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# Do Welfare Regimes Matter? A Comparative Analysis of Area-Level Inequalities in Life Expectancy in Germany and the United Kingdom, 2003–2021

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## ABSTRACT

While area-level inequalities in life expectancy are well documented within individual countries, cross-national comparisons remain rare. We estimated and compared the magnitude of area-level life expectancy inequalities across districts in the UK and Germany, representing two distinct welfare regimes. We used mortality data from national statistical offices to estimate life expectancy for all districts between 2003 and 2021. Based on employment data, we assigned a deprivation decile to each district within both countries and calculated life expectancy for each decile. Using the slope index of inequality, we compared temporal trends in life expectancy inequalities across deciles in both countries. We found that, although life expectancy was similar in both countries, the UK consistently showed higher levels of area-level inequality than Germany. While district-level life expectancy inequalities increased in both countries over time, they rose more sharply in the UK, particularly during the first years of the Covid-19 pandemic. These findings are likely to reflect deeply rooted differences in governmental approaches to ensuring equitable living conditions across two distinct welfare regimes.

## 1 | Introduction

Inequalities in life expectancy are a persistent feature when disaggregating national-level mortality patterns and have been documented for most, if not all, countries with available data (Leon 2011). While life expectancy is firmly associated with health-related behavior, such behavior is itself shaped by a variety of factors (Chetty et al. 2016; Jackowska et al. 2024). Consequently, inequalities in life expectancy are typically analyzed across population subgroups—such as by sex, education, or income—or according to spatial characteristics such as geographical location and urbanicity. Cutting across these two dimensions, inequalities in life expectancy are particularly pronounced when examined at the area level (Shaw et al. 2000; Kyte and Wells 2010). Previous research has attributed area-level differences in life expectancy to a range of factors, including unequal access to resources and opportunities, the spatial distribution of these, and cross-level interactions between individuals and their environments (Singh and Siahpush 2014; Chetty et al. 2016; Dwyer-Lindgren et al. 2016; Ralston et al. 2022). Given this complex interplay, area-level approaches to assessing life expectancy have gained increasing attention, especially in light of the recent stagnation of population health improvements in several high-income countries. For example, despite a general

slowdown in life expectancy gains, both the timing and the magnitude of this deceleration varied considerably across the United States (US), likely reflecting macroeconomic factors, inequalities in wealth distribution, and differential effects of federal and state-level policies (Woolf and Schoomaker 2019; Woolf 2023).

More broadly, area-level inequalities in life expectancy can be seen as an indicator of a country's intention and success in providing equitable living conditions across its sub-national territories (Rau and Schmertmann 2020). While place-based interventions are common across many national policy plans, the specific levers and pathways through which states influence local areas and populations differ considerably between countries (Neumark and Simpson 2015). National approaches to local areas are typically shaped by overarching considerations regarding health, housing, social care, and education (Brady et al. 2016). A welfare state perspective is therefore particularly useful for cross-country comparisons of area-level health inequalities. Welfare state theory posits that countries with different welfare traditions adopt distinct strategies for redistributing resources and risks through taxation, education, employment, or the provision of childcare and healthcare (Brennenstuhl et al. 2012). Traditionally, three archetypes are distinguished based on the role of the state, family, and market in welfare provision: (1) a *liberal* type, where markets play a dominant role and access to services depends relatively highly on individual income (e.g., the US, Australia, the United Kingdom (UK)); (2) a *conservative* type, where responsibilities are balanced between state, market, family, and individual, often emphasizing subsidiarity and traditional family values (e.g., Germany, France, Netherlands); and (3) a *social-democratic* type, characterized by universal assistance and support, leading to a high degree of de-commodification (e.g., Denmark, Sweden, Norway, Finland) (Esping-Andersen 1990, 1999).

While area-level inequalities in life expectancy are often studied within individual countries, comparative analyses across different welfare state contexts remain rare. This is surprising for two reasons. First, the implicit age standardization of life expectancy allows for direct comparisons between areas and over time (Modig et al. 2020). Many European countries are divided into comparable areas of local government with similar devolved powers and centrally allocated resources (hereafter referred to as *districts*), making such cross-country comparisons feasible. Second, adopting a welfare state perspective helps to account for the upstream determinants of health inequalities. For instance, it allows us to examine how policy shapes outcomes for citizens at the sub-national level, linking socio-economic inequalities more directly to health inequalities (Hurrelmann et al. 2011).

In this paper, we estimated and compared district-level inequalities in life expectancy across two distinct welfare regimes: (1) the UK (i.e., *liberal* type) and its four nations—England, Wales, Scotland, and Northern Ireland—and (2) Germany (i.e., *conservative* type). Using a consistent methodology, we estimated life expectancy for all districts in both countries between 2003 and 2021. Within each country, districts were ranked by employment rate, serving as both a contextual macroeconomic indicator and a proxy for deprivation, and life expectancy was subsequently estimated for the resulting deciles. Using the slope index of inequality (SII), we then analyzed temporal trends in district-level life expectancy inequalities across deciles in both countries. In doing so, we aimed to assess how life expectancy evolved at the sub-national level under two distinct types of welfare state.

## 2 | Background

### 2.1 | Two Different Welfare States: Germany and the UK

We have chosen Germany as a representative of *conservative* welfare regimes and the UK as a representative of *liberal* welfare regimes. This decision was based on Esping-Andersen's (1990) typology. Since its original publication, this typology has undergone criticism for various reasons and has been refined accordingly (Bambra 2004; Deeming 2017). For example, in light of persistent health and socio-economic inequalities among the Nordic countries, it has been argued that their social-democratic regimes may be less 'de-commodified' than often assumed (Jasilionis 2024; Fritzell et al. 2022; Popham et al. 2013). In addition, some convergence across historically distinct welfare regimes has occurred over the past decades (Henriksen et al. 2012). Nevertheless, the classification of Germany and the UK into two distinct types of welfare regimes has generally remained uncontested in the literature (Buhr and Stoy 2015). This is evident from the consistency with which both countries continue to be classified as distinct types of welfare regimes in studies that have refined or criticized Esping-Andersen's original archetypes. Even the dichotomous *varieties of capitalism* (VoC) approach regards Germany (a *coordinated market economy*) as systematically different from the UK (a *liberal market economy*), grouping Germany with the Scandinavian countries instead (Hall and Soskice 2001).

To further enhance comparability, we selected Germany and the UK as two countries with similar demographic and macroeconomic characteristics. Both are high-income countries with comparable population size (2021: 67 million in the UK, 83 million in Germany), population density, land area, geographical features, distribution of economic sectors, and economic output (e.g., GDP per capita in 2019: $46.9 k in the UK, $51.4 k in Germany) (World Bank Group 2024). In addition, both countries are divided into local government units (*districts*) of similar size and structure (Bulkeley and Kern 2006). At national level, Germany and the UK have similar levels of life expectancy and have experienced a slowdown in its growth in recent years (HMD 2024). In the following, we describe these trends in more detail within the context of each country.

### 2.2 | Life Expectancy Trends in the UK Throughout Austerity and the Covid-19 Pandemic

In the UK, a long-term trend of improving life expectancy came to a halt in the 2010s, with stagnation and even reversal of gains (Minton et al. 2020). Following the onset of the Covid-19 pandemic, life expectancy fell sharply in 2020 and increased only slightly thereafter (Aburto et al. 2022; Schöley et al. 2022; Bonnet et al. 2024a, 2024b). As a result, in 2020–2022, life expectancy for men and women was roughly the same as a decade earlier—78.6 years for men and 82.6 years for women—lower

than in 2017–2019, when the UK recorded its highest values (79.3 and 83.0 years, respectively) (ONS 2024).

Historically, sub-national life expectancy has varied considerably, with England highest, followed by Northern Ireland, Wales, and Scotland (McCartney et al. 2012). All four nations experienced slowing growth after 2010, but to varying degrees. England's life expectancy has been about 2 years higher than Scotland's in recent decades. In Wales, the gap with England widened to around 1 year due to declines in the late 2010s. Northern Ireland, by contrast, recorded modest gains and a less pronounced decline during the Covid-19 pandemic, surpassing Wales in the mid-2010s and narrowing its gap with England to roughly half a year by 2020–2022 (ONS 2024). Within England and Wales, less urbanized areas tend to have higher life expectancy (Ebeling et al. 2022).

The pre-pandemic stagnation in life expectancy coincided with rising area-based socio-economic inequalities (Walsh and McCartney 2024). Analyses using area-based deprivation measures show that mortality improvements slowed in the least deprived areas and stalled or reversed in more deprived areas over the past two decades (McCartney et al. 2017; Marmot et al. 2020; Seaman et al. 2024). Previous research links these adverse trends to the UK's austerity measures, introduced in 2010 in response to the 2008 Great Recession, which cut social security budgets and essential services. These cuts disproportionately affected vulnerable population subgroups (Walsh et al. 2022), and districts most affected by these cuts experienced the most adverse trends in life expectancy (Seaman et al. 2024). During the first year of the pandemic, the greatest losses in life expectancy were observed in the most deprived areas (Kontopantelis et al. 2021, 2022). However, a comparative study covering all UK districts and quantifying the widening of area-level life expectancy inequalities in an international context is currently missing.

### 2.3 | Closing and Remaining Gaps: Trajectories of Life Expectancy in Germany

Similar to the UK, mortality improvements in Germany have slowed since 2010, although they did not stagnate to the same extent in the years preceding the Covid-19 pandemic. While the long-term annual increase in life expectancy had been 0.3 years for males and 0.2 years for females, it declined to around 0.1 years for both sexes during the decade prior to the pandemic (Mühlichen et al. 2024). Life expectancy at the national level peaked in 2017/2019 (78.6 years for men and 83.4 years for women), before falling slightly for three consecutive years during the pandemic, reaching 78.3 years for men and 83.2 years for women in 2020/2022 (Mühlichen et al. 2024).

Despite its slightly more favorable pre-pandemic trajectory in comparison to the UK, Germany has been considered a long-term life expectancy 'laggard' (Jasilionis et al. 2023). In spite of high healthcare expenditures and social security spending, life expectancy in Germany remains significantly lower than in Japan, Switzerland, France, or Spain (Jasilionis et al. 2023; Grigoriev et al. 2024). In contrast, life expectancy in Germany is close to the level observed in the UK, despite the latter being a liberal welfare state with markedly lower per capita spending on health and welfare (Jasilionis et al. 2023).

A particular feature of Germany's geopolitical trajectory is its division into East and West Germany between 1949 and 1990. Research has shown that during this period a substantial life expectancy gap emerged to the disadvantage of the then-Communist east (Luy 2004), primarily driven by cardiovascular deaths, and peaked in 1990, the year of reunification (Vogt 2013; Grigoriev and Pechholdová 2017). Thereafter, the gap declined considerably, primarily due to a rapid equalization of local living conditions, facilitated by targeted increases in public spending addressing area-level needs (Luy 2004). Tailored investments contributed substantially to infrastructure improvements and more equitable access to modern medical technology and welfare state resources in the east (Vogt and Kluge 2015). Germany's post-reunification trajectory thus represents a strong example of a successful place-based leveling-up approach that reduced area-level health inequalities (Bambra 2022). Even prior to reunification, Germany had achieved notable redevelopment of traditionally agriculture-dominated rural areas in southern and southwestern regions, such as Bavaria and Baden-Württemberg (Hill 2024). These regions now rank among the strongest in terms of economic output, productivity, and earnings.

Beyond the east–west gap, which persists for men but has largely disappeared for women, a north–south gradient is evident, with Baden-Württemberg and Upper Bavaria showing the highest life expectancy levels (Rau and Schmertmann 2020; Mühlichen, Grigoriev, and Klüsener 2023). This gradient has been attributed to slower mortality improvements in northwestern Germany compared to the south (Kibele et al. 2015; Mühlichen, Grigoriev, and Klüsener 2023). In 2019, the gap between southern Germany and the rest of western Germany was around 1 year for both sexes, while the gap between southern and eastern Germany was 2 years for men and only half a year for women (Mühlichen, Grigoriev, and Klüsener 2023). During the Covid-19 pandemic, the timing and extent of excess mortality varied considerably across Germany, with eastern regions particularly affected in late 2020 and in 2021, and the northwest more affected in 2022 (Marinetti et al. 2023; Mühlichen 2023; Mühlichen, Sauerberg, and Grigoriev 2023).

Regional mortality differences at the level of Germany's 16 *Länder* (federal states) are relatively low in international comparison and have further declined over the past two decades (van Raalte et al. 2020). Despite persistent economic inequalities, this generally low level of area-level inequalities is considered a remarkable achievement (Rau and Schmertmann 2020; van Raalte et al. 2020; Hrzic et al. 2023). Hrzic et al. (2023) also found convergence in life expectancy at the district level between 1997 and 2016. Both the low baseline inequalities and their further reduction across areas are often attributed to the German state's strong commitment to providing equitable living conditions, formalized in the constitution and related legislation (Rau and Schmertmann 2020; van Raalte et al. 2020; Hrzic et al. 2023). Given its success in addressing geopolitical challenges, Germany serves as a suitable 'benchmark' in comparison to the UK.

## 3 | Data and Methods

### 3.1 | Accessing and Harmonizing Population and Mortality Data

Our analysis is conducted at the district level and covers all years from 2003 to 2021. In the UK, districts correspond to the 374 *lower-tier local authorities*, while in Germany the closest equivalent are the 400 *Kreise*. Across both countries, districts represent a comparable geographical scope, covering both rural and urban areas. As units of local government, districts in both countries can be regarded as broadly equivalent in terms of devolved powers, as reflected in their central role in decision-making and service delivery at the local level (Wollmann et al. 2016). In both countries, districts are responsible for similar key services—such as education, social and health services, and infrastructure—and operate within a comparable governance framework characterized by semi-autonomous decision-making within a devolved multi-tier system (Wollmann 2012; Wollmann et al. 2016). However, due to differences in their institutional functioning, districts are not fully equivalent and reflect distinct historical and cultural trajectories in the two countries (Wollmann 2000, 2008).

For all UK districts, we obtained mid-year population estimates from the Office for National Statistics (ONS). Corresponding mortality data were obtained from the respective national statistical offices that is, the ONS (for England and Wales), the National Records of Scotland (NRS) and the Northern Ireland Statistics and Research Agency (NISRA). All UK districts were captured consistently over time, using their 2021 boundary definitions. Since the ONS adjusts mid-year population estimates for small areas to reflect boundary changes and census revisions, no additional harmonization was required.

For all German districts, population estimates and death counts were harmonized according to the most recent territorial division as of 2022. Information on changes in the territorial division was obtained from the federal and state statistical offices. Since the 2011 German Census revealed that official population counts had been overestimated by around 1.5 million people at the national level, we harmonized pre-2011 population estimates at the district level by proportionally redistributing the 2011 differences between the initially published and census-corrected age- and sex-specific numbers across the preceding intercensal years (cf. Klüsener et al. 2018). All regional population and death counts for Germany and the UK were disaggregated by sex and five-year age groups (0, 1–4, 5–9, 10–14, …, 85–89, 90+).

### 3.2 | Quantifying and Comparing District-Level Inequalities in Life Expectancy

We used routinely reported district-level employment rates as a proxy for socio-economic deprivation at the area level. Employment rates for men and women combined were available for Germany for the entire study period, for Scotland, England, and Wales from 2005, and for Northern Ireland from 2009 onward. To ensure comparability and robustness, we calculated an average of the employment rate over the 13 years available for all regions (2009–2021). Using this average, we ranked all districts in ascending order within each country to construct national deprivation deciles.

Life expectancy for each decile was estimated following a consistent approach. After assigning each area within a country to a deprivation decile, we aggregated exposures (mid-year populations) and deaths by decile and calculated age-specific mortality rates. Based on these rates, we estimated life expectancy annually (2003–2021) for each decile in both countries. We deviated from this annual pattern only for spatial visualizations, where we present district-level life expectancy for multi-year periods. These periods combine adjacent years to account for annual fluctuation and were defined as 2003/2005 (the starting point of our observation), 2009/2011 (an intermediate and turning point when mortality improvements began to slow), 2017/2019 (the final pre-pandemic period, marking the highest recorded life expectancy in both countries), and 2020/2021 (the main years of the Covid-19 pandemic).

To quantify spatial inequalities between deprivation deciles, we used the slope index of inequality (SII) (Pamuk 1985; Mackenbach and Kunst 1997). The SII provides a quantification of the linear association between the deprivation rank and a (health) outcome reflecting the entire socio-economic scale (Moreno-Betancur et al. 2015). In our case, it measures the association between deprivation rank—based on employment rate information—and life expectancy across deprivation deciles. To ensure that the SII did not mis-specify a non-linear relationship as linear, we tested whether life expectancy followed a linear pattern across deciles and over time, for which we found compelling evidence. The SII was estimated using a linear-regression approach with a square root transformation to account for heteroskedasticity (Anderson et al. 2020).

We constructed abridged life tables and life expectancy estimates following the approach described by Chiang (1984). No prior adjustments were applied to the raw mortality data. All estimates of life expectancy, inequality indicators, and corresponding 95% confidence intervals were derived using the *R* package *PHEindicatormethods* (Anderson et al. 2020; R Core Team 2024). Geographical visualizations were produced using *ArcGIS* (Esri. 2020).

### 3.3 | Identifying Comparable Indicators for Area-Level Deprivation

Operationalizing inequalities through deprivation deciles ensured direct comparability of life expectancy inequalities over time and across countries. Our decision to use routinely reported employment rate data as a proxy for area-level deprivation was primarily pragmatic. Employment is the main source to generate income and hence of significant importance for the wellbeing of individuals and household members (Lugo 2007). At the same time, our choice was driven by the lack of alternative contextual factors that are available and comparable for both countries. Moreover, several studies in the UK context have shown a strong relationship between separate socio-economic domains of deprivation indices (such as income and employment) and the overall deprivation rank (Rice et al. 2025; Bradford et al. 2023).

Despite minor differences, such as in the measurement of self-employment, the employment rate—defined as the share of the working-age population in employment—remains the most consistent contextual factor within and across the two countries. For the UK, we obtained this indicator from the Labour Force Survey. For Germany, the employment rate was calculated as 100% minus the share of unemployed people, based on data from the INKAR database (BBSR 2024). We chose this approach because there was no direct equivalent available for Germany's districts.

Identifying comparable contextual factors for small areas of two countries is generally challenging. Even within one country, the reporting of small-area socio-economic indicators is not always consistent. For example, many common socio-economic indicators are not reported consistently over time across all four UK nations. In addition, available UK data are often subject to high uncertainty as well as censoring for small areas or areas with low response rates, as estimates are typically survey-based (e.g., Labour Force Survey, Annual Population Survey). Although there are well-established district-level deprivation indices for Germany and the UK, they cannot be used in conjunction, as they differ systematically not only between the two countries but also between the UK's devolved nations due to differences in the indicators captured and the time periods (Abel et al. 2016).

## 4 | Results

### 4.1 | Trends in Life Expectancy for Countries and Regions

We first explored annual trends in male and female life expectancy (Figure 1) across districts (gray lines) and higher-level geographical regions (colored lines) in Germany and the UK. Both countries experienced a marked slowdown in life expectancy improvements during the 2010s, with influenza-related declines in 2015 (both countries) and 2018 (more pronounced in Germany), followed by a sharp drop in 2020 associated with the Covid-19 pandemic. The decrease in 2020 compared with pre-pandemic years was generally larger among men than women, and substantially greater across districts in the UK than in Germany. In Germany, life expectancy continued to decline into 2021 across all regions. In the UK, life expectancy between 2020 and 2021 increased slightly in England (both sexes), Scotland (men only), and in Wales and Northern Ireland

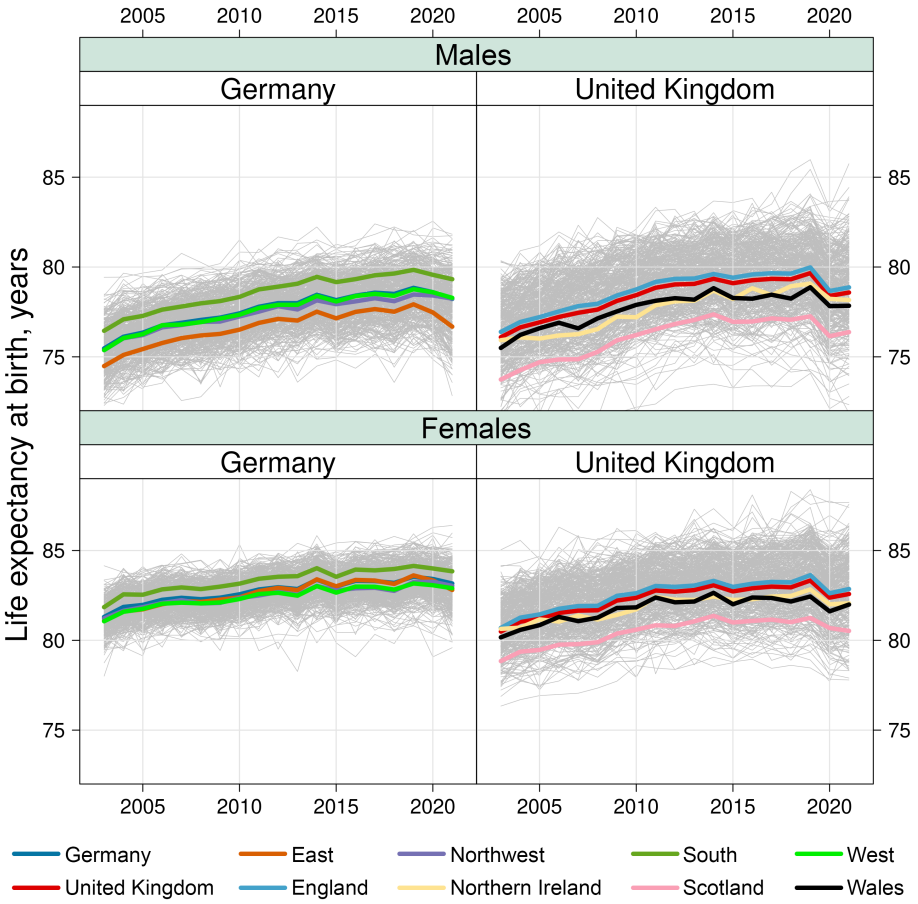


**FIGURE 1** | Annual estimates of life expectancy at birth in Germany and the UK by sex, overarching region (colored lines) and district (gray lines), 2003–2021. For Germany, the overarching regions are classified as East (Brandenburg, Berlin, Mecklenburg-Vorpommern, Saxony, Saxony-Anhalt, and Thuringia), Northwest (Bremen, Hamburg, Lower Saxony, and Schleswig-Holstein), South (Baden-Württemberg and Bavaria) and West (Hessen, North Rhine-Westphalia, Rhineland-Palatinate, and Saarland). For the UK, the classification of overarching regions follows the administrative boundaries of England, Scotland, Wales, and Northern Ireland.

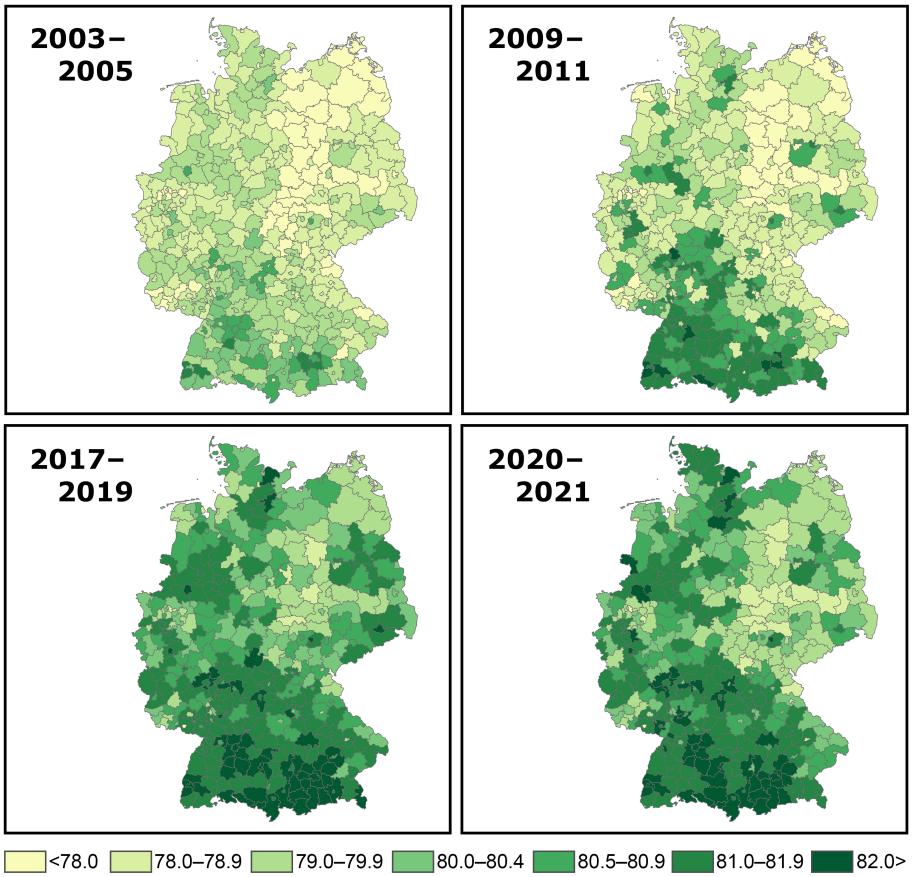


**FIGURE 2** | Life expectancy at birth across all of the districts in Germany for both sexes combined, reflecting the four periods 2003–2005, 2009–2011, 2017–2019, and 2020–2021.

(women only), but remained clearly below pre-pandemic levels. The decline in life expectancy during the two pandemic years was particularly pronounced among men in eastern Germany (from 77.9 years in 2019 to 76.7 years in 2021). Overall, among all regions, the lowest life expectancy was consistently observed among Scottish men (76.4 years in 2021).

Across all districts in both countries, life expectancy was consistently higher for women than for men. Overall, sex differences in life expectancy were more pronounced in Germany than in the UK, particularly in eastern Germany. In 2021, the gap between female and male life expectancy was 6.1 years in eastern Germany, compared with 4.5–4.8 years in the three western German regions and around 4.0 years in the UK, with little variation between its four nations (3.9–4.1 years). On average, life expectancy levels across districts were broadly similar in both countries. While UK men experienced higher life expectancy than their German counterparts, the opposite was true for women, as German women had a higher life expectancy than UK women. Due to higher annual gains in life expectancy between 2012 and 2017 and a smaller decline in 2020 in Germany, the UK advantage among men narrowed, while the German advantage among women increased slightly.

For both males and females in the UK, life expectancy showed a consistent regional gradient, being highest in England and lowest in Scotland. In Germany, life expectancy was consistently highest in the south for both sexes. However, patterns across the remaining regions were less uniform: male life expectancy was lowest in eastern Germany, whereas female life expectancy showed similar levels in western, eastern, and northwestern Germany. At the district level, variability in life expectancy was substantially greater in the UK than in Germany. For instance, in 2003, the difference between the districts with the highest and lowest life expectancy was 7.1 years for men and 6.1 years for women in Germany, compared with 11.2 and 8.7 years, respectively, in the UK. By 2021, this gap had widened to 9.0 years for men and 6.8 years for women in Germany, and to 13.9 and 9.9 years, respectively, in the UK.

### 4.2 | Changes and Consistencies in Spatial Patterns

Figures 2 and 3 illustrate variation at the district level in Germany and the UK for selected multi-year periods, with both sexes combined. In Germany (Figure 2), a clear north–south gradient was observed, along with an east–west gap across all selected periods. The east–west gap was, however, only evident among men, whereas for women, it had largely disappeared by the start of our study period in 2003/2005 (see Figures S1 and S2 for sex-specific maps). In eastern Germany, districts in Saxony-Anhalt had a particularly low life expectancy, as did the Ruhr area, Saarland and the coastal areas of Lower Saxony in the west. In contrast, higher values were observed in the metropolitan areas of Dresden and Berlin, the moderately urbanized areas of central Thuringia, and

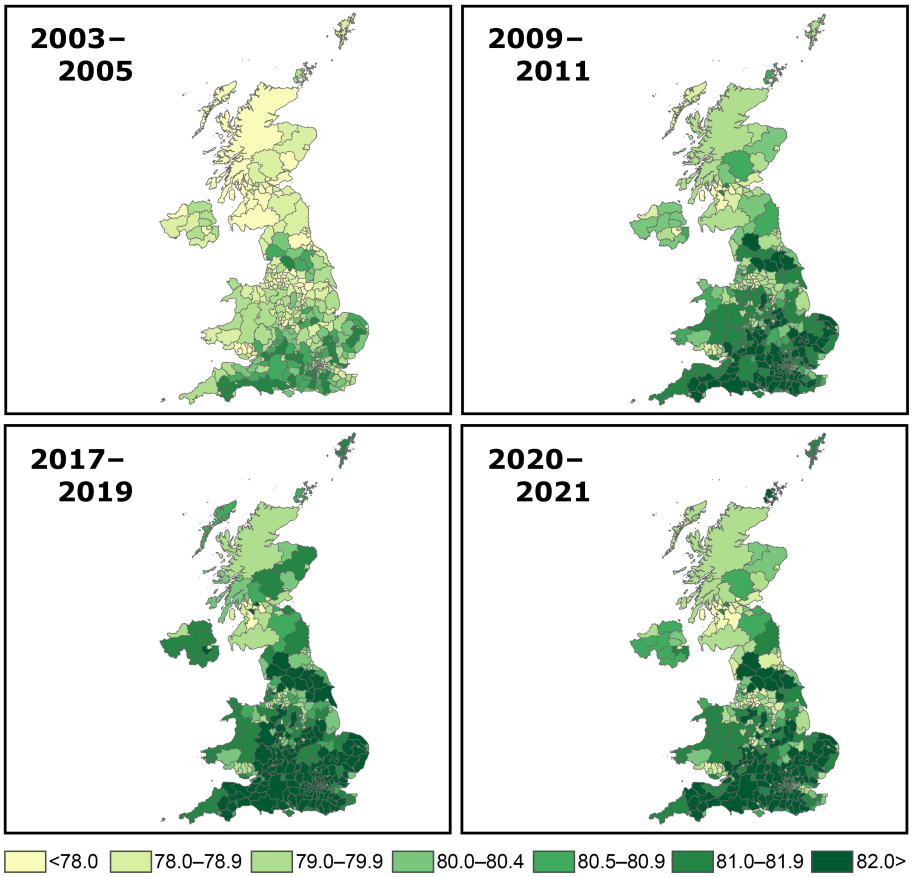


**FIGURE 3** | Life expectancy at birth across all of the districts in the UK for both sexes combined, reflecting the four periods 2003–2005, 2009–2011, 2017–2019, and 2020–2021.

the coastal areas of Mecklenburg. The districts with the highest life expectancy are concentrated in Upper Bavaria and in central and southern Baden-Württemberg, in southern Germany. Between 2003/2005 and 2017/2019, all German districts experienced gains in life expectancy. Changes between 2017/2019 and the pandemic years 2020/2021 were more heterogeneous: many eastern German districts saw declines, while districts in the west showed little change, with some regions, particularly in Schleswig-Holstein, even showing increases. Consequently, the German east–west gap widened during the Covid-19 pandemic. Because the pre-pandemic period (2017–2019) includes 2018, a year with relatively high influenza-related mortality, the decline in life expectancy during the pandemic appears less drastic than if compared with 2019 alone, when life expectancy was comparatively high (Figure 1).

As in Germany, life expectancy in the UK varied across regions. Figure 3 shows that regional patterns were generally more stable over time in the UK than in Germany. A pronounced north–south gradient was evident, with the lowest life expectancy observed in some districts of the Glasgow City region and in post-industrial coastal areas of northern England. In contrast, some areas in close proximity to these low-life-expectancy districts—such as rural parts of North Yorkshire or suburban districts around Glasgow (e.g., East Renfrewshire and East Dunbartonshire)—exhibited comparatively high level of life expectancy. The highest values were consistently found in the south of England, particularly in districts surrounding London and some coastal areas. While these patterns persisted throughout the study period, they became more pronounced during the Covid-19 pandemic. As in Germany, area-level inequalities were greater among males than females in the UK (see Figures S3 and S4 for sex-specific maps). The decline in life expectancy in 2020/2021 compared with pre-pandemic years was substantial and particularly pronounced in Scotland, Northern Ireland, and the industrial areas of northern England. Between 2003/2005 and 2009/2011, most regions experienced considerable gains in life expectancy, whereas gains between 2009/2011 and 2017/2019 were comparatively small.

### 4.3 | Trends in Life Expectancy Inequalities

Figure 4 presents annual trends in life expectancy by deprivation decile, showing a consistent stratification by employment level across districts in both countries over time. In both Germany and the UK, the gap in life expectancy between the most and least deprived districts, as illustrated by deciles, widened over the study period. In Germany, the gap increased from 2.4 years for men and 1.2 years for women in 2003 to 3.1 and 1.6 years, respectively, in 2021. In the UK, the increase was more pronounced, from 4.3 years for men and 2.8 years for women in 2003 to 4.8 and 4.1 years, respectively, in 2021.

In both countries, life expectancy across all deciles was markedly lower in 2020 and 2021 compared with pre-pandemic levels.


**FIGURE 4** | Life expectancy at birth by sex and deprivation decile in Germany and the UK, 2003–2021.

This decline was especially pronounced in the UK, with the most deprived deciles being affected the most, while the least deprived deciles experienced smaller reductions. For example, between 2019 and 2020, life expectancy in the lowest UK decile decreased by 2.0 years for men and 1.4 years for women, whereas the decline in the least deprived decile was 1.1 and 0.9 years, respectively. After this sharp decline, life expectancy in all UK deciles increased slightly between 2020 and 2021.

In contrast to the UK, reductions in life expectancy during 2020 and 2021 were comparatively smaller across all deciles in Germany relative to pre-pandemic levels. Among women, for instance, the fifth and sixth deciles remained relatively stable or even experienced a slight increase in 2020. Nevertheless, all deciles in Germany saw a further decline in life expectancy in 2021.

We then examined annual changes in inequality between deprivation deciles, as measured by the SII, for both countries (Figure 5). Overall, SII values were consistently higher in the UK than in Germany, indicating substantially greater area-level mortality inequalities in the UK. This gap persisted throughout the study period and widened during the pandemic. In both countries, SII was higher among males than females, indicating that area-level life expectancy inequalities were greater for men.

As further shown in Figure 5, trends in the SII over time varied by country and sex. In the UK, SII among males decreased slightly between 2003 (4.5 years) and 2019 (4.0 years), before rising sharply during the pandemic (5.2 years in 2020; 5.1 years in 2021). Among UK females, SII increased modestly from 2003 (3.0 years) to 2019 (3.5 years), before also seeing a sharp increase in 2020 (4.2 years) and 2021 (4.4 years). Patterns for Germany differed: SII for males rose slightly during pre-pandemic years (2.7 years in 2003; 2.9 years in 2019), remained stable in 2020, and peaked at 3.4 years in 2021. Among German females, SII did not change substantially before the pandemic (1.3 years in 2003; 1.4 years in 2019), but rose in 2020 (1.5 years) and 2021 (1.8 years), with a peak already observed in 2018 (1.8 years). While both countries experienced excess mortality in 2018 due to severe influenza waves (Raleigh 2018; Schindler et al. 2024), the peak of area-level inequalities in Germany in 2018 suggests that regions were affected differently, with southern Germany being less affected than the rest of Germany.

## 5 | Discussion

### 5.1 | Summary of Key Findings

This study is the first to directly compare life expectancy inequalities across all districts in Germany and the UK using a consistent methodology. Previous research has examined only selected areas (Taulbut et al. 2014; Ebeling et al. 2022). By including all districts, we were able to rank them within each national context according to employment rate as an indicator of area-level deprivation.

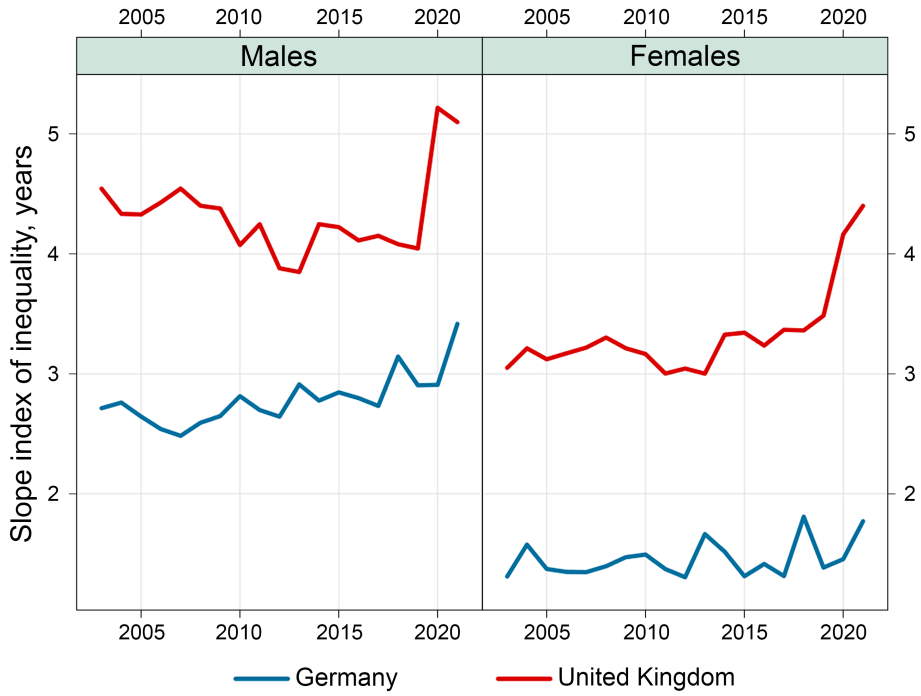


**FIGURE 5** | Slope index of inequality (SII) by sex in Germany and the UK, 2003–2021.

We then explored trends in district-level life expectancy inequalities over time using the slope index of inequality (SII). Our analysis spans a substantial period, covering phases of substantial gains in life expectancy, followed by slowed improvements, and finally the onset of the Covid-19 pandemic. This long-term perspective allowed us to identify both trends and period effects. On average, life expectancy was similar in both countries. However, the UK achieved this average at substantially higher levels of inequality between districts. District-level life expectancy inequalities increased in both countries during the Covid-19 pandemic (2020–2021), with a markedly sharper rise in the UK. While differences in the spatial distribution of deprivation within districts may have contributed, we hypothesize that our findings reflect deeply rooted differences in governmental approaches to providing equitable living conditions under two distinct welfare regimes.

## 5.2 | The Case of the UK

Our findings of increasing inequalities across UK districts are consistent with previous results by Rashid et al. (2021), who observed a widening range of life expectancy outcomes. However, their analysis was limited to England and used a different level of spatial granularity (middle layer super output areas). The already high—and further increasing—level of spatial inequalities in the UK is typically attributed to the country's strong regional imbalances in socio-demographic conditions among the member countries of the Organization for Economic Co-operation and Development (OECD) (McCann 2020). Part of the reason is that many policy efforts since the 1960s to achieve more equitable conditions across areas, though often well-intentioned, have been 'place-blind' in their conceptualisation (Coyle and Muhtar 2023). In addition, more recent initiatives aimed at reducing area-level inequalities have often been offset by national-level policymaking. Specifically, social policy research has almost consistently highlighted that the tension between national and local policies is contradictory and detrimental to the overarching goal of reducing area-based inequalities in the UK (Ralston et al. 2022; Tomaney and Pike 2020).

Our results provide further evidence of a substantial area-level gradient in population health across the UK and its four nations. Seaman et al. (2024) have shown that social security cuts were predictive of life expectancy losses across upper-tier local authorities in England, Scotland, and Wales. Inequalities may have increased because some areas were disproportionately affected due to the socio-demographic profile of their populations. Measures reducing welfare benefits, such as the austerity policies introduced in the UK, typically have a larger impact on more deprived areas, as they reduce the real-term value of welfare and security payments and increase constraints on their conditionality and eligibility (Broadbent et al. 2024). Similarly, Alexiou et al. (2023) attributed worsening mortality from alcohol and drug-related causes to changes in the allocation of social security funding, disproportionately affecting more deprived areas.

Life expectancy inequalities across districts in the UK increased sharply during the Covid-19 pandemic. This trend was evident for both men and women, despite the UK government's efforts to mitigate economic hardship, such as the Coronavirus Job Retention Scheme (Kopasker et al. 2024). As part of this scheme, employees who were in work in February 2020 but became unable to work during the immediate onset of the pandemic—either because they were made redundant or had to stop working in March 2020—had their incomes supplemented by up to 80% of pay (capped at £2500) (Dunn et al. 2020). The increase in area-level life expectancy inequalities is consistent with previous studies showing that the direct and indirect impacts

of the pandemic had disproportionate effects by sex, age, ethnicity, health-risk factors, employment sector, and deprivation (e.g., Bambra et al. 2021; Mishra et al. 2021). While direct effects primarily manifested in excess mortality and long-term morbidity, indirect consequences included disruption to healthcare and social services, job loss, and the breakdown of social networks (Katikireddi et al. 2021).

The pronounced rise in area-level life expectancy inequalities during this acute public health crisis did not arise out of nowhere but reflects a trajectory shaped by the UK's pre-existing socio-economic inequalities (Bambra et al. 2020). In light of the ongoing cost-of-living crisis and its likely disproportionate impact on already deprived households and areas (Höhn et al. 2023), it remains uncertain whether pre-pandemic levels of area-level inequality will be restored or whether higher inequalities will simply become the 'new normal'.

### 5.3 | The Case of Germany

Area-level inequalities in life expectancy in Germany were particularly pronounced along the north–south axis and, for males, also along the east–west axis, confirming previous literature (Kibele et al. 2015; Rau and Schmertmann 2020). In international comparison, regional mortality differences are rather small in Germany, a pattern attributed to Germany's constitutional requirement for equal living conditions across regions, as reflected in legislation such as the inter-state fiscal adjustment (*Länderfinanzausgleich*) (Vogt and Kluge 2015; van Raalte et al. 2020).

Unlike the UK, Germany experienced no major welfare state reforms comparable in scale to the UK's austerity measures over recent decades. Regional differences in German life expectancy have been linked to health-related behaviors (particularly smoking), the quality of healthcare, socio-economic conditions and selective migration, among others (Luy and Caselli 2007; Kibele et al. 2015; Grigoriev et al. 2022; Mühlichen, Grigoriev, and Klüsener 2023; Tetzlaff et al. 2024). In addition, the effectiveness of health policies in ensuring timely and adequate healthcare, as well as in preventing risky behaviors—including sub-optimal use of available healthcare services—has been shown to vary across regions (Mühlichen, Lerch, et al. 2023). Indicators of particularly disadvantaged groups, such as unemployment rates and welfare dependency, were found to be strong predictors of regional life expectancy (Rau and Schmertmann 2020). The impact of socio-economic conditions on health-related behavior and life expectancy is generally more pronounced among men than women (Oksuzyan et al. 2014; Hiller et al. 2017), which may explain the larger gaps between deprivation deciles observed for males, especially when coupled with adverse events such as the Covid-19 pandemic.

In Germany, some areas still lag behind the south in terms of economic development and life expectancy, particularly peripheral regions in the east and densely populated post-industrial areas in the west currently facing structural change, such as the Ruhr area and Saarland. In addition, the female advantage in life expectancy is more pronounced in Germany, especially in the east, than in the UK. Tailored policies targeting socio-economic conditions and unemployment in these areas may further reduce inequality between regions and between sexes (Rau and Schmertmann 2020). For example, recent findings suggest that increasing social security expenditure could be an effective policy tool to reduce health inequalities between German regions with different levels of economic development (Simpson et al. 2024).

Compared with the UK, area-level inequalities in Germany remain substantially lower. Nevertheless, these inequalities have increased slightly over the study period, particularly among German men (Tetzlaff et al. 2024). Prior to this period, especially in the 1990s, spatial inequality declined substantially due to the eastern German convergence process (Luy 2004; Hrzic et al. 2023; Mühlichen, Lerch, et al. 2023). Tetzlaff et al. (2024) found that the recent increase was driven by an earlier slowing of life expectancy gains in more deprived districts, with cardiovascular diseases and cancer contributing most—cardiovascular mortality decreasing over time while cancer-related mortality increased.

Germany's population was also significantly affected by the Covid-19 pandemic. As in the UK, more deprived areas and individuals were disproportionately affected, likely influencing future trajectories of key inequalities (Ehlert 2021; Babitsch and Ciupitu-Plath 2025). Covid-19 mortality among individuals aged 45 years and older was a major driver of the widening gap in 2021 (Tetzlaff et al. 2024). Research on the public health implications of the recent cost-of-living crisis has suggested that its adverse effects on health were smaller in Germany and Sweden than in the UK (Grailey et al. 2024).

### 5.4 | Limitations

Our study is subject to some limitations. Life expectancy, one of the most robust indicators of population health, measures mortality and—due to its implicit age standardization—allows for direct comparisons across areas and over time (Modig et al. 2020). However, as it focuses solely on mortality, it may not capture the full burden of ill health experienced across deprived areas (Beltrán-Sánchez et al. 2015). Studies analyzing inequalities in health expectancies—such as healthy life expectancy (HLE) or quality-adjusted life expectancy (QALE)—which combine information on both health and mortality, typically report substantially larger area-level inequalities than those based on life expectancy alone. The absolute magnitude of these inequalities can be up to twice as high. For example, Höhn et al. (2024) found this doubling in disadvantage for QALE across local authorities in Great Britain between 2018 and 2020, consistent with standard reporting of HLE by the UK's national statistical offices (e.g., ONS 2022; NRS 2022).

Another limitation of our study is that we could not assess the impact of individual-level characteristics such as income, employment, education, or occupation. Area-level inequalities are inevitably shaped by the population composition and the spatial distribution of individual-level characteristics. For instance, the same degree of individual-level differences can produce minimal area-level inequalities if deprivation is evenly spread, but substantial inequalities if it is highly spatially polarized.

Additionally, the magnitude of area-level inequalities in both countries could have been influenced by the definition of geographical boundaries, an issue known as the *modifiable areal unit problem* (MAUP) (Gehlke and Biehl 1934; Openshaw 1984). Two key design features may give rise to MAUP: the choice of spatial units and the overarching background considered. Regarding the first, we focused on districts as predefined local government units. For the UK, previous studies indicate that while the absolute level of health inequalities may vary with the choice of spatial units, the relative pattern of inequalities remains largely stable when areas of comparable size are used (Stafford et al. 2008; Flowerdew 2011; Tuson et al. 2020). However, more granular units typically show substantially higher disparities than larger units (Rashid et al. 2021), a pattern reflected in our results, which show less variation in life expectancy at the level of broader regions than at the district level. Regarding the overarching background, results may differ when analyses are conducted within subnational regions rather than within entire countries, as within-country regions may not necessarily follow overarching national-level patterns. Consequently, gradients in life expectancy inequalities might vary across the NUTS-1 areas of Germany (16 *Länder*) and the UK (12 *regions*).

Throughout the study period, Germany and the UK differed markedly with respect to net migration rates, particularly in the nature of in-migration. For instance, Germany has experienced a substantially higher intake of migrants since the 1990s, including 1 million refugees from Syria, particularly during 2015 and 2016. While such migration may have affected population health—for example, through an initial, yet diminishing, healthy migrant effect (Loi et al. 2025)—to our knowledge, cross-country differences in the impact of migration on population health have not yet been explored from a comparative perspective that explicitly accounts for migration.

While our study covers two comparable countries representing distinct welfare regimes, they may not be representative of other countries classified similarly, such as France (*conservative*) or the US (*liberal*). This may limit the generalisability of our findings to other countries or the overarching welfare state type represented. Moreover, our study did not include a comparator from a social-democratic welfare regime. One reason is the substantial differences in key demographic and geographic characteristics between the Nordic countries and the UK and Germany (see *Background*). Another reason is the limited number of local government districts in potential European comparators—Denmark (5 *regioner*), Sweden (21 *län*), Finland (19 *maakunta*), Norway (15 *fylker*)—*which* makes it unfeasible to create deciles (or quintiles) for the slope index of inequality. Using a more granular spatial level in these countries would increase the number of areas (98 Danish, 290 Swedish, 309 Finnish and 357 Norwegian municipalities). However, despite some similarities in devolved powers, the substantially smaller average population size and the much more granular scale of Nordic municipalities render them unsuitable for direct comparison with districts in Germany and the UK.

Social-democratic welfare states tend to place strong emphasis on economic inclusion and participation, independent of income, employment, or family background. This has often been linked to the Nordic countries' advantage in life expectancy and lower area-level life expectancy inequalities compared with other countries (Popham et al. 2013; Wilson et al. 2020). Despite their universalistic welfare state approach, the Nordic countries still exhibit clear gradients in mortality by income and education (Mackenbach 2012). While life expectancy inequalities within the Nordic countries have only increased in more recent years, inequalities in lifespan variation have been rising steadily for decades (van Raalte et al. 2014, 2018). Part of this 'Nordic paradox' may be that income redistribution alone is insufficient to reduce health inequalities, particularly at older ages, because it does not fully address deeper-rooted social inequalities related to wealth (Katikireddi et al. 2020).

## 6 | Conclusion

Mortality trajectories are strongly shaped by a multitude of upstream and downstream determinants, interacting with both individual- and area-level characteristics. Particularly due to upstream determinants, resulting 'differences' or 'disparities' in life expectancy are neither 'random' nor 'just', and should hence be referred to as 'inequalities' (McCartney et al. 2021). Welfare regimes can be understood as institutions that set the 'rules of the game' at an upstream level, producing and modifying the effects of social determinants of health and their distribution across population subgroups and areas (Beckfield et al. 2015). High levels of inequality in health and socio-economic conditions pose a significant risk to a country's social cohesion and are associated with a wide range of direct and indirect costs (Hill 2024). It is therefore in every country's interest to reduce these inequalities and keep them as low as possible.

Our study shows that the UK exhibited substantially higher inequality in life expectancy between districts compared with Germany and was more affected throughout the Covid-19 pandemic, in terms of both increasing overall mortality and area-level inequalities in life expectancy. The German example illustrates that a more pronounced welfare system with a decentralized approach and a strong commitment to equitable living conditions may result in markedly lower area-level inequalities as well as lower vulnerability to period effects that negatively affect living conditions. This outcome is particularly striking in light of German reunification, when the Federal Republic integrated a former Communist state with substantially lower levels of population health and economic development. Therefore, we argue that our findings likely reflect deeply-rooted differences in governmental approaches to welfare state policies.

### Author Contributions

M.M., A.H., and P.G. queried and curated the underlying data, performed the formal analysis, validated the results, and drafted the initial manuscript. All authors contributed to the conceptualization of the study and interpreted the findings and their implications. M.M. led the revision process, including the incorporation of reviewers' comments, and finalized the manuscript. All authors reviewed and provided feedback on the revised manuscript and approved the final version for submission.

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## Conflicts of Interest

The authors declare no conflicts of interest.

## Data Availability Statement

Due to German data protection regulations, the raw German data underlying this study cannot be shared publicly. Detailed individual-level death records can be requested for a fee and analyzed at the research data centre of the German statistical offices (https://www.forschungsdatenzentrum.de/de/gesundheit/todesursachen). German population estimates by age and sex at the district level can be obtained from the Federal Statistical Office (https://www.destatis.de). For the UK, mid-year population estimates by age, sex, and local authority district are available from the Office for National Statistics (ONS): https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/populationestimatesforukenglandandwalesscotlandandnorthernireland. Corresponding death counts can be accessed via ONS for England and Wales (https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/adhocs/15229totaldeathsbylocalauthorityandsexbetween2003and2021englandandwales), the National Records of Scotland (https://www.nrscotland.gov.uk/publications/deaths-time-series-data-2024), and the Northern Ireland Statistics and Research Agency (https://www.nisra.gov.uk/statistics/births-deaths-and-marriages/registrar-general-annual-report). We provide all estimates derived from the time-series data, the main results, and visualizations as an open-access resource via the Open Science Framework (OSF): https://doi.org/10.17605/OSF.IO/ZG5TJ.

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## Supporting Information

Additional supporting information can be found online in the Supporting Information section. **FIGURE S1:** Male life expectancy at birth across districts in Germany, 2003–2005, 2009–2011, 2017–2019 and 2020–2021. **FIGURE S2:** Female life expectancy at birth across districts in Germany, 2003–2005, 2009–2011, 2017–2019 and 2020–2021. **FIGURE S3:** Male life expectancy at birth across districts in the United Kingdom, 2003–2005, 2009–2011, 2017–2019 and 2020–2021. **FIGURE S4:** Female life expectancy at birth across districts in the United Kingdom, 2003–2005, 2009–2011, 2017–2019 and 2020–2021.