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District-Level Mortality Convergence in Reunified Germany: Long-Term Trends and Contextual Determinants

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ABSTRACT The mortality gap between former East and West Germany decreased rapidly in the decade following the reunification of the country in 1990. However, because no previous study has estimated life expectancy (e_0) over time for all German districts, the extent of mortality convergence across districts and its determinants are largely unknown. We used a novel relational Bayesian model to estimate district e_0 in Germany during 1997–2016, examined mortality convergence using a novel convergence groups approach, and explored the role of selected district characteristics in the process. Differences in e_0 between German districts decreased for both sexes during 1997–2016, mainly driven by rapid mortality improvements in eastern German districts. However, considerable heterogeneity in district-level e_0 trajectories within federal states was evident. For example, district clusters in northwestern Germany showed increasing e_0 disadvantage, which led to a north–south divergence in mortality. A multinomial regression analysis showed a robust association between the e_0 trajectory and the district-level tax base and long-term unemployment but not with hospital density. Thus, an equitable "leveling up" of health seems possible with policies investing in places and the people who inhabit them.

KEYWORDS Regional mortality disparities • Small-area studies • German reunification • Regional development • Political epidemiology

Introduction

The mortality gap between former East and West Germany closed rapidly in the decade following the country's reunification in 1990 (Grigoriev and Pechholdová 2017; Vogt 2013). Postreunification mortality convergence and its potential drivers have been studied extensively for the former states (e.g., Grigoriev et al. 2021). However, the extent of long-term mortality convergence across districts and its determinants are largely unknown. Such information could provide key insights into how reunification policies and regional characteristics shape mortality convergence over time (Razum et al. 2008) and help guide the federal government's regional development policy (Hrzic and Brand 2020).

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Most previous research on the drivers of postreunification mortality convergence focused on comparisons of the former East and West Germany, where data availability allowed researchers to characterize mortality dynamics before, during, and after reunification. At the time of reunification, the East–West German mortality gap was at its historical maximum and dominated by the East German disadvantage in cardiovascular deaths (especially cerebrovascular deaths) in middle and older ages for both sexes and external and digestive system causes of death among younger males (especially motor vehicle accidents and liver cirrhosis; Clark et al. 2000; Grigoriev and Pechholdová 2017; Grigoriev et al. 2021; Häussler et al. 1995). Cardiovascular mortality was declining in East Germany before reunification, but the more precipitous drop that contributed to the observed rapid mortality convergence did not occur until the 1990s, driven largely by a rapid reduction in cerebrovascular deaths at older ages (Grigoriev and Pechholdová 2017; Grigoriev et al. 2021). Deaths associated with motor vehicle accidents increased rapidly during reunification in East Germany for males aged 15–30 but declined to preunification levels by the late 1990s (Clark et al. 2000; Grigoriev and Pechholdová 2017; Häussler et al. 1995). Deaths due to liver cirrhosis increased until the mid-1990s among men aged 30–65 and only slowly declined, particularly for the older half of this group (Grigoriev et al. 2021).

On the basis of these trends, researchers proposed numerous potential contributors to the phenomenon of mortality convergence in Germany, including better access to modern medical technology, the improved social position of eastern German retirees, and changes in health-related behaviors (for comprehensive reviews, see Diehl 2008; Luy 2004). The many changes accompanying reunification complicate disentangling the mechanisms driving the convergence. First, welfare and monetary unification almost instantly led to significantly increased pension incomes and purchasing power for eastern Germans, especially those who were retirees (Ritter 2011; Vogt and Kluge 2015). Second, liberalized movement led to the migration of an estimated 1.2 million eastern Germans to western Germany after 1990 (Stawarz et al. 2020). Third, the solidarity tax and Solidarity Pact created substantial investment in eastern German infrastructure, including health care infrastructure (Ritter 2011; Vogt and Vaupel 2015). Finally, health-related behaviors (e.g., smoking) began shifting even before reunification (Grigoriev and Pechholdová 2017; Vogt et al. 2017).

To date, however, less research has examined regional-level postreunification mortality. Van Raalte et al. (2020) found that despite persistent differences in the economic output of German states, mortality differences between states decreased in the decade after 1991, perhaps owing to postreunification economic transfers between states. Kibele et al. (2015) examined life expectancy in German districts in 1995–1997 (the earliest period for which postreunification district mortality data are available), 2002–2004, and 2009–2011. They found a complex spatial mortality pattern. Eastern German districts caught up after reunification, with high-mortality hotspots in economically disadvantaged areas of western Germany (e.g., in the deindustrialized Ruhr area and North Sea harbor towns) and low-mortality areas emerging in eastern Germany (e.g., affluent suburbs in Brandenburg surrounding Berlin). In a study comparing postreunification mortality dynamics in districts with and without university clinics, Vogt and Vaupel (2015) showed that access to high-quality health care influenced the process of mortality convergence. Mühlichen (2019) studied district-level mortality in the German Baltic Sea region and found notable disparities between urban and rural districts. Finally, in a district-level analysis of Germany in 2015–2017, Rau and Schmertmann (2020a) found that district-level economic indicators (e.g., gross domestic product and unemployment and poverty rates) had a stronger cross-sectional association with district life expectancy than population density or physician density. Their analysis also indicated that these associations differed between districts in eastern and western Germany.

However, this literature has three key limitations. First, the analyses were limited to the aggregated level of German states (van Raalte et al. 2020), districts in eastern Germany (Vogt and Vaupel 2015), districts in two German states (Mühlichen 2019), or a few time points (Kibele et al. 2015; Rau and Schmertmann 2020a). Second, although these authors' conclusions about mortality convergence were based on comparing life expectancies and mortality rates, they did not use formal convergence measures or approaches, such as beta, sigma, or delta convergence. These measures are helpful in clarifying, formalizing, and quantifying the multifaceted notion of convergence (*cf.* Heichel et al. 2005; Hrzic et al. 2020; Mascherini et al. 2018). Finally, with the exception of the Rau and Schmertmann (2020a) analysis, previous district-level studies did not adjust for potential instability in mortality rate estimates because of small population sizes at the district level.

Thus, our objectives are systematically examining district-level mortality convergence in the decades since German reunification and, in the process, exploring the role of selected district characteristics. We begin by assessing overall mortality convergence, which we operationalize as convergence in period life expectancy at birth (henceforth, e_0), using beta and sigma convergence measures. We then examine the contribution of individual districts to the overall mortality convergence or divergence pattern by comparing each district's e_0 trajectory with the overall average trajectory (delta convergence). Finally, we explore the association between each district's e_0 trajectory and its characteristics, including its tax base, long-term unemployment rate, hospital density, and average resident age. Our analyses refer to all German districts during 1997–2016 and are stratified by sex. When our findings depart from the general trend, we also report results stratified by decade in the study (1997–2006 and 2007–2016) and by eastern and western Germany.

Our study contributes to research on mortality convergence in three ways. First, we examine whether east–west mortality convergence emerged because of equitable improvements in district-level mortality conditions or because of outsized improvements in a few districts. Second, we help clarify the association between district-level characteristics and postreunification district mortality trajectories. Finally, by interrogating the relationships between political, social, and economic integration and mortality convergence, our study adds to the broader literature on the impact of social and economic policies on spatial health disparities in high-income countries.

Data and Methods

Study Setting

Germany is organized into three administrative levels: federal states, districts, and municipalities. We focus on districts, both rural (*Landkreise* or *Kreise*) and urban (*kreisfreie Städte* or *Stadtkreise*), which are the ideal unit of analysis for our study. In addition to reflecting urban–rural dynamics, districts broadly capture the socioeconomic heterogeneity of populations within federal states. Further, district governments play a role in directing spending on infrastructure (including hospitals), welfare, and local economy (OECD/UCLG 2019). The number of districts in Germany varied during 1997–2016 but is currently 401. District populations in our data set range from fewer than 35,000 inhabitants to more than 3.5 million (in Berlin). No systematic differences in average population size exist between districts of different federal states or between eastern and western Germany.

Data

To estimate district-level e_0, we extracted district age- and sex-specific population and death counts for 1997–2016 from the German regional statistics database (Statistische Ämter des Bundes und der Länder 2021). Because of data limitations, we first adjusted the death and population counts (see the next section) and then used them in a Bayesian relational model (see the Estimation of Mortality Schedules section). The relevant data for the years preceding this period are not publicly accessible. The estimation process also required mortality schedules for eastern Germany, western Germany, and all of Germany for the same period. We calculated these schedules from the age- and sex-specific population and death counts using the Human Mortality Database (2021).

To explore associations between the districts' characteristics and their mortality trajectories, we obtained district-level information on economic conditions (tax base and long-term unemployment rate) and hospital care availability (hospital density). For each district, we extracted data on the tax potential and the long-term unemployment rate for both sexes combined from the INKAR (Indikatoren und Karten zur Raum- und Stadtentwicklung) database (Bundesinstitut für Bau-, Stadt- und Raumforschung 2021). We obtained data on the number of hospitals in each district for 1997–2016 (1998–2016 for the long-term unemployment rate owing to the unavailability of 1997 data) from the German regional statistics database (Statistische Ämter des Bundes und der Länder 2021).

Adjusting Death and Population Count Data

To calculate mortality rates by age group, we had to adjust the death and population counts to overcome four problems: differences in the data set structures for the deaths compared with the population counts, changes over time in Germany's administrative structure, districts' nonreporting of death counts in the open age category, and districts' nonreporting of cells with counts of one or two deaths.

First, we disaggregated deaths into 19 age groups (0–1, 1–4, 5–9, . . . , 80–84, and 85+) and the population count into 17 age groups (0–2, 3–5, 6–9, 10–14, 15–17, 18–19, 20–24, . . . , 60–64, 65–74, and 75+). Because of these different age groups, we used the nonstandard age groups 0–9 and 65–74 and the open age group 75+ when calculating district age-specific mortality rates.

Second, because of administrative reforms in four federal states, we consolidated death and population counts in the 37 districts into 15 new districts and recoded three districts to arrive at a longitudinal data set matching Germany's administrative structure in 2017.

Third, 162 districts did not report death counts for either sex in the age categories 75–79, 80–84, or 85+ during 1997–1999. The number of such districts decreased to 65 in 2000, to 50 in 2001–2006, and to 0 thereafter. Because all districts reported total death counts by sex, we calculated deaths at ages 75+ by subtracting from the total all deaths reported for lower age categories.

Fourth, during 1995–2008, 42–68 districts had censored cells with one or two deaths. We replaced the missing death counts in these cells with 1.5.

Further, to reduce data sparseness, we pooled the data into three-year intervals to estimate the mortality rates for the middle year. For example, we used data from 1996–1998 to estimate the rates for 1997, data from 1997–1999 to estimate the rates for 1998, and so on.

Estimation of Mortality Schedules

To estimate mortality schedules for single ages and their 95% confidence intervals (CIs) from the mortality rates by age group, we used a relational Bayesian model that Rau and Schmertmann (2020a) used to estimate district life expectancy in Germany during 2015–2017. The underlying approach is based on the tool for projecting age-specific rates using linear splines (TOPALS) model (de Beer 2012). In this case, TOPALS applies a linear spline to estimate the ratios between district age-specific probabilities of death and a smoothed standard age schedule. The log mortality at any age is thus modeled as the standard mortality schedule ($\log \mu^*_x$) plus a linear spline function:

$$\log\hat{\mu}_x = \log\mu^*_x + \mathbf{B}'_x\hat{\alpha}.$$

The model uses a B-spline with spline knots located at ages 0, 1, 10, 20, 40, 70, and 90 to estimate district mortality age schedules for single ages 0–89. The spline coefficients, α, thus correspond to deviations in the mortality age schedule from the standard at the knot locations. The standard mortality schedule was constructed from the Human Mortality Database (HMD) (2021) data for Germany.

Using the TOPALS model in a Bayesian hierarchical framework enforces a mortality schedule shape derived from the combination of the national mortality schedule and the mortality schedules of districts in the same federal state. This shape is implemented as three priors: a hierarchical spatial prior, a normal prior distribution for the differences between TOPALS coefficients (β) for consecutive age groups, and a prior for male–female differences in log mortality rates. The use of the standard mortality schedule in combination with the hierarchical spatial prior ensures that each of the six district TOPALS coefficients shares a common national mean and a common federal state deviation from the standard. This hierarchical specification enforces similarity between districts by political geography, which is a reasonable theoretical assumption given similarities in socioeconomic context and health policy.

The second prior for the differences in coefficients between consecutive age groups effectively smooths the mortality age schedules by expecting these differences to follow a normal distribution $N\left(0, \sqrt{0.5}\right)$. Smoothing has a relatively greater impact in districts with particularly large variations between adjacent age groups that arise owing to small population sizes or incomplete data (Gonzaga and Schmertmann 2016).

The third prior for male–female differences in log mortality rates per age, zone, and year ($\delta^*_{x,z,t}$) was based on empirical sex differences in HMD life tables estimated for each year in the study for western Germany, eastern Germany, or all of Germany for districts in the west of the country, east of the country, or Berlin, respectively. For more detail on the hierarchical TOPALS model, see Rau and Schmertmann (2020b).

Our model implementation closely followed the previously described canonical approach. The sole exception is that we used spline knots located at ages 0, 1, 10, 20, 40, and 70 because our open age group was 75+ and would be too distant from the seventh knot at age 90. We did not include temporal smoothing, so we treated each period as independent.

The model was fit by Markov Chain Monte Carlo sampling from the joint posterior distribution implemented via the *RStan* package (Stan Development Team 2022). To extrapolate the estimated mortality schedules and their 95% CIs to ages 85–119, we modeled mortality rates for ages 70–89 using the two-parameter Kannisto model (Thatcher et al. 1998), which is often used for this task.

Finally, we used standard methods to calculate the life expectancies at birth (e_0) and their 95% CIs for 401 German districts during 1997–2016 from the estimated mortality schedules (Preston et al. 2000). The uncertainty intervals around district e_0 point estimates, ranging from 0.15 to 0.94 years, were small enough to justify our focus only on the point estimates of district e_0, ignoring the uncertainty intervals for the rest of the analyses (see the online appendix, section 1). We used R to perform all calculations (R Core Team 2022); the code used is available online (https://github.com/rhrzic/Demography_GerDistrMortConv).

To assess the model's performance, we applied standard Markov chain diagnostics (i.e., examining trace plots for convergence and agreement between parallel chains), which did not indicate any issues with parameter estimation. In addition, we aggregated the estimated mortality schedules for all districts by year and sex to arrive at a model estimate for the national mortality schedule, which we compared with the HMD national mortality schedule by sex and year. The comparison showed that the model underestimated mortality rates in childhood and very old age categories for men—the age groups with the lowest death counts (see Figures A3 and A4, which appear in the online appendix along with all other figures and tables designated with an "A").

Assessment of Mortality Convergence

Our study examined mortality convergence across districts, which we operationalized as convergence in district e_0. Because convergence is a multidimensional phenomenon, we used different measures to examine it (Heichel et al. 2005).

Table 1 Overview of the convergence concepts used in this study

Convergence Concept	Explanation
Beta Convergence	Mortality improved faster in districts with initially lower life expectancy at the start of observation period than in districts with initially higher life expectancy.
Sigma Convergence	District life expectancy dispersion declined in the period observed.
Delta Convergence	A district's life expectancy became closer to that of a goal—for example, the country average—in the period observed.
Uniform Convergence	The life expectancy of *all* observed districts changed in line with the change in the average.
Upward Convergence	The average life expectancy across districts *improved* in the study period.

We began by examining trends in e_0 over time. Next, we assessed beta and sigma convergence to determine, respectively, whether lagging districts caught up over time and whether overall dispersion in e_0 decreased over time. This allowed us to characterize the overall district-level mortality dynamics over time as uniform or not, trending upward or downward, and moving toward convergence or divergence (Mascherini et al. 2018). *Uniform* refers to whether the average upward or downward trend in e_0 also pertained to each district. *Trending upward or downward* refers to whether the average e_0 was increasing or decreasing. *Convergence or divergence* refers to whether dispersion in e_0 was decreasing or increasing (sigma convergence), which would be enabled by laggard districts catching up (beta convergence). Our aim was to establish whether we could observe uniform upward mortality convergence, which is the most desirable scenario: it would indicate that mortality conditions were not only becoming more similar but also improving across all districts.

In the second part of the analysis, we assessed delta convergence by examining whether the e_0 trajectories of individual districts were becoming more similar to the German average district e_0 trajectory. This analysis allowed us to identify groups of districts contributing to mortality convergence or divergence and to identify district characteristics associated with particular district life expectancy trajectories. See Table 1 for an overview of the key convergence concepts used in this article.

Beta Convergence

To assess beta convergence, we examined whether e_0 improved faster in the districts with lower e_0 at the start of the observation period than in the districts with initially higher e_0 (Sala-i-Martin 1996). We did so by using linear regression to examine the association between e_0 of district i at the start of a period ($e_{0\ i,t_1}$) and the change in e_0 in district i between t_1 and t_2:

$$\Delta e_{0\ i,t_2-t_1} = \alpha + \beta\ e_{0\ i,t_1} + \varepsilon.$$

If the relationship was inverse (β was negative) and the association was statistically significant, we concluded that beta convergence occurred between t_1 and t_2.

Sigma Convergence

To assess sigma convergence, we examined whether there was a reduction in dispersion in district e_0 over time (Sala-i-Martin 1996). We measured district e_0 dispersion using the variance, which we calculated for each sex and year included in the analysis. If the variance was smaller at t_2 than at t_1, we concluded that sigma convergence occurred between t_1 and t_2. Statistical inference regarding sigma convergence can be incorporated (*cf.* Hrzic et al. 2021; Janssen et al. 2016). However, because our analysis focuses primarily on describing long-term trends instead of formal inference tests of precise hypotheses, we did not pursue the strategy in this study.

Using established one-stage decomposition procedures (Akita 2003; Shorrocks and Wan 2005), we decomposed the total variance in district e_0 into (1) the *between* component, representing the average district e_0 in eastern and western Germany; and (2) the *within* component, representing the differences between district e_0 within eastern Germany and within western Germany (Conceição and Ferreira 2000). With this step, we aimed to highlight the relative importance of changes in district mortality disparities at the level of eastern and western Germany compared with the changes in mortality disparities between districts within each part of Germany. We thereby provide additional insight into the long-term impact of postreunification policies because they largely targeted the districts in eastern Germany.

Delta Convergence (e_0 trajectory groups)

Delta convergence assesses a unit's performance in an indicator achieving a specific goal—for example, the life expectancy of German men reaching that of Swedish men (Heichel et al. 2005; Noy and Sprague-Jones 2016). In this case, the goal is the matching of German districts' life expectancy trajectory with that of the average German district. To assess delta convergence, we therefore compared district e_0 trajectories with the average German district e_0 trajectory by comparing starting levels of e_0 and change over time in e_0. The selected goal allowed us to identify four groups of districts: (1) the *decreasing disadvantage* group of districts that started below the average German e_0 but saw greater than average e_0 gains; (2) the *decreasing advantage* group of districts that started above the average German e_0 but saw lower than average e_0 gains; (3) the *increasing disadvantage* group of districts that started below the average German e_0 and had lower than average e_0 gains; and (4) the *increasing advantage* group of districts that started above the average German e_0 and saw greater than average e_0 gains (see Figure 1 for an illustration).

This characterization of districts has several advantages. First, it allows us to examine the spatial distribution of the mortality convergence process because the first two district groups contributed to mortality convergence, whereas the latter two groups contributed to mortality divergence. Second, it allows us to examine whether the overall mortality convergence process is uniform and stable, with most districts contributing to mortality convergence. Third, it allows us to examine whether the convergence process is dominated by districts with a decreasing mortality disadvantage or instead by districts with a decreasing mortality advantage; the former is the more favorable scenario.

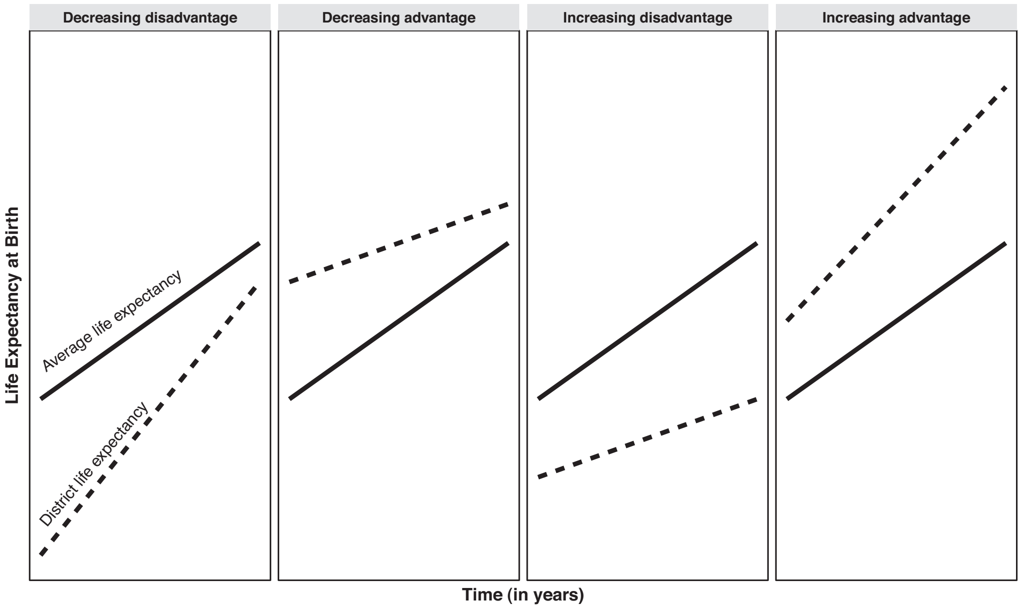

Fig. 1 Illustration of the district e_0 life expectancy trajectory groups

The Association of District e_0 Trajectory Groups With District Characteristics

To identify possible mechanisms driving mortality convergence and divergence, we explored the associations between district characteristics and district membership in one of four e_0 trajectory groups established in the delta convergence analysis. We did so by fitting multinomial regression models for each sex that controlled for federal state, using the increasing disadvantage district group as the reference category because it represents the poorest performing districts. From the literature identifying district economic performance and deindustrialization and improved access to health care as important determinants of district mortality in Germany (see the Introduction), we selected the following independent variables: the district tax base, long-term unemployment rate, hospital density (hospitals per 100,000 population), and the average resident age. We included the average age as a proxy for differences in the extent of population aging and out-migration across districts.

For each independent variable, we calculated the average value over time for the district because we expect that long-term trends in district mortality are driven by long-term exposure to protecting or harming contexts, such as easy access to hospital care or high unemployment, respectively. To enable comparisons between the different contextual characteristics, we rescaled (normalized) the variables by subtracting the overall mean and dividing by the standard deviation to produce standardized effect size estimates. We fit the multinomial logit probability models simultaneously using the *nnet* R package (Venables and Ripley 2002).

Sensitivity Analyses

To test the robustness of our findings, we performed several sensitivity analyses. First, we calculated all the convergence measures using partial life expectancy between ages 25 and 75 (e_{25}^{75}) instead of e_0. We performed this calculation because of the data limitations in the youngest and oldest ages and the possibility of our estimated mortality schedules exhibiting bias in these ages. The results were aligned with those reported for e_0 (see the online appendix).

Second, we focused on unweighted measures of beta and sigma convergence in our analyses. However, because population-weighted measures reflect both disparities between places and their relative population sizes, we also calculated weighted versions of the measures. The weighted measures exhibited the same trends and led to the same conclusions as the unweighted outcomes.

Third, we focused on variance as a dispersion measure to assess sigma convergence. However, because dispersion measures differ in their mathematical properties and ability to summarize a distribution, we also calculated the Theil index, which remains unchanged by equal proportional changes in the district life expectancy distribution (Cowell 2011). Results using the Theil index were aligned with the results for the variance (see the online appendix, section 3).

Fourth, when exploring the association of district e_0 trajectories with contextual characteristics, we also explored bivariate associations and an extended model that controlled for the average annual change in the included variables and not simply their average values. The results were generally aligned with those of the primary model (see the online appendix, section 6).

Results

Overall Mortality Convergence

Between 1997 and 2016, life expectancy increased for both sexes in all 401 German districts (Figure 2 and Table 2). Districts in the eastern part of the country experienced greater improvements in e_0 than those in the west. A clear east–west gap was visible in 1997, and a north–south gradient could be seen in 2016. The increase in e_0 was larger in 1997–2006 than in 2007–2016 for both sexes and for both western and eastern Germany (Table 2).

The association between the change in e_0 and the initial e_0 was significant and negative for both sexes, indicating beta convergence and suggesting that districts with initially lower e_0 caught up over time ($\text{beta}_{\text{men}} = -0.31$, 95% CI [–0.36, –0.26]; $\text{beta}_{\text{women}} = -0.46$, 95% CI [–0.53, –0.40]). Comparing the early and late study periods (1997–2006 vs. 2007–2016), we found that the association was attenuated: mortality convergence weakened over time (Table 2).

The total variance in e_0 declined for both sexes over the study period, indicating sigma convergence (Figure 3). The decomposition shows that the overall mortality convergence was driven mainly by the reduction in the *between* component, which corresponds to a reduction in the average difference in e_0 between the eastern and the western German districts. This reduction was rapid at first but slowed over time for

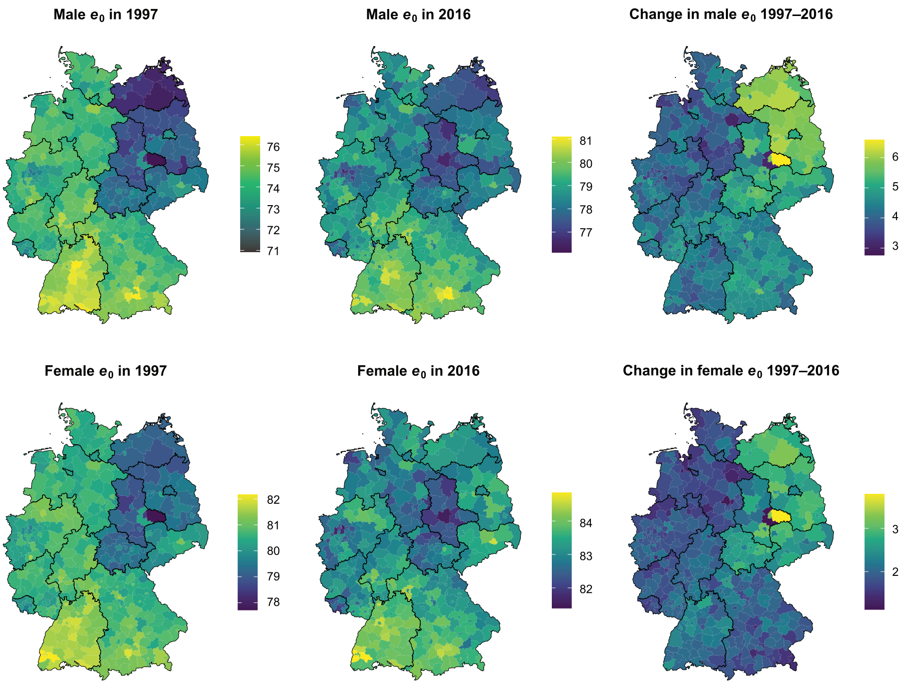

Fig. 2 Estimated life expectancy at birth (e_0) for 401 German districts, by sex, in 1997 and 2016, and the change (in years) from 1997 to 2016

both sexes. At the same time, the *within* component of variance increased, indicating an increase in differences between district e_0 within eastern Germany or within western Germany. The within component steadily increased until 2006 and then followed a U-shape, with a nadir in 2011. Because the within component could be driven by increased differences in district e_0 in either or both parts of Germany, we stratified the examination of dispersion by area of Germany (east vs. west) and study period (early vs. late). The stratified analysis indicates that district mortality differences predominantly increased within western Germany and decreased within eastern Germany. Further, the mortality convergence within eastern Germany slowed over time (Table 2).

In sum, the study period was characterized by uniform upward mortality convergence that was driven primarily by a reduction in the average difference in e_0 between eastern and western Germany, which in turn was driven by rapid mortality improvements in all eastern German districts. However, we also found evidence of the overall convergence process slowing over time owing to the mortality divergence within western Germany and the slowing of mortality convergence within eastern Germany.

District e_0 Trajectory Groups

To assess delta convergence, we compared the district e_0 trajectories with the overall German district average e_0 trajectory to identify four groups of districts: decreasing

Table 2 Change in life expectancy at birth (e_0), beta convergence coefficient, and change in the variance across the German districts, 1997–2016, by sex, decade, and region

	Average Life Expectancy Change (years)		Beta Convergence Coefficient (95% CI)		Annual Relative Change in the Variance (%)	
	Early Period: 1997–2006	Late Period: 2007–2016	Early Period: 1997–2006	Late Period: 2007–2016	Early Period: 1997–2006	Late Period: 2007–2016
Germany, Male	3.08	1.10	−0.25* (−0.28, −0.21)	−0.10* (−0.14, −0.06)	−2.84	−0.13
Germany, Female	2.04	0.60	−0.33* (−0.37, −0.28)	−0.11* (−0.15, −0.06)	−3.27	0.58
East, Male	3.75	1.23	−0.39* (−0.5, −0.28)	−0.07 (−0.18, 0.05)	−3.95	1.31
West, Male	2.92	1.07	0.13* (0.08, 0.18)	−0.08* (−0.13, −0.03)	4.78	0.73
East, Female	2.65	0.78	−0.34* (−0.48, −0.21)	0.05 (−0.08, 0.18)	−2.21	4.00
West, Female	1.89	0.56	0.02 (−0.03, 0.08)	−0.08* (−0.14, −0.03)	3.10	0.99

Notes: If the beta coefficient is negative, life expectancy improved fastest in districts with the lowest life expectancy at the start. CI = confidence interval.

*$p < .05$

disadvantage, increasing disadvantage, increasing advantage, and decreasing advantage (Figure 4).

Two thirds of districts for both sexes were in the decreasing disadvantage or decreasing advantage groups, contributing to mortality convergence. This finding indicates a stable process of mortality convergence, given that it resulted from mortality trends in most districts and was not driven by outliers. Most eastern German districts (71 of 76 for both sexes) belonged to the decreasing disadvantage group, and eastern Germany makes up the majority of districts in this group. Not surprisingly, all districts in the decreasing advantage were in western Germany. However, approximately 10% of western German districts also saw above-average mortality improvements during the study period despite starting at a disadvantage, which was unexpected.

The districts in groups contributing to mortality divergence—increasing disadvantage and increasing advantage—were predominantly in western Germany. Most districts in the increasing advantage group were in southern Germany, whereas the districts in the increasing disadvantage group formed clusters in northwest Germany. Overall, the district group clusters did not follow state borders.

Thus, the overall mortality convergence process was driven by a robust and uniform process of catching up that included almost all eastern German districts and by the relative mortality stagnation in northwestern Germany. In addition, the strong e_0 gains in the south and the concurrent falling behind of district clusters in

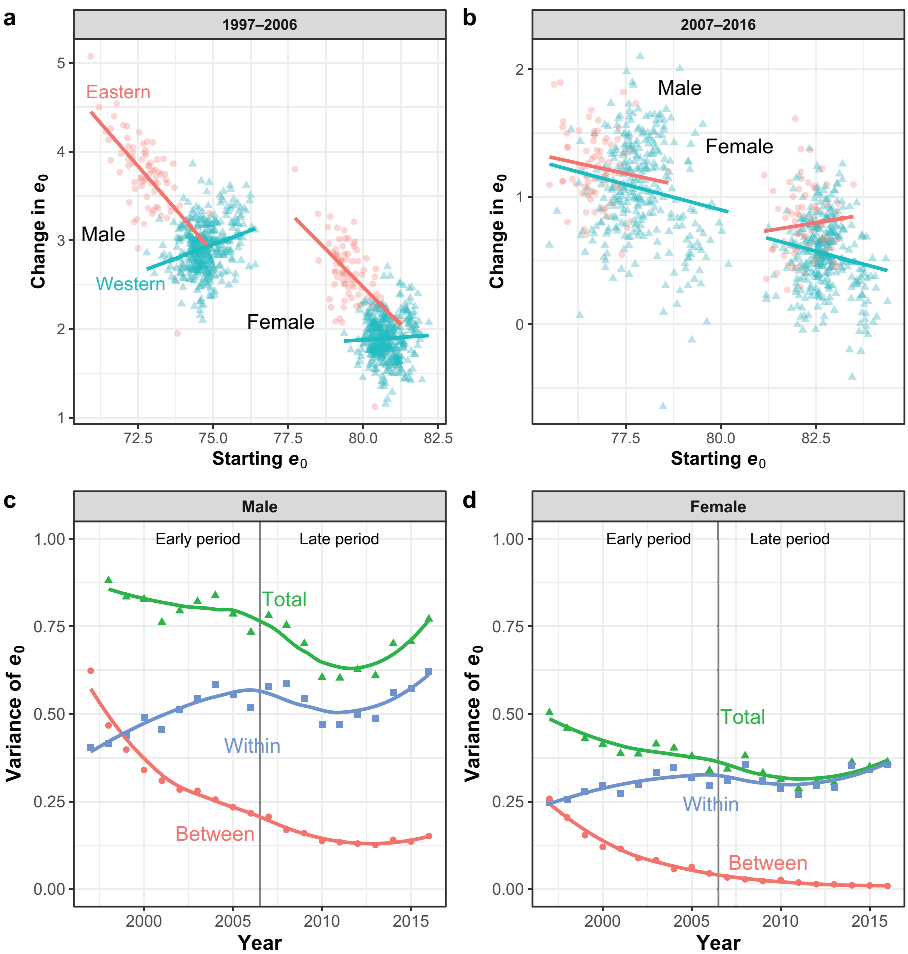

Fig. 3 Convergence in district life expectancy at birth (e_0) in Germany, 1997–2016, by sex, region, and decade. Panels a and b show scatterplots of district e_0 at the starting year against the change in district e_0 during the study period (1997–2006 in panel a and 2007–2016 in panel b) by sex and part of Germany (eastern, western, and both). Panels c and d show smoothed trends in total variance and the between and within components of the total variance, by sex. The between component corresponds to the average difference between eastern and western German districts, whereas the within component corresponds to the differences between districts within both eastern and western Germany.

northwestern Germany indicate an increasingly dominant mortality divergence following a north–south pattern. However, unlike the east–west convergence, the north–south divergence pattern appears to be more spatially complex and driven by clusters of districts not characterized by federal state borders.

The Association of District e_0 Trajectory Groups With District Characteristics

To identify possible mechanisms driving mortality convergence and divergence, we used multinomial regression to explore the association between district characteristics

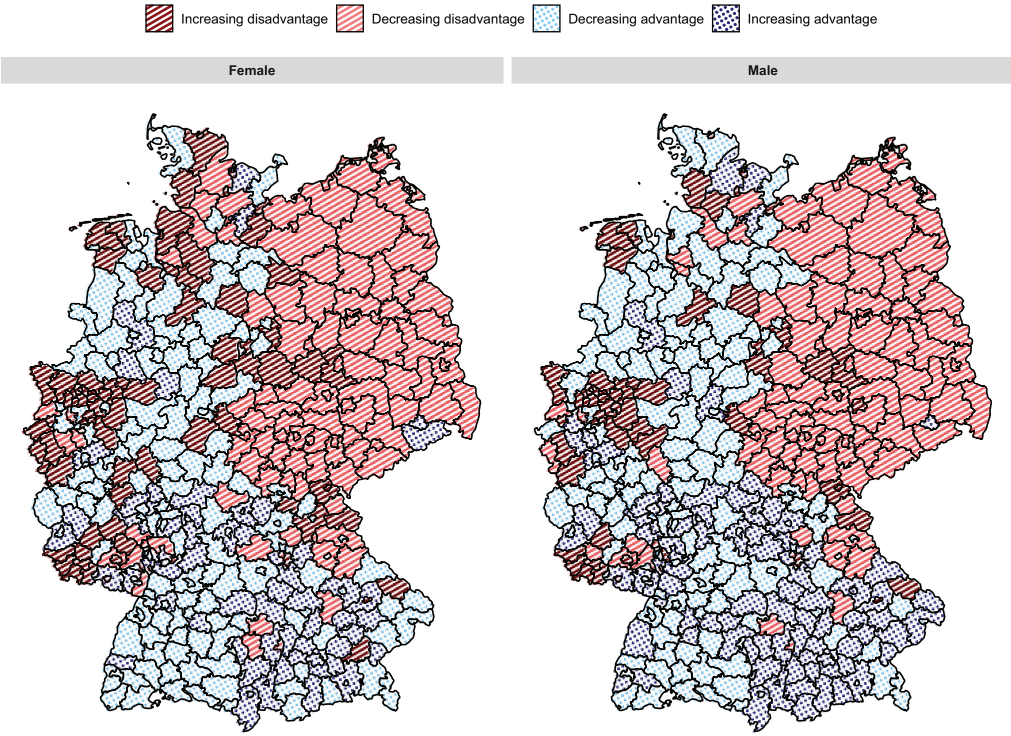

Fig. 4 German district trajectories in life expectancy at birth (e_0) compared with the average German e_0 trajectory. Four groups of districts are distinguished according to their e_0 trajectory: decreasing disadvantage, increasing disadvantage, increasing advantage, and decreasing advantage during 1997–2016, by sex.

(long-term unemployment, tax base, hospital density, and average resident age) and the district e_0 trajectory groups (described earlier). Figure A9 illustrates the spatial distribution of the examined district characteristics.

The results suggest that a higher average tax base and a lower average long-term unemployment rate relative to those of the reference group (increasing disadvantage) were associated with a district exhibiting an e_0 advantage for both sexes throughout the study period (Figure 5 and Table A2). A higher tax base was also associated with a decreasing e_0 disadvantage for women but not men. The average hospital density, a proxy for access to secondary and tertiary health care, did not systematically differ between the reference and other mortality trajectory groups. Finally, compared with the reference group, all other district groups had a lower average resident age, especially the groups with an above-average improvement in e_0—that is, decreasing disadvantage and increasing advantage.

In sum, we found the strongest association with district e_0 trajectory groups with the economic performance variables: the district tax base and the long-term unemployment rate. Stronger economic performance was associated with a district maintaining or increasing its e_0 advantage.

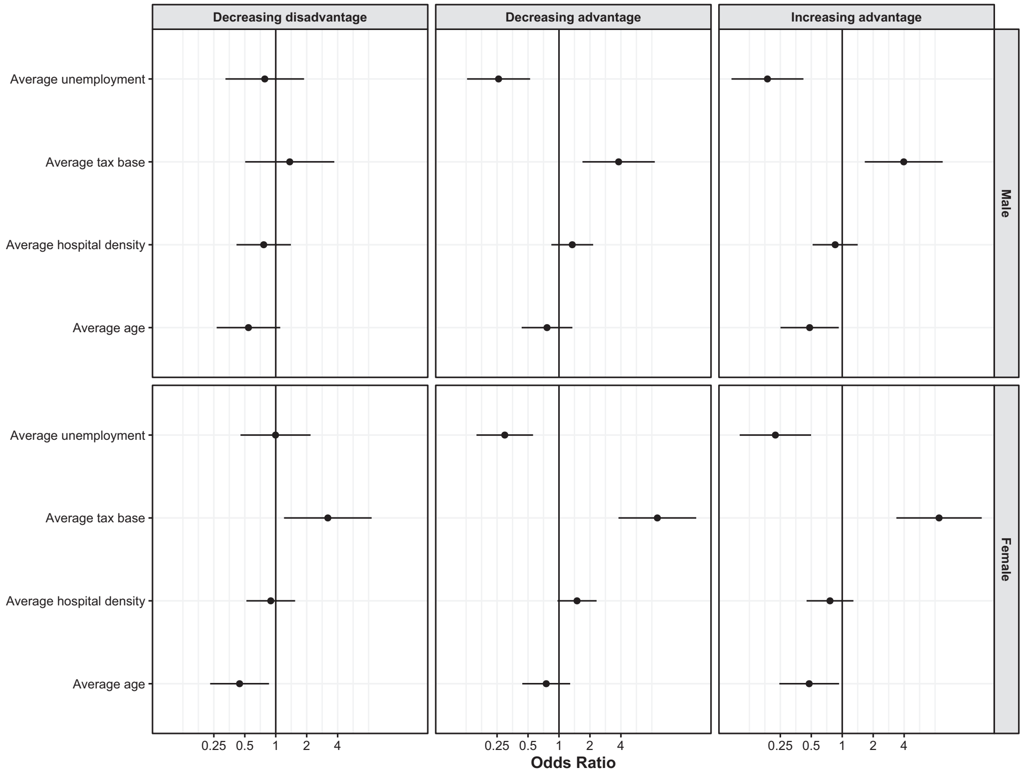

Fig. 5 Association of district e_0 trajectory groups with district characteristics for 1997–2006, by sex. The increasing disadvantage trajectory group was used as the reference.

Discussion

We analyzed long-term trends in mortality convergence across German districts during 1997–2016 and explored contextual determinants of the process. We found that all German districts experienced improved e_0 and that the overall dispersion in district e_0 decreased. This overall trend toward convergence was mainly driven by rapid life expectancy increases in the eastern German districts. However, we found considerable heterogeneity in the district e_0 trajectories within federal states. This heterogeneity was reflected in the formation of district clusters in northwestern Germany with increasing e_0 disadvantage relative to the average German district e_0 trajectory that contributed to an emerging north–south mortality divergence. Finally, we found that district e_0 trajectory groups were strongly associated with two indicators of district economic performance: the tax base and the long-term unemployment rate. The district hospital density seemed to play a less important role.

Interpretation of Main Findings

Our finding that mortality in Germany overall converged over our study period is in line with the results of previous studies examining mortality convergence in

Germany at the level of former East and West Germany and at the level of federal states (Grigoriev and Pechholdová 2017; Grigoriev et al. 2021; van Raalte et al. 2020). However, our study is the first to show that this east–west convergence was driven by an above-average e_0 improvement in almost all eastern German districts, particularly in the decade 1997–2006. Even more rapid mortality improvements in eastern Germany that we could not observe likely occurred immediately after reunification, in 1991–1996. We also found that the rapid mortality improvements did not result in increased mortality differences between eastern German districts during 1997–2006. This is an important and welcome finding, given that the differences between eastern German districts in terms of economic performance, population structure, availability of health care, and other characteristics would normally lead us to expect more heterogeneous trends in district e_0. Although our study design does not allow for inferences on the mechanisms behind this observation, we speculate that the substantial postreunification public spending that improved the eastern German health care infrastructure and provided more generous social welfare transfers for individuals, especially though pension incomes (Ritter 2011; Vogt and Kluge 2015), may have diluted the effects of economic, demographic, and other differences between districts on district mortality conditions. The short-term effects of this postreunification public spending likely benefited eastern German retirees the most (Grigoriev et al. 2021; Vogt and Vaupel 2015) because their health was primarily influenced by the unification of social welfare systems of former East and West Germany, and because the improvements in the health care system were largely independent of district characteristics. However, the more recent district mortality trends in eastern Germany are driven by cohorts of working ages during reunification who experienced significant economic restructuring and prolonged high unemployment in the years after; these cohorts have not uniformly reaped economic or health benefits from the reunification (Akerlof et al. 1991; Collier and Siebert 1991; Lenhart 2017; Richter et al. 2020; Snower and Merkl 2006). We would expect the district characteristics to matter more for the mortality of these cohorts and thus for eastern German district e_0 trends to diverge. In support of this hypothesis, we found increased dispersion in district e_0 in eastern Germany during 2007–2016, indicating mortality divergence. However, this result requires further study using data collected in the future since these cohorts have not yet reached the ages at which the risk of death is high enough to allow for an unequivocal test of the hypothesis.

Our study showed that different e_0 trajectory groups coexisted in the same federal state—a pattern that would be obscured in studies considering state-level data only. Because this heterogeneity was stable over time and present for both sexes, it is unlikely to be a statistical artifact. The districts in the increasing disadvantage e_0 trajectory group coincided with the deindustrialized areas in northwestern Germany that could not match the pace of average mortality improvements in Germany. This situation led to a north–south mortality divide, also documented previously (Kibele et al. 2015). Our exploration of district characteristics indicates that economic performance, as measured by each district's tax base and long-term unemployment rate, influenced the development of this e_0 trajectory group and, consequently, of the north–south mortality divergence. Reinforcing the importance of the economic context in the mortality divergence in Germany, previous studies found that deindustrialized regions experiencing a difficult economic transition tend to have worse population health and increased mortality (Silver et al. 2011; Walsh et al. 2010; Wami et al. 2021). In Germany, the north–south economic and mortality divergence may also be a reflection of differences in the socioeconomic conditions of the eastern and the western parts of the country. Whereas districts in the east experienced economic restructuring and received subsidized welfare transfers (Ritter 2011), western German deindustrialized regions experienced economic restructuring without additional welfare support (Hospers 2004).

We found that the district hospital density was not as strongly associated with district mortality trajectories as the district economic performance, which aligns with the conclusions of a recent study of German district-level life expectancy in 2015–2017 (Rau and Schmertmann 2020a). We note two potential explanations for this finding. First, economic circumstances may influence mortality through mechanisms independent of medical care access. For example, the prevalence of harmful lifestyle choices—such as smoking, alcohol consumption, and low physical activity—is associated with adverse regional economic circumstances in Germany and elsewhere (Galán et al. 2021; Kaiser et al. 2018; Kleinjans and Gill 2022; Schüle and Bolte 2015) and is not directly influenced by health care availability. Second, the impact of health care availability may be attenuated by selective out-migration: individuals who are healthier, better educated, and higher earners are more likely to move to more economically prosperous regions, leaving behind districts with fewer opportunities and a sicker population (Vaalavuo and Sihvola 2021). In the German context, reunification led to considerable east–west migration flows, with out-migration from rural eastern Germany being particularly high (Stawarz et al. 2020). Given the younger ages of most postreunification internal migrants, though, selective out-migration in this context did not lead to the concentration of frail elderly persons in eastern Germany during our study period (Vogt and Missov 2017). Instead, it resulted in an economic disadvantage due to workforce losses. We interpret our results as supporting the first potential explanation, but further research on this question is needed. In particular, studies leveraging currently unavailable individual- and district-level data on health behaviors, migrant status, health care access and utilization, and cause-specific mortality would be able to support further inference in this regard (see Recommendations for Further Research).

Evaluation of Data and Methods

Our study utilized a novel flexible model to interpolate the missing district-level mortality data and smooth the age mortality schedules, allowing a close examination of the process of district-level mortality convergence in Germany over two decades. However, the interpolation, smoothing, and borrowing of data between districts within states may have introduced model-related bias into our analysis and decreased our ability to detect short-term mortality fluctuations. Borrowing data between districts within states relies on the assumption that state borders are more important mortality determinants than geographic proximity, which may not always be the case. One issue we detected was that relative to the HMD data by sex and year, our model underestimated mortality rates in childhood and at very old ages—the age groups with very low death counts (see Figures A1 and A2). However, we do not believe that the underestimation of mortality rates in these age groups substantially influenced our results: we replicated the key findings using life expectancy between ages 25 and 75 (e_{25}^{75}) as the outcome, and these model estimates were closer to the estimates based on HMD data (see Figure A5).

Focusing on the district level, for which our modeling was imperative, also had several key advantages. First, we could identify district clusters that over- or underperformed the average life expectancy trajectory within federal states and those that stretched beyond state lines. Furthermore, we could highlight differences between districts within federal states—a particularly relevant study feature given the heterogeneity in district e_0 trajectories, which are obscured in analyses using state-level data. The advantages of using this level of analysis outweigh the possible issues with quantitative precision.

Our study also benefitted from our multiple sensitivity analyses verifying the main findings by using population-weighted measures of convergence and the Theil index instead of variance as the measure of life expectancy dispersion. These analyses increase our confidence in our results.

Our exploration of the role of district characteristics in mortality trajectories was limited for three reasons. First, we did not include all relevant contextual factors (e.g., the built environment) or the prevalence of health-related behaviors (e.g., smoking, diet, physical activity, alcohol consumption). Unfortunately, district-level data on these factors are not readily available. Second, the variables we selected to reflect district economic performance and access to health care were likely imperfect. Economic context and health care access are multidimensional concepts, and a comprehensive evaluation of their role in district mortality convergence in Germany requires data that are not currently available and is beyond the scope of this study. Third, by using the multinomial regression model, we forfeited information on variation in the life expectancy trajectories by effectively flattening them into four categories. However, the aim of our analysis of the role of district characteristics in mortality trajectories was to explore the findings from the mortality convergence portion of the study, particularly the identification of high-mortality clusters. Indeed, the data and the models we used are not well suited to making causal claims about the relationship between the district context and the individual outcomes. However, the robustness of the core findings to model specification and period choice (see Table A2) supports our conclusions.

Recommendations for Further Research

Our findings indicate that the north–south mortality divergence in Germany may be driven primarily by the increasing e_0 disadvantage trajectory group in economically distressed clusters of districts in deindustrialized areas in northwestern Germany. This observation suggests several directions for future research. First, it is necessary to establish whether economic performance is indeed the salient characteristic that distinguishes the increasing e_0 disadvantage trajectory group from the others. Doing so will require a more comprehensive examination of the implicated districts as places (e.g., their environmental and social contexts) and populations (e.g., their age structure). In-depth case studies of vanguard and laggard districts can be helpful in this task because they allow for a careful examination of the interplay of various district characteristics. Longitudinal studies examining the age groups driving the observed trends in mortality convergence and divergence and the association between district mortality trajectories and their characteristics will be a valuable contribution to the literature (*cf.* Grigoriev et al. 2019), attainable when more complete district-level mortality data become available.

Second, if differences in local economic performance are indeed the key distinctions between the e_0 trajectory groups, we also need to understand the mechanisms through which the local economic context shaped the health and mortality outcomes of district populations in Germany over the past two decades. Both research directions will require better district-level data on these variables than are currently available, including district-level data on health care utilization, employment, income, health-related behaviors, and cause-specific mortality. Studies focusing on the mechanisms of these effects would also benefit from linking individual or household survey data, such as data from the German Socio-Economic Panel (Wagner et al. 2007), with information on the district context.

Third, future studies could compare the socioeconomic and demographic drivers of mortality convergence and divergence in different contexts. Germany shares the high-income country status with other polities, such as the United States, but has a distinct vision of the welfare state—a particular manifestation of the European social model (Alber 2006). The cultural and political differences associated with the variety of welfare regimes and regional development models across high-income countries may engender unique mechanisms of mortality convergence and divergence, masking some contextual drivers while exaggerating others. Therefore, cross-national comparative research on the mechanisms of regional mortality convergence is necessary to evaluate the generalizability of our conclusions.

Implications for Policy

Our study suggests a path to achieving regional mortality convergence using socioeconomic policy. First, our results indicating that life expectancy was improving in almost all eastern German districts in 1997–2016 demonstrate that it is possible to engineer a "leveling up" of population health on a national scale without increasing disparities between targeted regions. This observation is particularly relevant in light of current efforts to improve living conditions and health of historically disadvantaged regions in other high-income countries, particularly the United Kingdom (Bambra 2022; Tomaney and Pike 2020), and in countries that share in the European social model of the welfare state. However, the concentration of the increasing e_0 disadvantage trajectory group in northwestern Germany warns against the adoption of a narrow regional focus that does not sufficiently support individuals negatively affected by economic transitions, regardless of their place of residence. As we discussed earlier, the German government's policy approach to the redevelopment of eastern Germany was multifaceted and used infrastructure investments and expanded pension transfers, respectively, to support eastern Germany as a *place* and eastern

German *individuals*. By contrast, the government did not apply a similarly comprehensive strategy to support economically disadvantaged districts in western Germany, which perhaps contributed to the north–south mortality divergence we observed. We therefore agree with other authors in calling for a more place-sensitive, distributed development policy in Germany and elsewhere (Iammarino et al. 2019), combined with adequate social welfare support to prevent economic shocks from triggering a delayed deterioration of individual health (Bíró and Branyiczki 2020). Nevertheless, we urge decision makers to remain mindful of the limited generalizability of these recommendations in light of different welfare regimes, regional development models, and the extent of regional mortality differences.

Conclusion

Our results corroborate previous evidence indicating that mortality has been converging across different regions of Germany. By studying mortality convergence over a long period at the district level, we demonstrated that this convergence resulted from above-average improvements in mortality throughout eastern Germany. In addition, we found that the past process of mortality convergence between eastern and western Germany has been giving way to a mortality divergence between the north and the south of the country. This divergence appears to be partly driven by economically distressed districts in northwestern Germany, likely due to a failure to provide these districts with targeted social welfare support during the economic shocks brought on by deindustrialization.

More district-level mortality research in Germany is needed to fully unravel the role of the socioeconomic context in mortality convergence and divergence. Future studies would benefit from better district data on health care utilization, employment, income, health-related behaviors (e.g., smoking), and cause-specific mortality. Moreover, future research should focus on individual vanguard and laggard districts.

Our study shows that it is possible to engineer a "leveling up" of health without increasing disparities between targeted regions with the implementation of policies that invest in both places and the people who live in them. ■

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References

Akerlof, G. A., Rose, A. K., Yellen, J. L., Hessenius, H., Dornbusch, R., & Guitian, M. (1991). East Germany in from the cold: The economic aftermath of currency union. *Brookings Papers on Economic Activity, 1991*(1), 1–105.

Akita, T. (2003). Decomposing regional income inequality in China and Indonesia using two-stage nested Theil decomposition method. *Annals of Regional Science, 37,* 55–77.

Alber, J. (2006). The European social model and the United States. *European Union Politics, 7,* 393–419.

Bambra, C. (2022). Levelling up: Global examples of reducing health inequalities. *Scandinavian Journal of Public Health, 50,* 908–913.

Bíró, A., & Branyiczki, R. (2020). Transition shocks during adulthood and health a few decades later in post-socialist Central and Eastern Europe. *BMC Public Health, 20,* 698. https://doi.org/10.1186/s12889-020-08839-7

Bundesinstitut für Bau-, Stadt- und Raumforschung. (2021). INKAR – *Indikatoren und karten zur raum- und stadtentwicklung* [INKAR – Indicators and maps for spatial and urban development]. Retrieved from https://www.inkar.de

Clark, D. E., Wildner, M., & Bergmann, K. E. (2000). Injury mortality in east Germany. *American Journal of Public Health, 90,* 1761–1764.

Collier, I. L., Jr., & Siebert, H. (1991). The economic integration of post-wall Germany. *American Economic Review: Papers & Proceedings, 81,* 196–201.

Conceição, P., & Ferreira, P. (2000). *The young person's guide to the Theil index: Suggesting intuitive interpretations and exploring analytical applications* (UTIP Working Paper No. 14). Austin: University of Texas Inequality Project. Retrieved from https://ssrn.com/abstract=228703

Cowell, F. A. (2011). *Measuring inequality* (3rd ed.). Oxford, UK: Oxford University Press.

de Beer, J. (2012). Smoothing and projecting age-specific probabilities of death by TOPALS. *Demographic Research, 27,* 543–592. https://doi.org/10.4054/DemRes.2012.27.20

Diehl, K. (2008). Mögliche Faktoren für die rasche Reduktion der ostdeutschen Übersterblichkeit nach der Wiedervereinigung: Warum leben Ostdeutsche seit der Wiedervereinigung länger? [Potential Factors for the rapid Reduction in Eastern German Excess Mortality after Reunification: Why are Eastern Germans living longer after German Reunification?]. *Zeitschrift für Bevölkerungswissenschaft, 33,* 89–109. https://doi.org/10.1007/s12523-008-0006-x

Galán, I., Rodríguez-Blázquez, C., Simón, L., Ortiz, C., López-Cuadrado, T., & Merlo, J. (2021). Small area influences on the individual unhealthy lifestyle behaviors: A multilevel analysis of discriminatory accuracy. *Health & Place, 67,* 102506. https://doi.org/10.1016/j.healthplace.2021.102506

Gonzaga, M. R., & Schmertmann, C. P. (2016). Estimating age- and sex-specific mortality rates for small areas with TOPALS regression: An application to Brazil in 2010. *Revista Brasileira de Estudos de População, 33,* 629–652.

Grigoriev, P., & Pechholdová, M. (2017). Health convergence between East and West Germany as reflected in long-term cause-specific mortality trends: To what extent was it due to reunification? *European Journal of Population / Revue Européenne de Démographie, 33,* 701–731.

Grigoriev, P., Pechholdová, M., Mühlichen, M., Scholz, R. D., & Klüsener, S. (2021). 30 jahre Deutsche einheit: Errungenschaften und verbliebene unterschiede in der mortalitätsentwicklung nach alter und todesursachen [30 years of German unification: Achievements and remaining differences in mortality trends by age and cause of death]. *Bundesgesundheitsblatt – Gesundheitsforschung – Gesundheitsschutz, 64,* 481–490.

Grigoriev, P., Scholz, R., & Shkolnikov, V. M. (2019). Socioeconomic differences in mortality among 27 million economically active Germans: A cross-sectional analysis of the German Pension Fund data. *BMJ Open, 9,* e028001. https://doi.org/10.1136/bmjopen-2018-028001

Häussler, B., Hempel, E., & Reschke, P. (1995). Die entwicklung der lebenserwartung und sterblichkeit in Ostdeutschland nach der wende (1989–1992) [Changes in life expectancy and mortality in East Germany after reunification (1989–1992)]. *Die Gesundheitswesen, 57*(7), 365–372.

Heichel, S., Pape, J., & Sommerer, T. (2005). Is there convergence in convergence research? An overview of empirical studies on policy convergence. *Journal of European Public Policy, 12,* 817–840.

Hospers, G.-J. (2004). Restructuring Europe's rustbelt: The case of the German Ruhrgebiet. *Intereconomics, 39,* 147–156.

Hrzic, R., & Brand, H. (2020). Thirty years after German reunification: Population health between solidarity and global competitiveness. *European Journal of Public Health, 30,* 845–846.

Hrzic, R., Vogt, T., Brand, H., & Janssen, F. (2021). The short-term effects of European integration on mortality convergence: A case study of European Union's 2004 enlargement. *European Journal of Population, 37,* 909–931.

Hrzic, R., Vogt, T., Janssen, F., & Brand, H. (2020). Mortality convergence in the enlarged European Union: A systematic literature review. *European Journal of Public Health, 30,* 1108–1115.

Human Mortality Database. (2021). Berkeley, CA (USA): University of California, Berkeley; Rostock, Germany: Max Planck Institute for Demographic Research. Available from www.mortality.org

Iammarino, S., Rodriguez-Pose, A., & Storper, M. (2019). Regional inequality in Europe: Evidence, theory and policy implications. *Journal of Economic Geography, 19,* 273–298.

Janssen, F., van den Hende, A., de Beer, J. A. A., & van Wissen, L. J. G. (2016). Sigma and beta convergence in regional mortality: A case study of the Netherlands. *Demographic Research, 35,* 81–116. https://doi.org/10.4054/DemRes.2016.35.4

Kaiser, M., Reutter, M., Sousa-Poza, A., & Strohmaier, K. (2018). Smoking and local unemployment: Evidence from Germany. *Economics & Human Biology, 29,* 138–147.

Kibele, E. U. B., Klüsener, S., & Scholz, R. D. (2015). Regionale mortalitätsunterschiede in Deutschland: Langfristige veränderungen und mögliche ursachen [Regional mortality disparities in Germany: Long-term dynamics and possible determinants]. *Kolner Zeitschrift fur Soziologie und Sozialpsychologie, 67,* 241–270.

Kleinjans, K. J., & Gill, A. (2022). Intergenerational transmission of disadvantage: Negative parental selection, economic upheaval, and smoking. *Journal of Family and Economic Issues, 43,* 799–814.

Lenhart, O. (2017). The role of economic shocks on health: Evidence from German reunification. *Southern Economic Journal, 84,* 275–296.

Luy, M. (2004). Mortality differences between western and eastern Germany before and after reunification: A macro and micro level analysis of developments and responsible factors. *Genus, 60*(3–4), 99–141.

Mascherini, M., Bisello, M., Dubois, H., Eiffe, F., & European Foundation for the Improvement of Living and Working Conditions. (2018). *Upward convergence in the EU: Concepts, measurements and indicators* (Eurofound report). Luxembourg: Publications Office of the European Union.

Mühlichen, M. (2019). Avoidable mortality in the German Baltic Sea region since reunification: Convergence or persistent disparities? *European Journal of Population, 35,* 609–637.

Noy, S., & Sprague-Jones, J. (2016). Comparative dynamics of public health spending: Re-conceptualizing delta-convergence to examine OECD and Latin America. *International Journal of Comparative Sociology, 57,* 425–448.

OECD/UCLG. (2019). *2019 report of the World Observatory on subnational government finance and investment: Country profiles.* Retrieved from https://www.sng-wofi.org/reports/SNGWOFI_2019_report_country_profiles_DEC2019_UPDATES.pdf

Preston, S. H., Heuveline, P., & Guillot, M. (2000). *Demography: Measuring and modeling population processes*. Edinburgh, UK: Wiley-Blackwell.

R Core Team. (2022). *R: A language and environment for statistical computing* [Computer software]. Retrieved from https://www.R-project.org/

Rau, R., & Schmertmann, C. P. (2020a). Lebenserwartung auf kreisebene in Deutschland [District-level life expectancy in Germany]. *Deutsches Äerzteblatt International, 117,* 493–499.

Rau, R., & Schmertmann, C. P. (2020b). *District-level life expectancy in Germany* (Supplementary information). Retrieved from https://schmert.net/german-district-mortality/docs/supplementary-info.pdf

Razum, O., Altenhöner, T., Breckenkamp, J., & Voigtländer, S. (2008). Social epidemiology after the German reunification: East vs. west or poor vs. rich? *International Journal of Public Health, 53,* 13–22.

Richter, E. P., Brähler, E., Stöbel-Richter, Y., Zenger, M., & Berth, H. (2020). The long-lasting impact of unemployment on life satisfaction: Results of a longitudinal study over 20 years in East Germany. *Health and Quality of Life Outcomes, 18,* 361. https://doi.org/10.1186/s12955-020-01608-5

Ritter, G. A. (2011). *The price of German unity: Reunification and the crisis of the welfare state* (R. Deveson, Trans.). Oxford, UK: Oxford University Press.

Sala-i-Martin, X. X. (1996). The classical approach to convergence analysis. *Economic Journal, 106,* 1019–1036.

Schüle, S. A., & Bolte, G. (2015). Interactive and independent associations between the socioeconomic and objective built environment on the neighbourhood level and individual health: A systematic review of multilevel studies. *PLoS One, 10,* e0123456. https://doi.org/10.1371/journal.pone.0123456

Shorrocks, A., & Wan, G. (2005). Spatial decomposition of inequality. *Journal of Economic Geography, 5,* 59–81.

Silver, D., Mijanovich, T., Uyei, J., Kapadia, F., & Weitzman, B. C. (2011). Lifting boats without closing gaps: Child health outcomes in distressed U.S. cities from 1992–2002. *American Journal of Public Health, 101,* 278–284.

Snower, D. J., & Merkl, C. (2006). The caring hand that cripples: The East German labor market after reunification. *American Economic Review: Papers & Proceedings, 96,* 375–382.

Stan Development Team. (2022). *RStan: The R interface to Stan* [Computer software]. Retrieved from https://mc-stan.org/

Statistische Ämter des Bundes und der Länder. (2021). *Regionaldatenbank Deutschland* [Regional database Germany] [Data set]. Retrieved from https://www.regionalstatistik.de/genesis/online

Stawarz, N., Sander, N., Sulak, H., & Rosenbaum-Feldbrügge, M. (2020). The turnaround in internal migration between east and west Germany over the period 1991 to 2018. *Demographic Research, 43,* 993–1008. https://doi.org/10.4054/DemRes.2020.43.33

Thatcher, A. R., Kannisto, V., & Vaupel, J. W. (1998). *The force of mortality at ages 80 to 120.* Odense, Denmark: Odense University Press.

Tomaney, J., & Pike, A. (2020). Levelling up? *Political Quarterly, 91,* 43–48.

Vaalavuo, M., & Sihvola, M.-W. (2021). Are the sick left behind at the peripheries? Health selection in migration to growing urban centres in Finland. *European Journal of Population, 37,* 341–366.

van Raalte, A. A., Klüsener, S., Oksuzyan, A., & Grigoriev, P. (2020). Declining regional disparities in mortality in the context of persisting large inequalities in economic conditions: The case of Germany. *International Journal of Epidemiology, 49,* 486–496.

Venables, W. N., & Ripley, B. D. (2002). *Modern applied statistics with S* (4th ed.). New York, NY: Springer Science+Business Media. Retrieved from https://www.stats.ox.ac.uk/pub/MASS4/

Vogt, T. C. (2013). How many years of life did the fall of the Berlin Wall add? A projection of East German life expectancy. *Gerontology, 59,* 276–282.

Vogt, T. C., & Kluge, F. A. (2015). Can public spending reduce mortality disparities? Findings from East Germany after reunification. *Journal of the Economics of Ageing, 5,* 7–13.

Vogt, T. C., & Missov, T. I. (2017). Estimating the contribution of mortality selection to the east-west German mortality convergence. *Population Health Metrics, 15,* 33. https://doi.org/10.1186/s12963-017-0151-3

Vogt, T. C., van Raalte, A., Grigoriev, P., & Myrskylä, M. (2017). The German east-west mortality difference: Two crossovers driven by smoking. *Demography, 54,* 1051–1071.

Vogt, T. C, & Vaupel, J. W. (2015). The importance of regional availability of health care for old age survival—Findings from German reunification. *Population Health Metrics, 13,* 26. https://doi.org/10.1186/s12963-015-0060-2

Wagner, G. G., Frick, J. R., & Schupp, J. (2007). *The German Socio-Economic Panel Study (SOEP): Scope, evolution and enhancements* (SOEPpapers on Multidisciplinary Panel Data Research, No. 1). Berlin, Germany: DIW Berlin.

Walsh, D., Taulbut, M., & Hanlon, P. (2010). The aftershock of deindustrialization—Trends in mortality in Scotland and other parts of post-industrial Europe. *European Journal of Public Health, 20,* 58–64.

Wami, W., Walsh, D., Hennig, B. D., McCartney, G., Dorling, D., Galea, S., . . . Dundas, R. (2021). Spatial and temporal inequalities in mortality in the USA, 1968–2016. *Health & Place, 70,* 102586. https://doi.org/10.1016/j.healthplace.2021.102586

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