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

5.1 Introduction

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

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

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

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

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5.1.1 Review of Multilevel Modeling in Health Research

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

5.1.1.1 From Single- to Multilevel Approaches

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

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

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

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

5.1.1.2 Existing Multilevel Studies on Health in Germany

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

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

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

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

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

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

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

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

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

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

5.1.1.3 Some International Evidence

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

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

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

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

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

Table 5.1 Study descriptions of selected multilevel mortality studies

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

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

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

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

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

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

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

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

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

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

5.2 Data

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

5.2.1 Data from the German Federal Pension Fund

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5.2.2 Variables in the Pension Insurance Dataset

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

The following variables are considered in the study.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5.2.3 Selection of the Study Population

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

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

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

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

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

Data source: FDZ-RV SUFRTBNRTWF94-04TDemoKibele

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

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

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

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

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

(continued)

Table 5.3 (continued)

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

Data source: FDZ-RV SUFRTBNRTWF94-04TDemoKibele

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

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

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

5.2.4 Distribution of Population Exposures and Deaths

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

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

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

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

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

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

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

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

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

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

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

5.2.5 Contextual Factors

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

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

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

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

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

5.3 Method

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

5.3.1 Theoretical Aspects

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

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

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

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

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

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

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

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

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

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

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

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

5.3.2 Multilevel Poisson Model

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5.4 Results

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

5.4.1 Single-Level Models: Mortality Across Districts

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

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

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

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

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

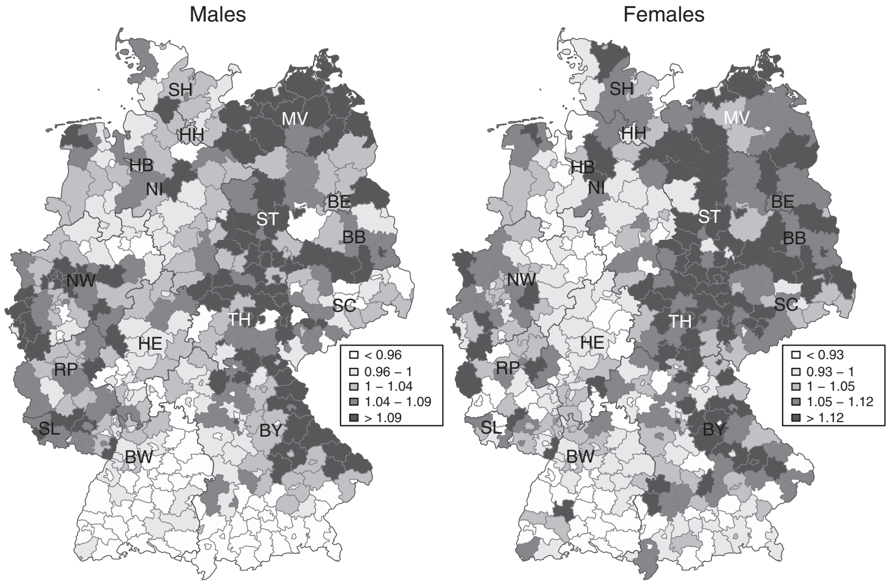

Fig. 5.1 Age-standardized MRR by district; 1998, 2001, 2004 (pooled). *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western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

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

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

5.4.2 Multilevel Models: Individual-Level Fixed Effects

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

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

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

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

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

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

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

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

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

Data source: FDZ-RV SUFRTBNRTWF94-04TDemoKibele

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

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

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

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

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

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

5.4.3 Multilevel Models: District-Level Random Effects

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

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

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

5.4.4 Multilevel Models: Context Effects

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

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

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

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

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

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

[a] Convergence not achieved, no significance level derived

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

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

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

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

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

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

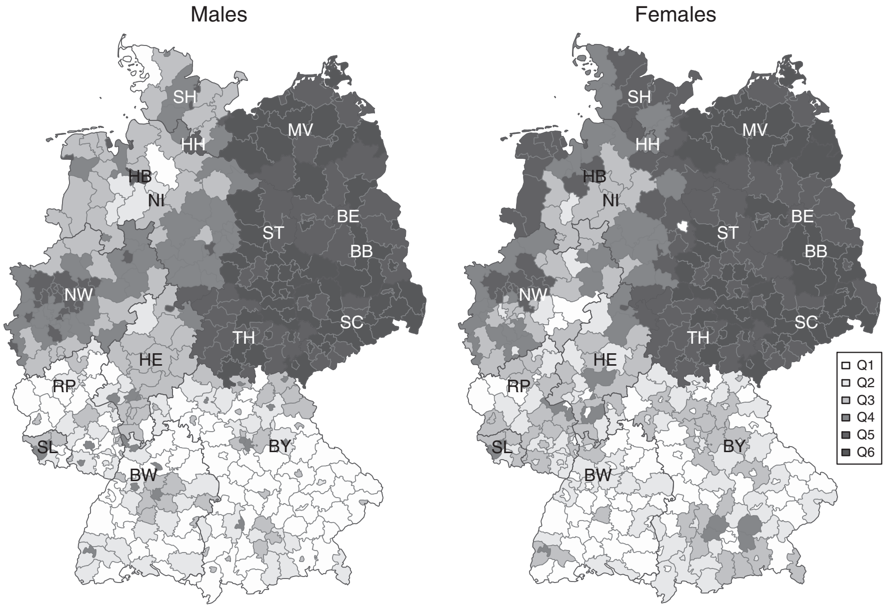

Fig. 5.2 Sex-specific mortality context scores by district (sextiles). *SH* Schleswig-Holstein, *HH* Hamburg, *NI* Lower Saxony, *HB* Bremen, *NW* North Rhine-Westphalia, *HE* Hesse, *RP* Rhineland-Palatinate, *BW* Baden-Württemberg, *BY* Bavaria, *SL* Saarland, *BE* Berlin, *BB* Brandenburg, *MV* Mecklenburg-Western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

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

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

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

5.4.5 Multilevel Models: Cross-Level Interactions

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

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

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

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

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

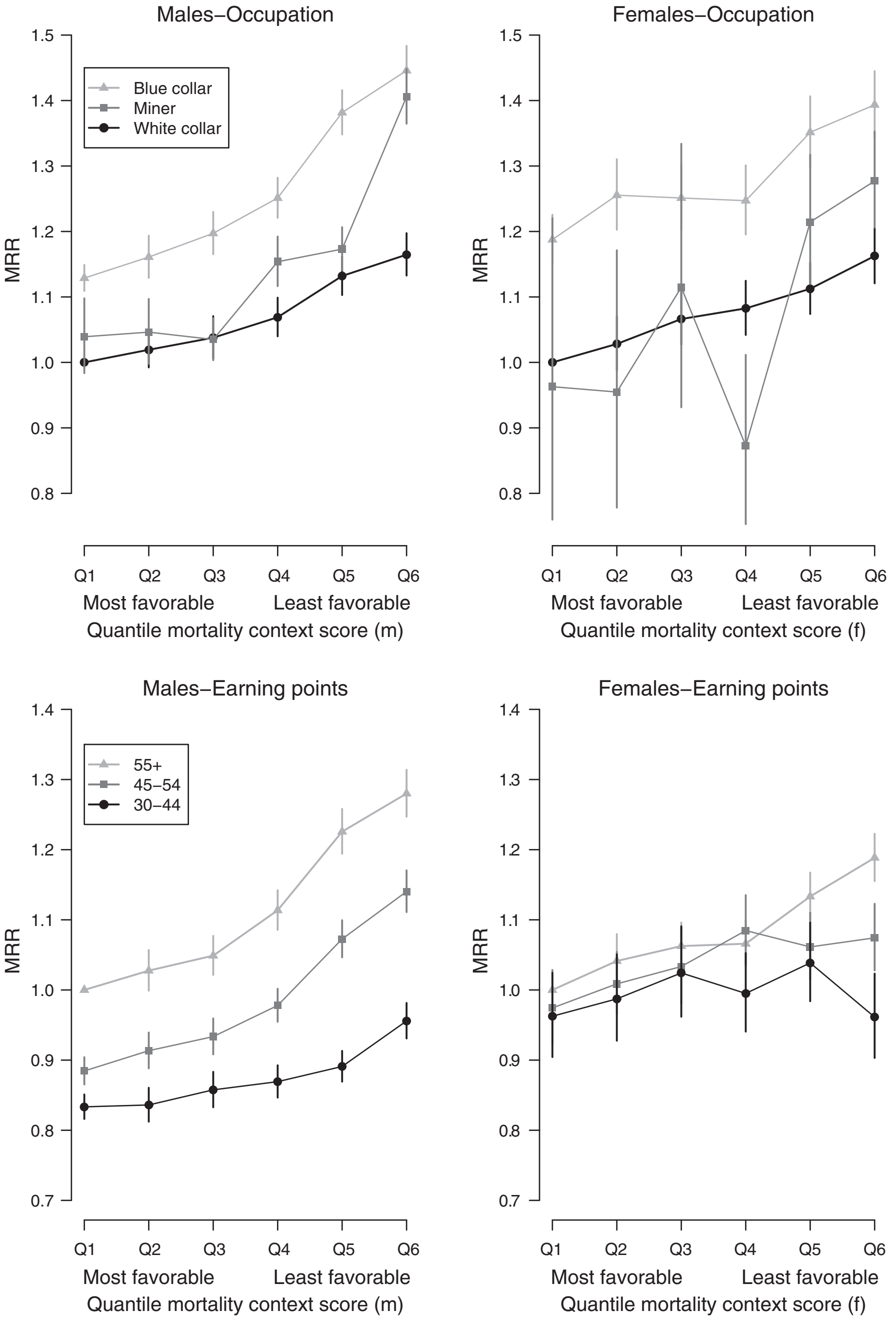

Fig. 5.3 Multilevel models: MRRs with 95% confidence intervals of cross-level interactions between the sextiles of sex-specific mortality context score and occupation and between the sextiles of sex-specific mortality context score and earning points; models controlled for all individual-level variables;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

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

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

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

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

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

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

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

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

(continued)

Table 5.8 (continued)

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

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

5.5 Summary

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

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

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

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

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

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

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

5.6 Discussion

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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