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 socioeconomic 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?