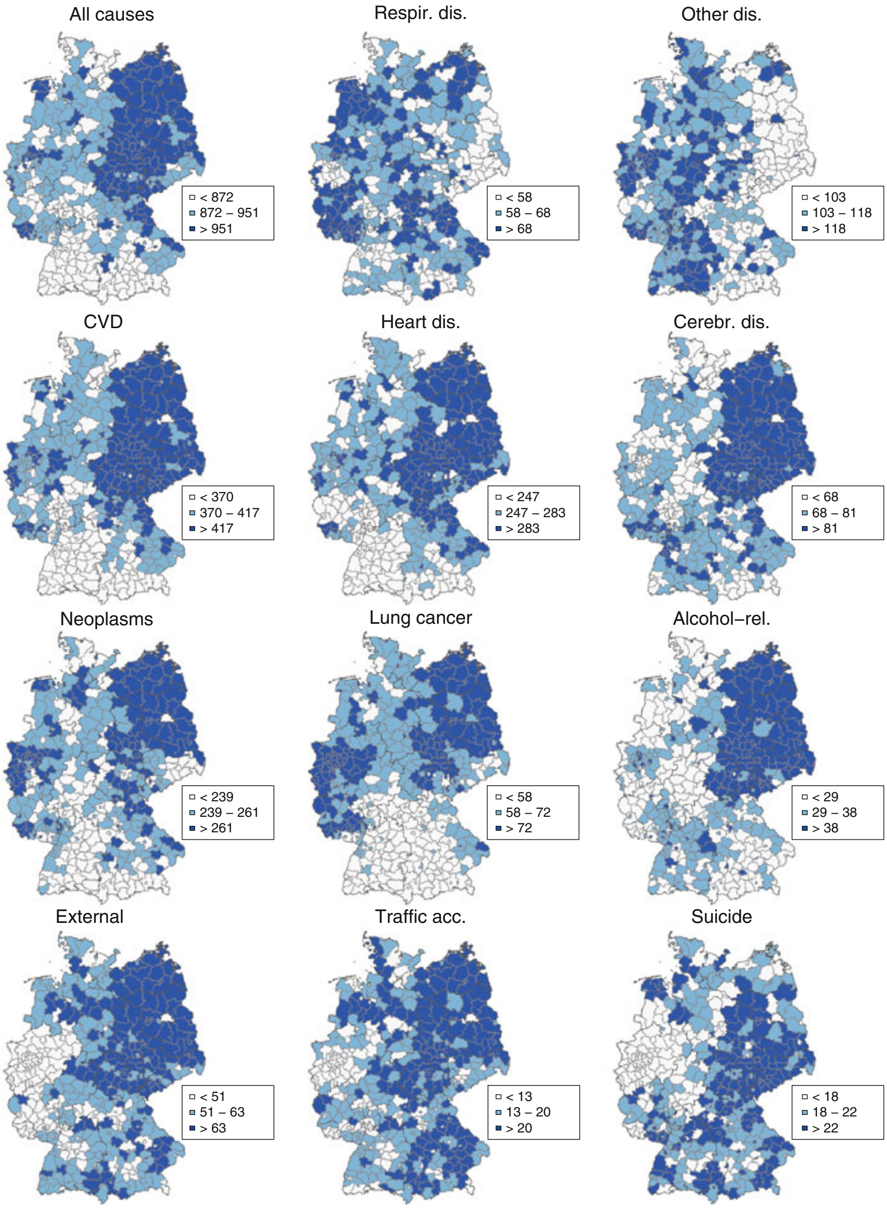

Fig. B.11 SDR by leading causes of death by district, males; 1998–2000 (Data source: Federal State Offices of Statistics, Germany; Research Data Center of the Federal Statistical Office and the Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy 2007)

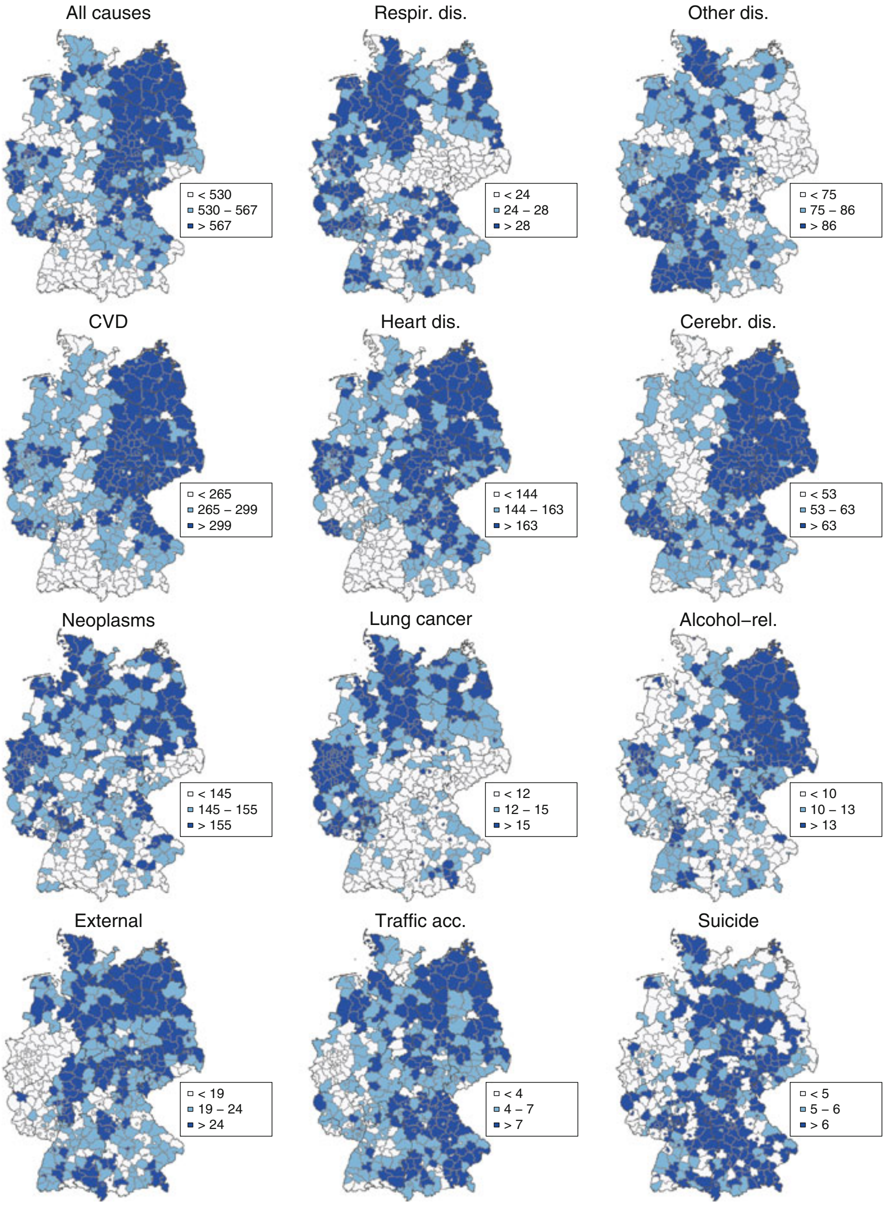

Fig. B.12 SDR by leading causes of death by district, females; 1998–2000 (Data source: Federal State Offices of Statistics, Germany; Research Data Center of the Federal Statistical Office and the Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy 2007)

Fig. B.13 SDR by leading causes of death by district, males; 2001–2003 (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)

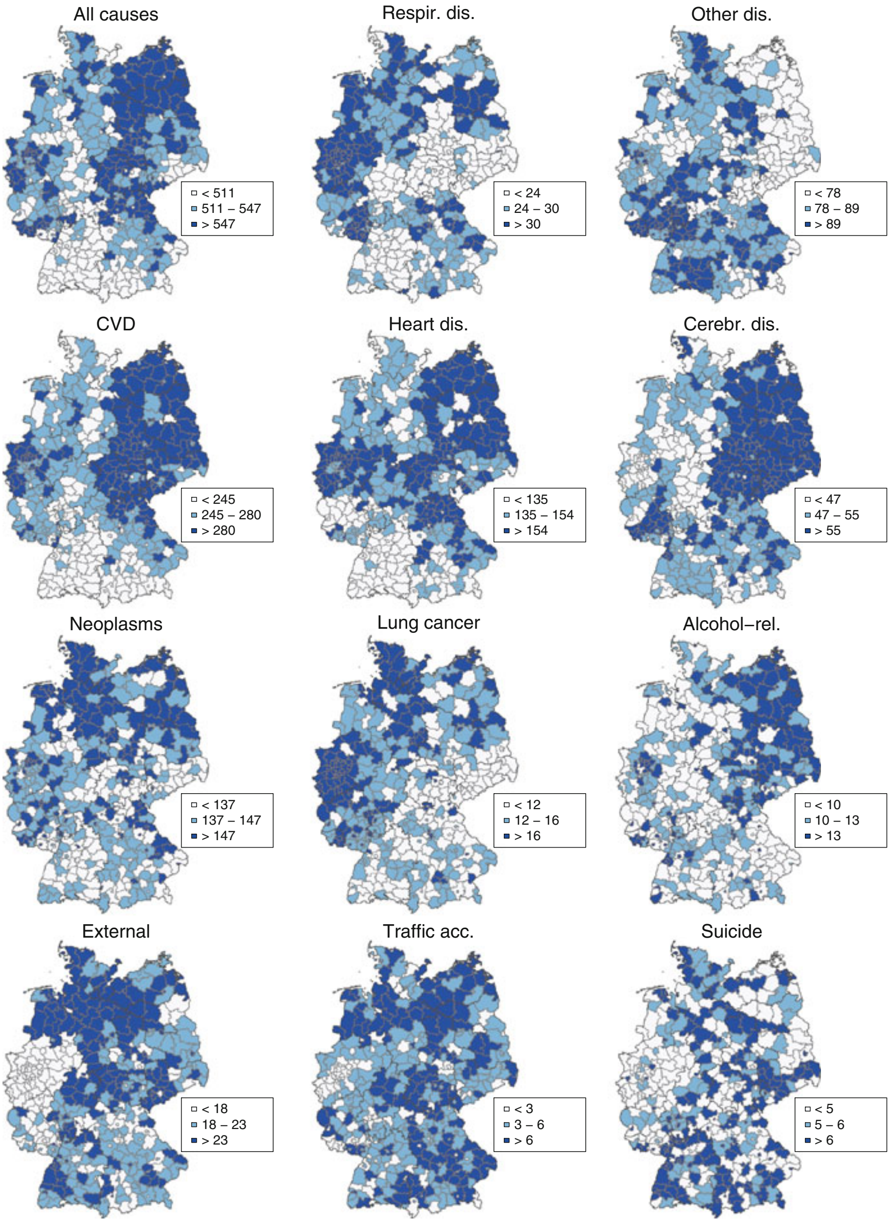

Fig. B.14 SDR by leading causes of death by district, females; 2001–2003 (Data source: Federal State Offices of Statistics, Germany; Research Data Center of the Federal Statistical Office and the Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy 2007)

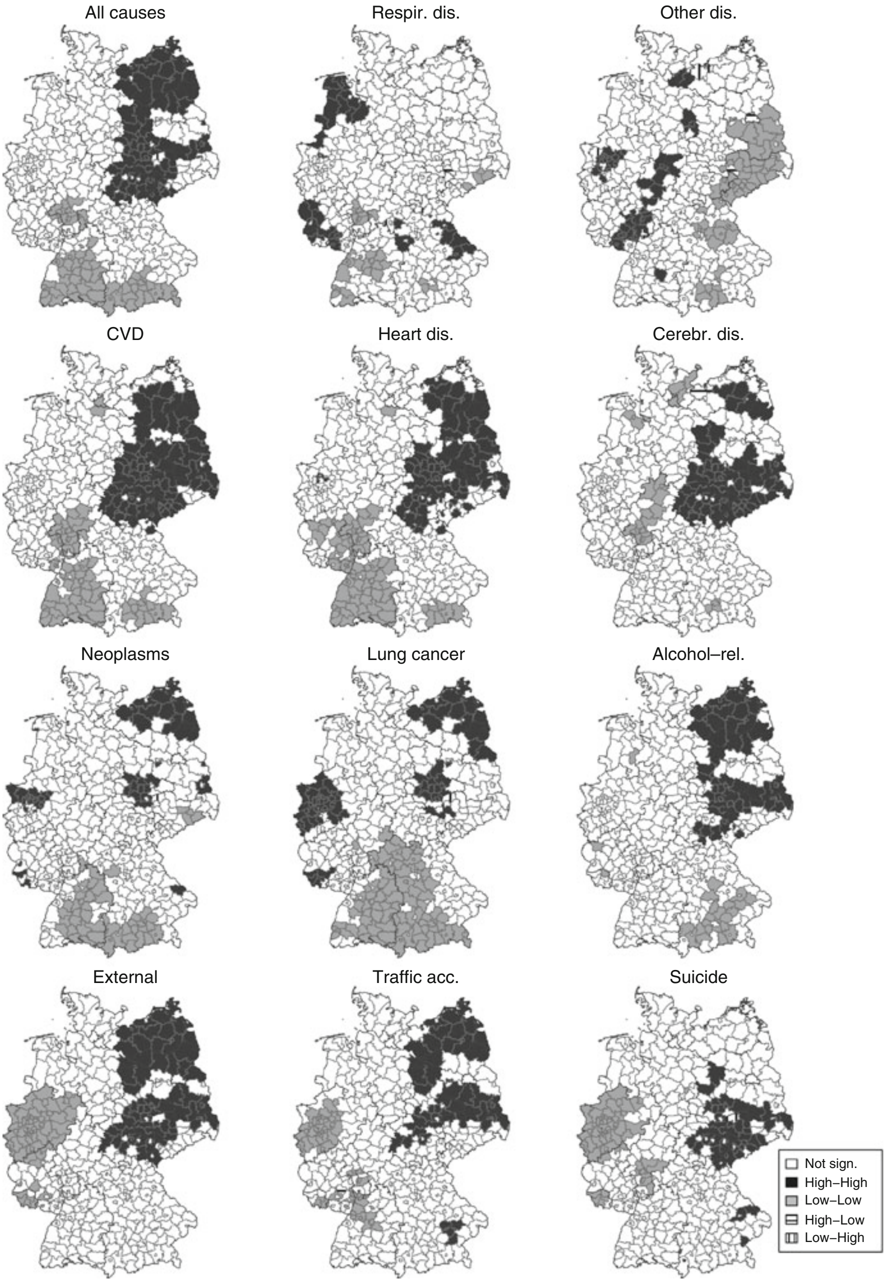

Fig. B.15 Local Moran's I of SDR by leading causes of death by district, males; 1996–1998. Legend description: Low-Low (*High-High*): Positive spatial autocorrelation; district with low (*high*) life expectancy surrounded by districts with low (*high*) life expectancy; Low-High (*High-Low*): Negative 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. B.16 Local Moran's I of SDR by leading causes of death by district, females; 1996–1998. 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. B.17 Local Moran's I of SDR by leading causes of death by district, males; 1998–2000. 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)

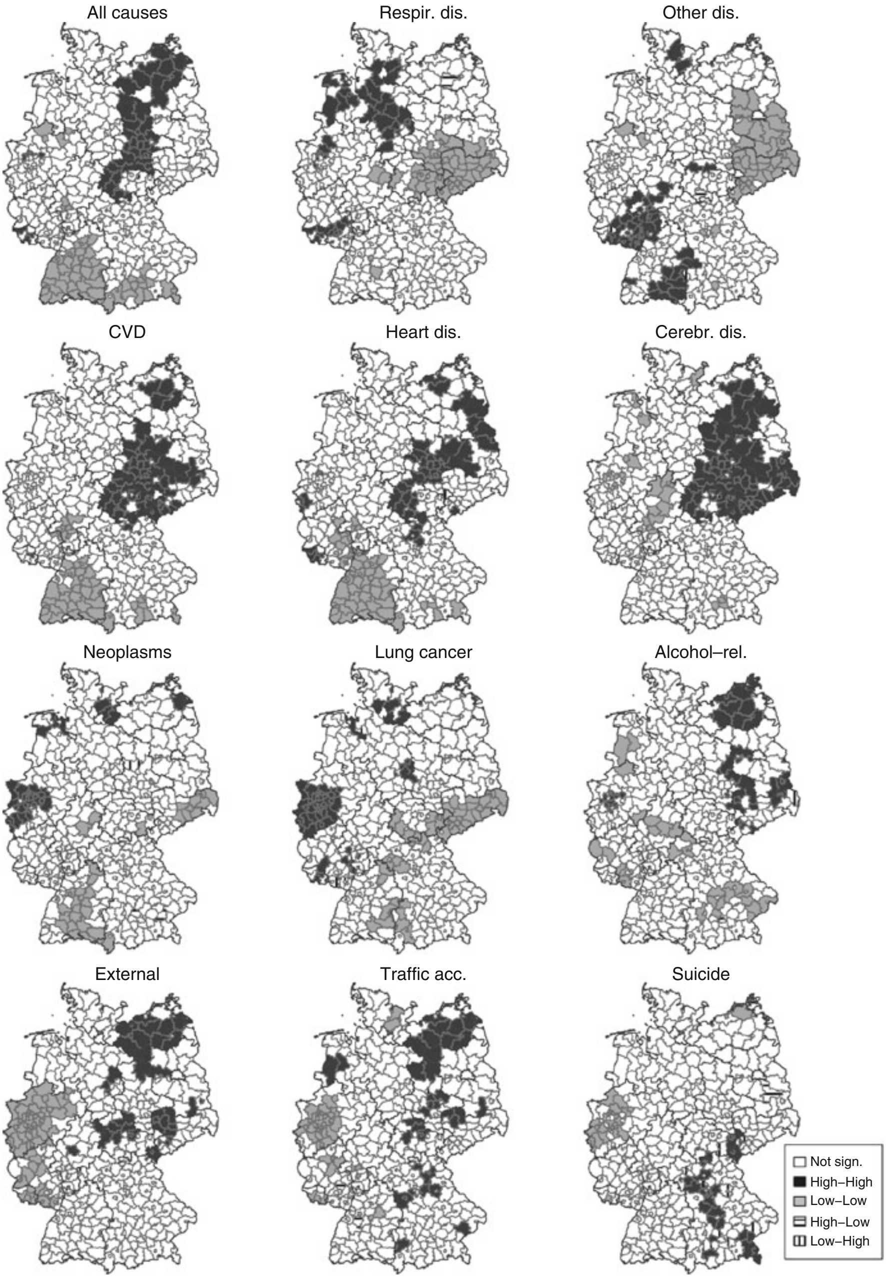

Fig. B.18 Local Moran's I of SDR by leading causes of death by district, females; 1998–2000. Legend description: Low-Low (*High-High*): Positive spatial autocorrelation; district with low (*high*) life expectancy surrounded by districts with low (*high*) life expectancy; Low-High (*High-Low*): Negative 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. B.19 Local Moran's I of SDR by leading causes of death by district, males; 2001–2003. 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. B.20 Local Moran's I of SDR by leading causes of death by district, females; 2001–2003. 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)

Table B.2 Correlation coefficients between districts' SDR from all causes and districts' SDR from leading causes of death; 1996–1998, 1998–2000, 2001–2003, 2004–2006

	1996–1998	1998–2000	2001–2003	2004–2006
Males				
Respiratory diseases	0.350	0.367	0.352	0.234
Cardiovascular diseases	0.908	0.911	0.897	0.882
Heart diseases	0.837	0.834	0.822	0.807
Cerebrovascular diseases	0.711	0.681	0.643	0.567
Neoplasms	0.732	0.778	0.829	0.855
Lung cancer	0.668	0.674	0.685	0.682
External causes	0.590	0.513	0.436	0.443
Traffic accidents	0.551	0.461	0.345	0.298
Suicide	0.364	0.207	0.257	0.036 (0.454)
Alcohol-related diseases	0.743	0.690	0.648	0.672
Other diseases	−0.018 (0.711)	0.033 (0.496)	0.065 (0.177)	0.339
Females				
Respiratory diseases	0.040 (0.408)	0.112 (0.012)	0.244	0.313
Cardiovascular diseases	0.871	0.856	0.807	0.757
Heart diseases	0.767	0.777	0.727	0.675
Cerebrovascular diseases	0.690	0.597	0.463	0.391
Neoplasms	0.419	0.463	0.521	0.516
Lung cancer	0.057 (0.232)	0.146 (0.002)	0.214	0.312
External causes	0.335	0.187	0.051 (0.284)	0.020 (0.673)
Traffic accidents	0.381	0.265	0.109 (0.023)	0.115 (0.016)
Suicide	0.047 (0.328)	−0.083 (0.081)	−0.1134 (0.018)	−0.106 (0.026)
Alcohol-related diseases	0.421	0.324	0.238	0.239
Other diseases	0.185	0.140 (0.003)	0.183	0.416

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 correlations significant at 0.1% level if not indicated otherwise (p-value in parentheses)

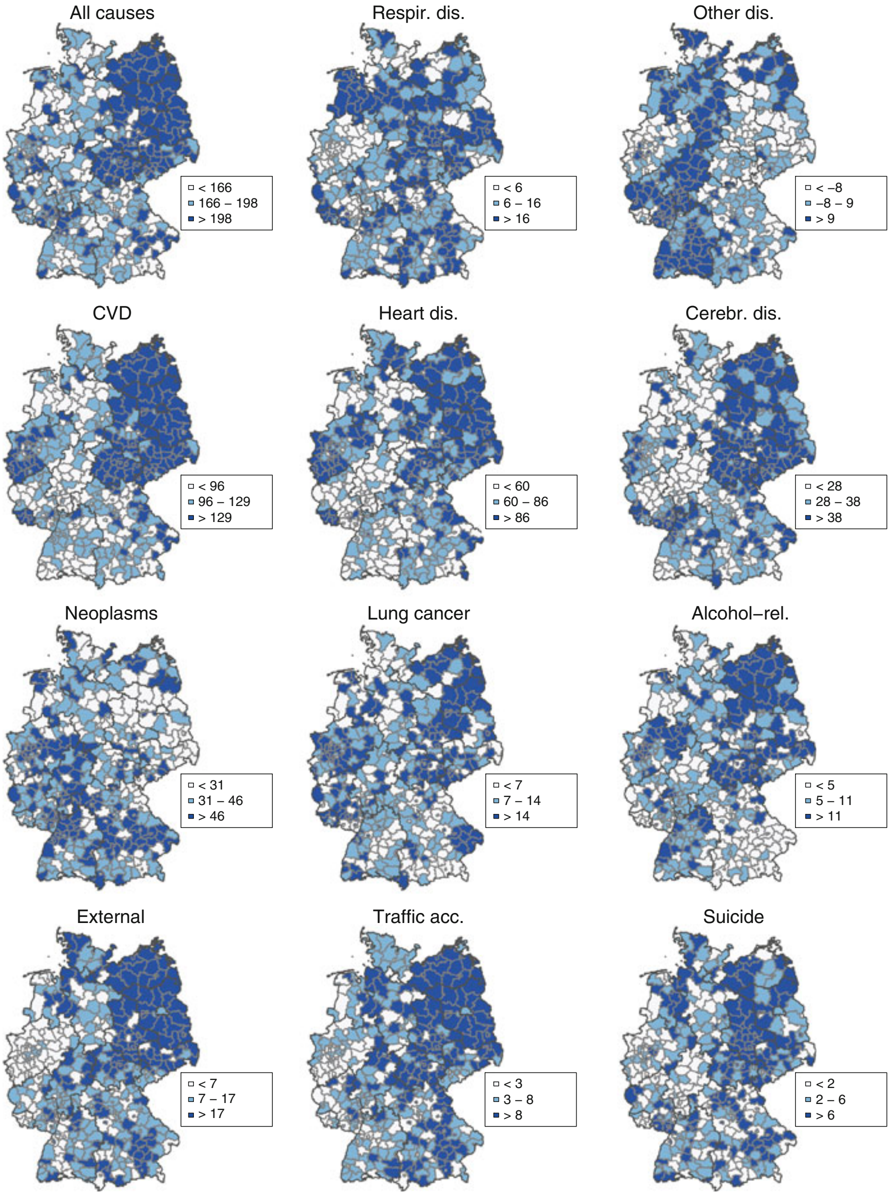

Fig. B.21 Absolute improvements in SDR by leading causes of death by district, males; 1996–1998 to 2004–2006 (Data source: Federal State Offices of Statistics, Germany; Research Data Center of the Federal Statistical Office and the Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy 2007)

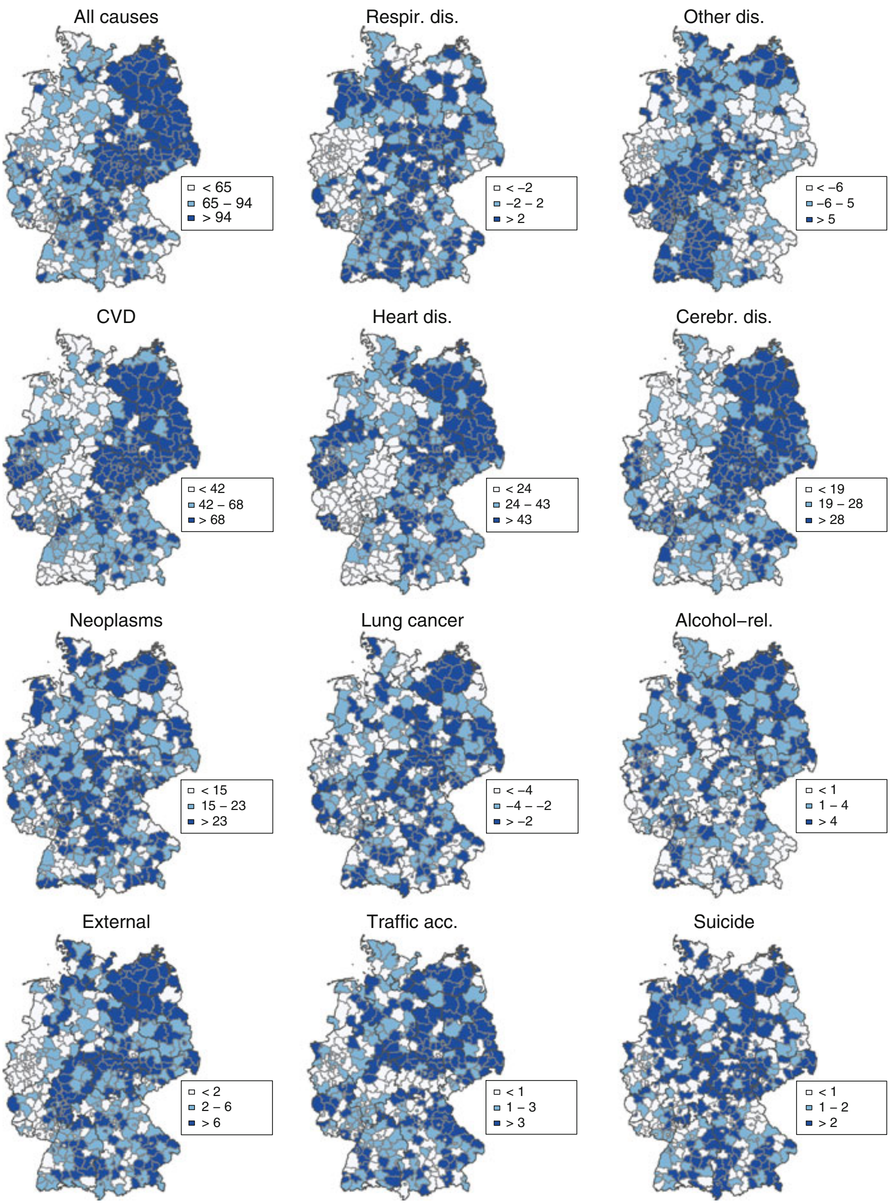

Fig. B.22 Absolute improvements in SDR by leading causes of death by district, females; 1996–1998 to 2004–2006 (Data source: Federal State Offices of Statistics, Germany; Research Data Center of the Federal Statistical Office and the Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy 2007)

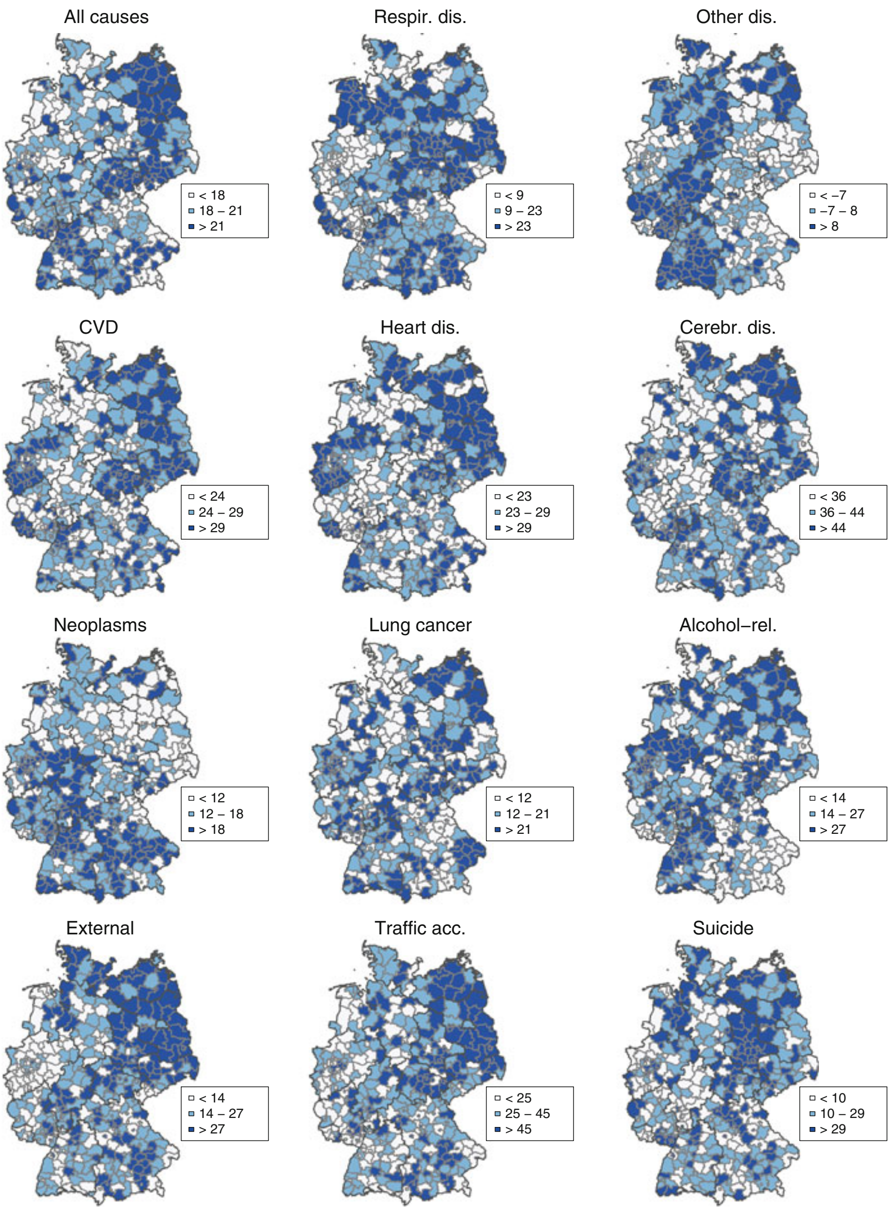

Fig. B.23 Relative improvements in SDR by leading causes of death by district, males; 1996–1998 to 2004–2006 (Data source: Federal State Offices of Statistics, Germany; Research Data Center of the Federal Statistical Office and the Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy 2007)

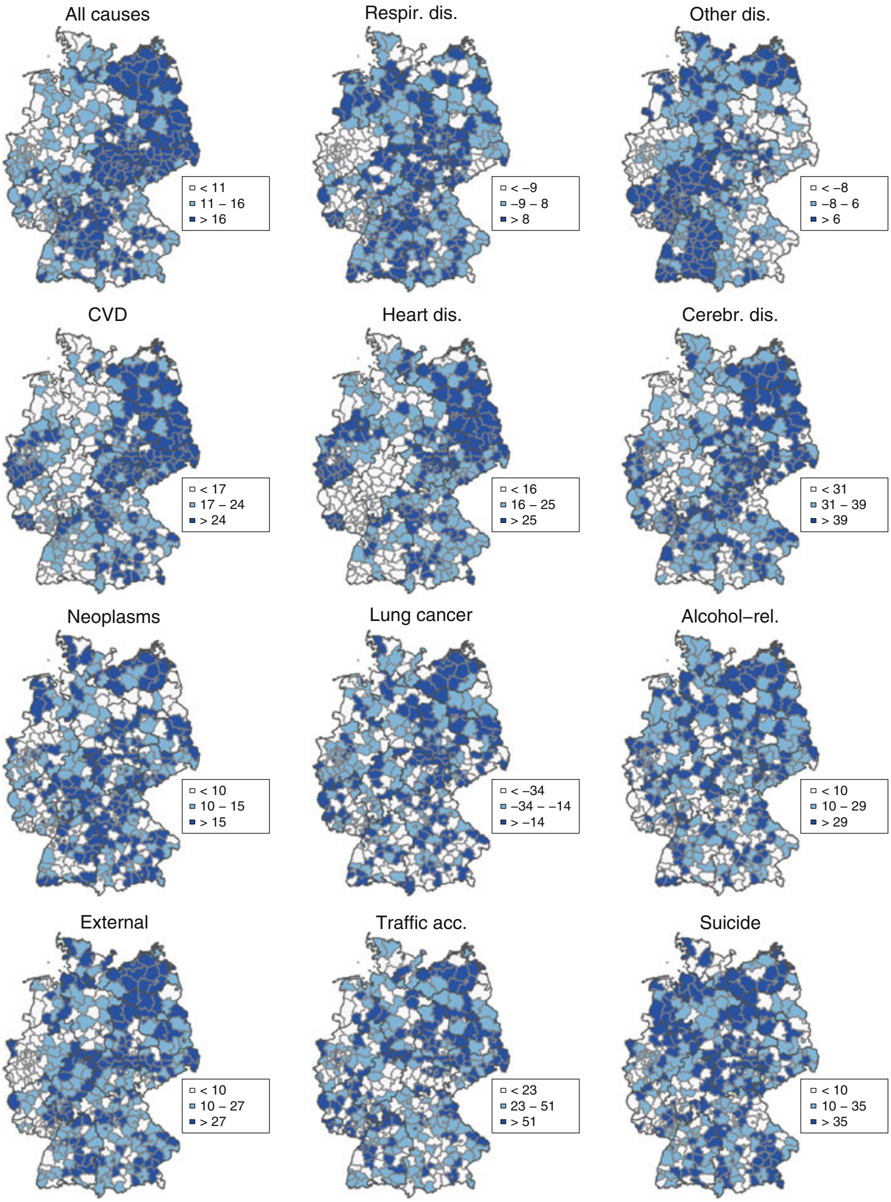

Fig. B.24 Relative improvements in SDR by leading causes of death by district, females; 1996–1998 to 2004–2006 (Data source: Federal State Offices of Statistics, Germany; Research Data Center of the Federal Statistical Office and the Federal State Offices of Statistics, Germany. Base map: German Federal Agency for Cartography and Geodesy 2007)

Table B.3 Correlation coefficients of districts' SDR from leading causes of death between males and females; 1996–1998, 1998–2000, 2001–2003, 2004–2006

	1996–1998	1998–2000	2001–2003	2004–2006
All causes	0.853	0.826	0.792	0.754
Respiratory diseases	0.530	0.565	0.670	0.761
Cardiovascular diseases	0.929	0.916	0.908	0.878
Heart diseases	0.895	0.878	0.870	0.837
Cerebrovascular diseases	0.894	0.903	0.875	0.837
Neoplasms	0.378	0.406	0.395	0.344
Lung cancer	0.428	0.455	0.416	0.431
External causes	0.730	0.702	0.639	0.534
Traffic accidents	0.727	0.694	0.664	0.567
Suicide	0.393	0.280	0.259	0.296
Alcohol-related diseases	0.716	0.674	0.614	0.605
Other diseases	0.769	0.729	0.720	0.699

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 correlations significant at 0.1% level

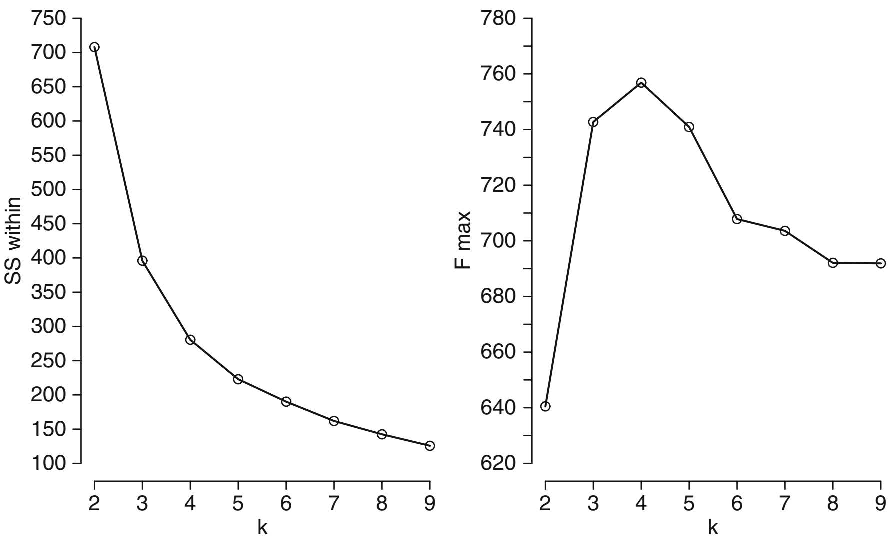

Fig. B.25 Classification of districts according to life expectancy level and change: SS_{within} and F_{max} of optimal solutions after 75,000 clustering rounds for $k = 2,...,k = 9$ (Data source: Federal State Offices of Statistics, Germany)

Table B.4 Correlation coefficients of districts' SDR from leading causes of death for different time periods

	1996–1998 to 1998–2000	1998–2000 to 2001–2003	2001–2003 to 2004–2006	1996–1998 to 2004–2006
Males				
All causes	0.934	0.932	0.930	0.885
Respiratory diseases	0.760	0.613	0.741	0.514
Cardiovascular diseases	0.926	0.920	0.880	0.852
Heart diseases	0.897	0.871	0.809	0.758
Cerebrovascular diseases	0.903	0.845	0.782	0.753
Neoplasms	0.792	0.728	0.776	0.700
Lung cancer	0.894	0.842	0.803	0.800
External causes	0.893	0.806	0.720	0.737
Traffic accidents	0.884	0.764	0.753	0.697
Suicide	0.707	0.539	0.462	0.433
Alcohol-related diseases	0.929	0.876	0.897	0.837
Other diseases	0.779	0.663	0.560	0.410
Females				
All causes	0.876	0.867	0.849	0.682
Respiratory diseases	0.776	0.676	0.812	0.615
Cardiovascular diseases	0.934	0.919	0.862	0.800
Heart diseases	0.905	0.845	0.756	0.684
Cerebrovascular diseases	0.932	0.880	0.847	0.781
Neoplasms	0.608	0.513	0.547	0.440
Lung cancer	0.827	0.743	0.806	0.771
External causes	0.775	0.637	0.508	0.528
Traffic accidents	0.717	0.484	0.468	0.508
Suicide	0.570	0.248	0.184	0.235
Alcohol-related diseases	0.783	0.574	0.635	0.600
Other diseases	0.800	0.708	0.581	0.412

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 correlations significant at 0.1% level

Table B.5 Contribution of cause-specific mortality to differences in life expectancy between rural and urban areas in East and West Germany; 1996–1997 and 2004–2006

	East Germany, rural–urban				West Germany, rural–urban			
	1996–1997	2004–2006	1996–1997	2004–2006	1996–1997	2004–2006	1996–1997	2004–2006
	m	m	f	f	m	m	f	f
All causes	–1.440	–1.051	–0.627	–0.381	0.590	0.570	0.174	0.298
Resp. diseases	–0.055	0.023	0.057	0.081	0.016	0.076	0.040	0.097
Cardiovascular diseases	–0.844	–0.828	–0.986	–0.902	0.088	0.048	–0.163	–0.123
Heart diseases	–0.470	–0.591	–0.377	–0.556	0.092	0.053	–0.016	–0.023
Cerebrovascular diseases	–0.254	–0.270	–0.432	–0.355	–0.033	–0.054	–0.129	–0.095
Neoplasms	–0.216	–0.222	0.079	0.131	0.154	0.169	0.100	0.158
Lung cancer	–0.050	–0.030	0.119	0.156	0.143	0.138	0.109	0.139
External causes	–0.599	–0.342	–0.155	–0.051	–0.244	–0.204	–0.047	–0.035
Traffic accidents	–0.484	–0.280	–0.158	–0.107	–0.245	–0.178	–0.080	–0.060
Suicide	–0.084	–0.048	0.016	0.038	–0.016	–0.022	0.024	0.034
Alcohol-related diseases	–0.111	–0.001	0.058	0.068	0.199	0.144	0.131	0.085
Other diseases	0.385	0.319	0.320	0.291	0.378	0.338	0.113	0.117

Data source: Federal State Offices of Statistics Germany; Research Data Center of the Federal Statistical Office and the Federal State Offices of Statistics, Germany

Table B.6 Contribution of cause-specific mortality to differences in life expectancy between cluster "Prosperous South" and the three other clusters; 1996–1997 and 2004–2006

	Life expectancy cluster "Prosperous South" compared to					
	Wealthy West		Heterogeneous Germany		Laggard East	
	1996–1997	2004–2006	1996–1997	2004–2006	1996–1997	2004–2006
Males						
All causes	–1.045	–1.234	–2.171	–2.250	–4.036	–3.651
Respiratory diseases	–0.132	–0.137	–0.208	–0.222	–0.222	–0.191
Cardiovascular diseases	–0.411	–0.510	–1.054	–0.901	–1.802	–1.523
Heart diseases	–0.308	–0.360	–0.756	–0.582	–1.233	–1.021
Cerebrovascular diseases	–0.010	–0.037	–0.133	–0.071	–0.317	–0.213
Neoplasms	–0.238	–0.279	–0.379	–0.515	–0.673	–0.844
Lung cancer	–0.167	–0.170	–0.295	–0.290	–0.397	–0.388
External causes	–0.064	–0.032	–0.112	–0.054	–0.612	–0.269
Traffic accidents	–0.055	–0.033	–0.072	–0.017	–0.364	–0.134
Suicide	0.020	0.022	0.004	0.019	–0.057	0.014
Alcohol-related diseases	–0.034	–0.007	–0.164	–0.125	–0.508	–0.339
Other diseases	–0.166	–0.270	–0.255	–0.432	–0.221	–0.486
Females						
All causes	–0.693	–0.921	–1.415	–1.557	–2.413	–2.130
Respiratory diseases	–0.067	–0.100	–0.084	–0.150	–0.058	–0.089
Cardiovascular diseases	–0.414	–0.437	–0.966	–0.778	–1.726	–1.345
Heart diseases	–0.294	–0.271	–0.657	–0.446	–1.054	–0.780
Cerebrovascular diseases	–0.024	–0.053	–0.150	–0.084	–0.423	–0.265
Neoplasms	–0.151	–0.190	–0.203	–0.260	–0.243	–0.282
Lung cancer	–0.042	–0.073	–0.085	–0.118	–0.048	–0.063
External causes	0.009	–0.001	0.023	0.002	–0.117	–0.036
Traffic accidents	–0.013	–0.008	–0.019	0.000	–0.117	–0.045
Suicide	0.017	0.011	0.022	0.016	0.032	0.034
Alcohol-related diseases	–0.015	–0.001	–0.066	–0.035	–0.144	–0.077
Other diseases	–0.055	–0.192	–0.118	–0.336	–0.124	–0.301

Data source: Federal State Offices of Statistics Germany; Research Data Center of the Federal Statistical Office and the Federal State Offices of Statistics, Germany

Table B.7 ICD-9 and ICD-10 codes for health-care- and health behavior-related causes of death

Causes of death	ICD-10	ICD-9	Age group
Causes amenable to health care			
Intestinal infection	A00–A09	001–009	0–14
Tuberculosis	A15–A19, B90	010–018, 137	0–74
Other infectious diseases (diphtheria, tetanus, poliomyelitis)	A36, A35, A80	032, 037, 045	0–74
Whooping cough	A37	33	0–14
Septicemia	A40, A41	38	0–74
Measles	B05	55	1–14
Malignant neoplasm of colon and rectum	C18–C21	153, 154	0–74
Malignant neoplasm of skin	C44	173	0–74
Malignant neoplasm of breast	C50	174	0–74
Malignant neoplasm of cervix uteri	C53	180	0–74
Malignant neoplasm of cervix uteri and body of the uterus	C54, C55	179, 182	0–44
Malignant neoplasm of the testis	C62	186	0–74
Hodgkin's diseases	C81	201	0–74
Leukemia	C91–C95	204–208	0–44
Diseases of the thyroid	E00–E07	240–246	0–74
Diabetes mellitus	E10–E14	250	0–49
Epilepsy	G40–G41	345	0–74
Chronic rheumatic heart disease	I05–I09	393–398	0–74
Hypertensive diseases	I10–I13, I15	401–405	0–74
Ischemic heart diseases[a]	I20–I25	410–414	0–74
Cerebrovascular diseases	I60–I69	430–438	0–74
Respiratory diseases (excl. influenza and pneumonia)	J00–J09, J20–J99	460–479, 488–519	1–14
Influenza	J10–J11	487	0–74
Pneumonia	J12–J18	480–486	0–74
Peptic ulcer	K25–K27	531–533	0–74
Appendicitis	K35–K38	540–543	0–74
Abdominal hernia	K40–K46	550–553	0–74
Cholelithiasis and cholecystitis	K80–K81	574–575.1	
Nephritis and nephrosis	N00–N07, N17–N19,	580–589	0–74
	N25–N27	580–589	0–74
Benign prostatic hyperplasia	N40	600	0–74
Maternal deaths	O00–O99	630–676	All
Congenital cardiovascular anomalies	Q20–Q28	745–747	0–74
Perinatal deaths (excl. stillbirths)	P00–P96, A33, A34	760–779	All
Misadventures to patients during surgical and medical care	Y60–Y69, Y83, Y84	E870–E876, E878–E879	All
Causes amenable to health behavior			
Malignant neoplasm of trachea, bronchus, and lung	C33, C34	162	0–74
Cirrhosis of liver	K70, K73–K74	571	0–74

Source: Nolte and McKee (2004, p. 66) and Nolte et al. (2002, p. 1907)

[a]Half of deaths included

Table B.8 Correlation coefficients between the explanatory variables selected for the pooled cross-sectional time series analysis; 1996–2006 (pooled)

	1.	2.	3.	4.	5.	6.	7.
1. GDP p.c. (in 1,000 euro)	1						
2. Income p.c. (in 1,000 euro)	0.49	1					
3. Living space (in m^2)	0.12	0.40	1				
4. % school graduates w/o degree	–0.18	–0.42	–0.16	1			
5. % annual population change	0.08	0.26	0.17	–0.18	1		
6. Health policy, males	–0.18	–0.47	–0.43	0.28	–0.25	1	
7. Health policy, females	0.05	–0.14	–0.25	0.13	–0.09	0.36	1

Data source: See Table 4.3 for more information and data sources of variables
All correlations significant at 0.1% level

Table B.9 Mean and standard deviation (SD) of district-level 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	
Variable	Mean	SD	Mean	SD	Mean	SD
e_0 males (in years)	75.23	1.78	75.71	1.51	73.81	1.73
e_0 females (in years)	81.20	1.18	81.39	1.07	80.68	1.31
GDP p.c. (in 1,000 euro)	23.47	9.57	25.67	9.90	17.05	4.21
% annual population change	–0.02	1.26	0.22	0.55	–0.74	2.16
% school graduates w/o degree	9.10	2.65	8.50	2.31	10.83	2.81
Income p.c. (in 1,000 euro)	16.82	2.30	17.75	1.88	14.11	0.79
Living space p.c. (in m^2)	39.26	3.84	40.67	3.09	35.16	2.69
Health policy, males	19.83	2.39	19.14	2.01	21.83	2.30
Health policy, females	17.81	2.31	17.68	2.25	18.18	2.43

Data source: See Table 4.3 for more information and data sources of variables

Table B.10 Mean and standard deviation (SD) of district-level life expectancy and explanatory variables selected for pooled cross-sectional time series analysis, Germany; 1996–2006

	e_0 males (in years)		e_0 females (in years)		GDP p.c. (in 1,000 euro)		% annual population change		% school graduates w/o degree	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1996	73.40	1.60	79.89	1.06	21.03	8.30	0.31	0.96	8.95	2.48
1997	73.90	1.57	80.29	1.00	21.45	8.48	0.17	0.98	9.08	2.52
1998	74.32	1.41	80.58	0.98	22.08	8.94	0.04	0.98	9.31	2.58
1999	74.64	1.36	80.82	0.88	22.60	9.16	–0.02	3.14	9.26	2.66
2000	74.94	1.42	81.10	0.94	23.17	9.48	0.02	0.86	9.63	2.78
2001	75.38	1.35	81.36	0.89	23.65	9.72	0.03	0.88	10.13	3.24
2002	75.55	1.43	81.39	0.93	24.00	9.61	0.02	0.85	9.50	2.58
2003	75.62	1.41	81.49	0.87	24.18	9.69	–0.07	0.95	9.17	2.57
2004	76.31	1.43	82.02	0.89	24.75	9.84	–0.18	0.68	8.57	2.43
2005	76.50	1.38	82.04	0.86	25.15	10.16	–0.21	0.72	8.37	2.25
2006	76.92	1.36	82.28	0.89	26.08	10.51	–0.35	0.67	8.11	2.35

(continued)

Table B.10 (continued)

	Income p.c. (in 1,000 euro)		Living space (in m^2)		Health policy, males		Health policy, females	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1996	16.22	2.25	36.76	3.72	20.87	2.54	19.07	2.24
1997	16.21	2.20	37.34	3.63	20.81	2.45	19.05	2.29
1998	16.25	2.33	37.90	3.57	20.29	2.38	18.15	2.25
1999	16.69	2.27	38.48	3.54	20.05	2.48	18.14	2.16
2000	17.04	2.28	39.02	3.52	20.04	2.28	18.00	2.20
2001	17.06	2.29	39.43	3.47	19.91	2.22	17.91	2.26
2002	16.96	2.21	39.80	3.45	19.66	2.25	17.43	2.25
2003	17.10	2.19	40.17	3.47	19.23	2.18	16.89	2.00
2004	17.09	2.24	40.59	3.53	19.38	2.31	17.43	2.15
2005	17.10	2.35	40.97	3.59	18.89	2.15	16.93	2.10
2006	17.25	2.38	41.41	3.67	19.00	2.13	17.00	2.18

Data source: See Table 4.3 for more information and data sources of variables

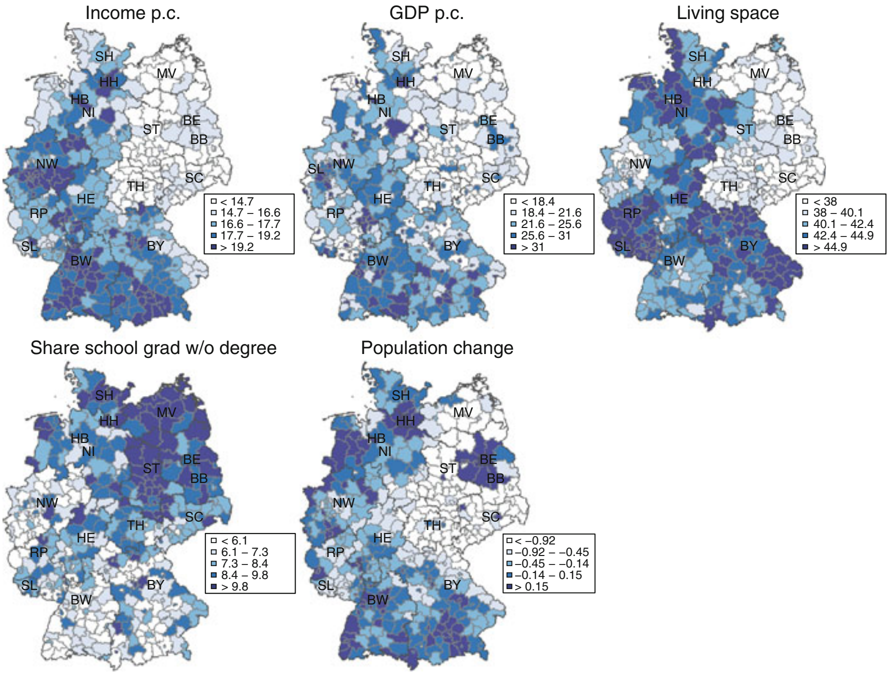

Fig. B.26 Context indicators by district: income p.c., GDP p.c., living space, share school graduates without degree, population change; 2006. *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western Pomerania, *SC* Saxony, *ST* Saxony-Anhalt, *TH* Thuringia (see Table 4.3 for data sources of variables. Base map: German Federal Agency for Cartography and Geodesy 2007)

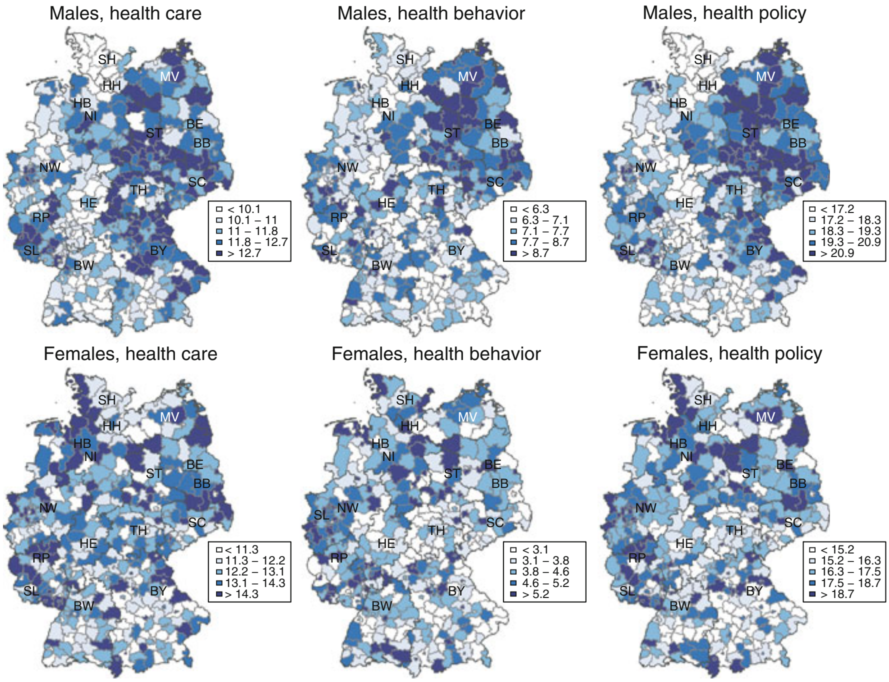

Fig. B.27 Health care, health behavior, and health policy by district: share of respective deaths in all deaths (SDR); 2006. *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *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; 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)

Table B.11 R^2 in stepwise regression models with BE, FE, RE specification; variables added according to greatest further improvement of respective R^2; 1996–2006

	Males				Females		
BE	Within	*Between*	Overall		Within	*Between*	Overall
Health policy	0.144	0.678	0.377	Income	0.309	0.345	0.212
+ Income	0.198	0.763	0.488	+ Health policy	0.250	0.454	0.331
+ School grad.	0.207	0.770	0.500	+ GDP	0.255	0.479	0.345
+ GDP	0.212	0.776	0.503	+ School grad.	0.256	0.495	0.352
+ Pop. change	0.194	0.778	0.497	+ Living space	0.236	0.497	0.341
+ Living space				+ Pop. change			
= All var.	0.174	0.780	0.485	= All var.	0.221	0.498	0.333
FE	*Within*	Between	Overall		*Within*	Between	Overall
Health policy	0.763	0.678	0.410	Health policy	0.652	0.181	0.425
+ Living space	0.764	0.337	0.462	+ Living space	0.653	0.112	0.435
+ Income	0.764	0.515	0.526	+ Income	0.654	0.259	0.494
+ GDP	0.764	0.405	0.496	+ BIP	0.654	0.178	0.462
+ School grad.	0.764	0.425	0.503	+ School grad.	0.654	0.169	0.459
+ Pop. change				+ Pop. change			
= All var.	0.764	0.422	0.500	= All var.	0.648	0.161	0.452
RE	Within	Between	*Overall*		Within	Between	*Overall*
Income	0.755	0.540	0.622	Income	0.634	0.345	0.516
+ Health policy	0.756	0.626	0.675	+ Health policy	0.651	0.421	0.554
+ School grad.	0.756	0.640	0.682	+ GDP	0.651	0.431	0.558
+ Living space	0.758	0.638	0.686	+ School grad.	0.650	0.436	0.560
+ GDP	0.758	0.639	0.688	+ Pop. change	0.650	0.437	0.560
+ Pop. change				+ Living space			
= All var.	0.758	0.641	0.689	= All var.	0.651	0.425	0.557

Data source: See Table 4.3 for more information and data sources of variables

Appendix C: Determinants of Old-Age Mortality

Table C.1 Percentage distribution of population exposure (P) and deaths (D) for cross tabulation of type of health insurance by earning points and type of former occupation by earning points; original and final sample; 1998, 2001, 2004 (pooled)

	Original data				Final sample			
	Males		Females		Males		Females	
	P	D	P	D	P	D	P	D
Type of health insurance * earning points								
PMI								
0–29	54.1	64.0	85.2	88.5				
30–44	13.2	13.9	8.5	6.7	28.3	38.5	57.1	57.9
44–54	7.8	6.3	3.2	2.6	16.8	17.5	21.6	22.5
55+	25.0	15.8	3.2	2.3	54.8	44.0	21.3	19.6
CHI								
0–29	11.3	13.4	72.7	79.8				
30–44	25.4	28.4	22.2	16.4	27.8	32.3	81.6	81.1
44–54	31.2	29.6	3.5	2.6	35.5	34.4	13.0	12.8
55+	32.2	28.6	1.5	1.2	36.7	33.3	5.5	6.1
Other								
0–29	77.9	77.7	98.3	97.6				
30–44	12.5	11.7	1.3	1.9	55.5	50.5	77.9	77.2
44–54	4.1	3.4	0.2	0.3	18.7	16.0	13.7	12.4
55+	5.5	7.1	0.1	0.2	25.8	33.6	8.4	10.5
Type of former occupation * earning points								
Blue-collar								
0–29	22.2	23.0	83.5	87.9				
30–44	30.8	33.1	15.8	11.7	38.7	42.4	96.0	96.3
44–54	31.8	29.2	0.6	0.4	41.6	38.3	3.5	3.3
55+	15.1	14.7	0.1	0.1	19.8	19.3	0.5	0.4
White-collar								
0–29	14.5	14.3	63.3	68.4				
30–44	14.0	16.7	26.4	22.3	16.2	19.3	71.7	70.5
44–54	20.3	21.3	7.0	6.1	23.7	24.8	19.0	19.3
55+	51.1	47.8	3.4	3.2	60.1	55.9	9.3	10.2
Miner								
0–29	6.4	5.9	62.6	74.9				
30–44	19.9	23.5	31.5	21.9	20.6	24.6	84.1	87.0
44–54	35.9	38.2	4.2	2.3	38.5	40.8	11.2	9.1
55+	37.9	32.4	1.7	1.0	40.9	34.6	4.7	3.9

Data source: FDZ-RV SUFRTBNRTWF94-04TDemoKibele

Table C.2 Mean, standard deviation (SD), minimum and maximum of district-level contextual variables; 1995–2003 (pooled)

Variable	Mean	SD	Min.	Max.	Source
Economy					
Unemployment rate	10.5	4.7	3.8	23.2	A
Income per capita	16,630.0	2,244.3	12,193.5	27,736.6	B
GDP per capita	22.5	9.0	11.2	67.4	B
% employed	33.3	2.5	25.7	40.2	B
% employed sec. sector	0.3	0.1	0.1	0.6	B
% employed tert. sector	0.6	0.1	0.0	0.9	B
Net business registrations	114.4	73.0	−151.9	432.0	B
Social conditions					
Voter turnout	79.0	4.3	65.2	86.9	B
Living space	38.4	3.5	30.1	48.9	B
Detached housing	81.6	12.6	40.8	97.0	B
Divorce rate	444.0	598.1	62.4	9,471.8	D
Welfare recipients	285.7	158.3	41.2	1,137.0	B
Education					
% empl. w university degree	17.3	4.7	8.2	31.8	B
% empl. w/o degree	7.7	3.5	2.9	23.7	B
% school graduates w *Abitur*	23.0	7.8	0.0	52.4	B
% school grad. w/o degree	9.3	2.3	3.6	15.5	B
Population					
% annual population change	0.8	6.6	−35.0	29.7	E
Net migration	2.3	6.4	−32.8	25.2	B
Population density	509.2	657.9	40.9	3,922.2	B
Urban vs. rural district	na	na	1	2	B
Population forecast 2010	99.4	4.8	81.1	113.4	F
Health care and traffic accidents					
Hospital beds	6.9	3.9	0.0	24.3	B
Physicians	140.5	44.4	76.1	336.4	B
Traffic accidents	651.4	109.1	401.3	1,042.4	B
Fatal traffic accidents	1,736.7	826.0	378.4	4,139.2	B

Data sources: A-Bundesagentur für Arbeit; B-Regionaldatenbank Deutschland; D-Deutsches Jugendinstitut, Regionaldatenbank; E-Federal State Offices of Statistics, Germany; F-INKAR
See Table 4.3 for more information

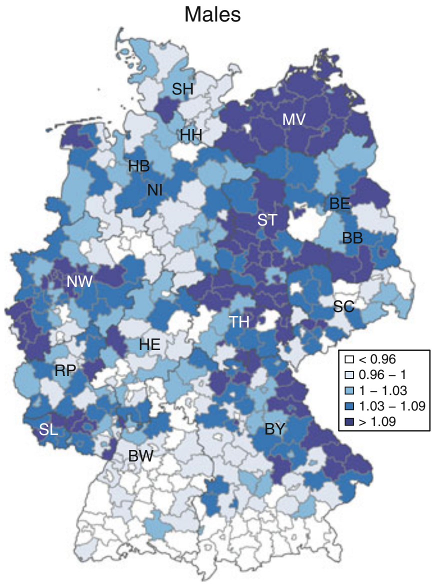

Fig. C.1 Age-standardized MRR by district, sample without income restriction; 1998, 2001, 2004 (pooled). *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western Pomerania, *SN* Saxony, *ST* Saxony-Anhalt, *TH* Thuringia (Data source: FDZ-RV SUFRTBNRTWF94-04TDemoKibele. Base map: German Federal Agency for Cartography and Geodesy 2007)

Table C.3 Single-level models: log likelihood in various models with individual-level covariates; final sample and sample without income restriction; 1998, 2001, 2004 (pooled)

	Final sample		Sample without income restriction	
Variables in the model	Males	Females	Males	Females
Age	−197,215	−65,696	−268,939	−178,431
Age + Occupation	−190,591	−64,891	−261,258	−174,701
Age + Health insurance	−194,582	−65,372	−265,500	−176,115
Age + Retirement age	−178,655	−62,679	−246,203	−160,623
Age + Earning points	−190,005	−65,376	−261,712	−177,988
Age + All individual-level covariates	−170,965	−61,325	−236,733	−155,461

Data source: FDZ-RV SUFRTBNRTWF94-04TDemoKibele

Table C.4 Single-level models: MRRs by individual-level variables with 95% confidence intervals (in parentheses); 1998, 2001, 2004 (pooled)

	Males		Females	
	Model 1	Model 2	Model 1	Model 2
Occupation				
White-collar	1	1	1	1
Blue-collar	**1.35**	**1.18**	**1.22**	**1.19**
	(1.34; 1.36)	(1.18; 1.19)	(1.21; 1.24)	(1.18; 1.21)
Miner	**1.34**	**1.10**	**1.12**	**1.09**
	(1.33; 1.36)	(1.09; 1.11)	(1.08; 1.16)	(1.05; 1.13)
Health insurance				
PMI	1	1	1	1
CHI	**1.54**	**1.35**	**1.48**	**1.37**
	(1.52; 1.56)	(1.33; 1.37)	(1.44; 1.53)	(1.32; 1.41)
Other	**2.21**	**2.07**	**1.73**	**1.76**
	(2.12; 2.31)	(1.98; 2.15)	(1.57; 1.91)	(1.59; 1.94)
Retirement age				
65+	1	1	1	1
60–64	**1.07**	**1.04**	**1.02**	1.00
	(1.06; 1.07)	(1.04; 1.05)	(1.01; 1.04)	(0.99; 1.02)
Before 60	**1.93**	**1.75**	**1.63**	**1.61**
	(1.91; 1.94)	(1.74; 1.77)	(1.60; 1.67)	(1.57; 1.65)
Missing	**0.18**	**0.18**	**0.08**	**0.08**
	(0.17; 0.19)	(0.17; 0.19)	(0.06; 0.09)	(0.07; 0.09)
Earning points				
30–44	1	1	1	1
45–54	**0.87**	**0.91**	**0.89**	**0.96**
	(0.87; 0.88)	(0.90; 0.91)	(0.87; 0.90)	(0.94; 0.97)
55+	**0.69**	**0.80**	**0.82**	**0.91**
	(0.69; 0.70)	(0.79; 0.80)	(0.80; 0.83)	(0.89; 0.93)

Data source: FDZ-RV SUFRTBNRTWF94-04TDemoKibele
Model 1: controlled for age
Model 2: controlled for age and all other individual-level variables
Bold figures indicate values significant at 5% level

Table C.5 Single-level models: MRRs by individual-level variables with 95% confidence intervals (in parentheses); sample without income restriction; 1998, 2001, 2004 (pooled)

	Males		Females	
	Model 1	Model 2	Model 1	Model 2
Occupation				
White-collar	1	1	1	1
Blue-collar	**1.35**	**1.19**	**1.21**	**1.19**
	(1.34; 1.35)	(1.18; 1.19)	(1.20; 1.21)	(1.19; 1.20)
Miner	**1.34**	**1.10**	**1.09**	**1.05**
	(1.33; 1.35)	(1.09; 1.12)	(1.07; 1.11)	(1.03; 1.06)

(continued)

Table C.5 (continued)

	Males		Females	
	Model 1	Model 2	Model 1	Model 2
Health insurance				
PMI	1	1	1	1
CHI	**1.35**	**1.29**	**1.44**	**1.35**
	(1.34; 1.36)	(1.28; 1.31)	(1.44; 1.46)	(1.34; 1.37)
Other	**1.84**	**1.83**	**1.44**	**1.45**
	(1.80; 1.88)	(1.79; 1.87)	(1.41; 1.46)	(1.42; 1.47)
Retirement age				
65+	1	1	1	1
60–64	**1.07**	**1.05**	1.01	**1.02**
	(1.07; 1.08)	(1.05; 1.06)	(1.00; 1.01)	(1.01; 1.02)
Before 60	**1.90**	**1.76**	**1.61**	**1.63**
	(1.89; 1.92)	(1.75; 1.77)	(1.60; 1.62)	(1.62; 1.64)
Missing	**0.18**	**0.19**	**0.11**	**0.12**
	(0.17; 0.19)	(0.18; 0.20)	(0.10; 0.11)	(0.11; 0.12)
Earning points				
0–29	1	1	1	1
30–44	**1.17**	**1.05**	0.99	**1.02**
	(1.16; 1.18)	(1.04; 1.06)	(0.99; 1.00)	(1.01; 1.03)
45–54	**1.02**	**0.95**	**0.88**	**0.97**
	(1.01; 1.03)	(0.94; 0.96)	(0.87; 0.89)	(0.96; 0.99)
55+	**0.81**	**0.84**	**0.81**	**0.93**
	(0.80; 0.82)	(0.83; 0.85)	(0.79; 0.82)	(0.91; 0.94)

Data source: FDZ-RV SUFRTBNRTWF94-04TDemoKibele
Model 1: controlled for age
Model 2: controlled for age and all other individual-level variables
Bold figures indicate values significant at 5% level

Table C.6 Multilevel models: MRRs by individual-level variables with 95% confidence intervals (in parentheses); sample without income restriction; 1998, 2001, 2004 (pooled)

	Males		Females	
	Model 1	Model 2	Model 1	Model 2
Occupation				
White-collar	1	1	1	1
Blue-collar	**1.34**	**1.18**	**1.21**	**1.19**
	(1.33; 1.35)	(1.15; 1.19)	(1.21; 1.22)	(1.19; 1.20)
Miner	**1.26**	**1.11**	**1.03**	1.01
	(1.24; 1.27)	(1.10; 1.12)	(1.02; 1.05)	(1.00; 1.03)
Health insurance				
PMI	1	1	1	1
CHI	**1.37**	**1.28**	**1.45**	**1.35**
	(1.35; 1.38)	(1.27; 1.30)	(1.44; 1.47)	(1.34; 1.37)
Other	**1.60**	**1.59**	**1.44**	**1.43**
	(1.55; 1.64)	(1.55; 1.63)	(1.42; 1.46)	(1.41; 1.45)

(continued)

Table C.6 (continued)

	Males		Females	
	Model 1	Model 2	Model 1	Model 2
Retirement age				
65+	1	1	1	1
60–64	**1.13**	**1.11**	1.00	**1.01**
	(1.13; 1.14)	(1.11; 1.12)	(0.98; 1.01)	(1.01; 1.02)
Before 60	**1.91**	**1.76**	**1.59**	**1.61**
	(1.89; 1.92)	(1.75; 1.77)	(1.58; 1.60)	(1.60; 1.62)
Missing	**0.23**	**0.23**	**0.10**	**0.11**
	(0.22; 0.24)	(0.23; 0.24)	(0.10; 0.11)	(0.10; 0.11)
Earning points				
0–29	1	1	1	1
30–44	**1.14**	**1.02**	**0.99**	**1.02**
	(1.13; 1.15)	(1.01; 1.03)	(0.98; 0.99)	(1.01; 1.02)
45–54	**0.97**	**0.91**	**0.87**	**0.97**
	(0.96; 0.98)	(0.90; 0.92)	(0.86; 0.99)	(0.95; 0.98)
55+	**0.77**	**0.80**	**0.80**	**0.93**
	(0.76; 0.78)	(0.79; 0.81)	(0.78; 0.82)	(0.91; 0.95)

Data source: FDZ-RV SUFRTBNRTWF94-04TDemoKibele
Model 1: controlled for age
Model 2: controlled for age and all other individual-level variables
Bold figures indicate values significant at 5% level

Table C.7 Multilevel models: Log likelihood (LL), constant (β_0), and random part (u_{0j}) in the models including age and further inclusion of another individual-level covariate; sample without income restriction; 1998, 2001, 2004 (pooled)

	Males				Females			
	LL	β_0	u_{0j}	%	LL	β_0	u_{0j}	%
Age	−236,991	−3.806	0.070	1.84	−169,640	−4.685	0.070	1.49
+ Occupation	−233,596	−4.007	0.065	1.62	−166,786	−4.802	0.071	1.49
+ Health insurance	−235,639	−4.078	0.062	1.51	−167,889	−5.038	0.066	1.31
+ Retirement age	−226,862	−4.023	0.086	2.14	−156,414	−4.748	0.063	1.32
+ Earning points	−233,249	−3.784	0.080	2.12	−169,343	−4.674	0.069	1.47
+ All indiv.-level cov.	−221,595	−4.255	0.088	2.06	−152,122	−5.150	0.061	1.18

Data source: FDZ-RV SUFRTBNRTWF94-04TDemoKibele

Abbreviations

A	Age
BB	Brandenburg
BE	Berlin
BE	Between-effects (in panel analysis)
BEE	Berlin East
BEW	Berlin West
BIC	Bayesian Information Criterion
BW	Baden-Württemberg
BY	Bayern (Bavaria)
C. of	Cancer of
CHI	Compulsory health insurance
COD	Cause(s) of death
CrLIA	Cross-level interaction (in multilevel modeling)
CVD	Cardiovascular diseases
D	Deaths
df	Degrees of freedom
DMM	Dispersion measure of mortality
DRV	Deutsche Rentenversicherung (German Federal Pension Fund)
EU	European Union
f	females
FE	Fixed-effects (in panel analysis)
FRG	Federal Republic of Germany
FS	Federal state
GDP	Gross domestic product
GDR	German Democratic Republic
GSOEP	German Socio-Economic Panel Study
HB	Bremen
HE	Hesse
HH	Hamburg
IHD	Ischemic Heart Diseases

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ICD	International classification of diseases
IMR	Infant mortality rate
IQR	Inter-quartile range
LKR	Landkreis (rural district)
LL	Log likelihood
m	males
MRR	Mortality rate ratio
MV	Mecklenburg-Vorpommern (Mecklenburg-Western Pomerania)
NI	Niedersachsen (Lower Saxony)
NW	North Rhine-Westphalia
NUTS	Nomenclature of Statistical Territorial Units
OECD	Organisation for Economic Cooperation and Development
OLS	Ordinary Least Squares
P	Population
p.c.	per capita
PMI	Private medical insurance
PY	Person years
RC	Random coefficient
RE	Random-effects (in panel analysis)
RP	Rhineland-Palatinate
S_{10}	Standard deviation of ages at death above age 10
SD	Standard deviation
SDR	Standardized death rate
SES	Socioeconomic status
SH	Schleswig-Holstein
SKR	Stadtkreis (urban district)
SL	Saarland
SN	Sachsen (Saxony)
ST	Saxony-Anhalt
T	Time
TH	Thuringia
UK	United Kingdom
USA	United States of America
WHO	World Health Organization

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